



Renewable Energy

SOLAR THERMAL ENERGY

Ravi Kiran Musunuri
David Sánchez
Ramon Rodriguez

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Energy Engineering

INDEX

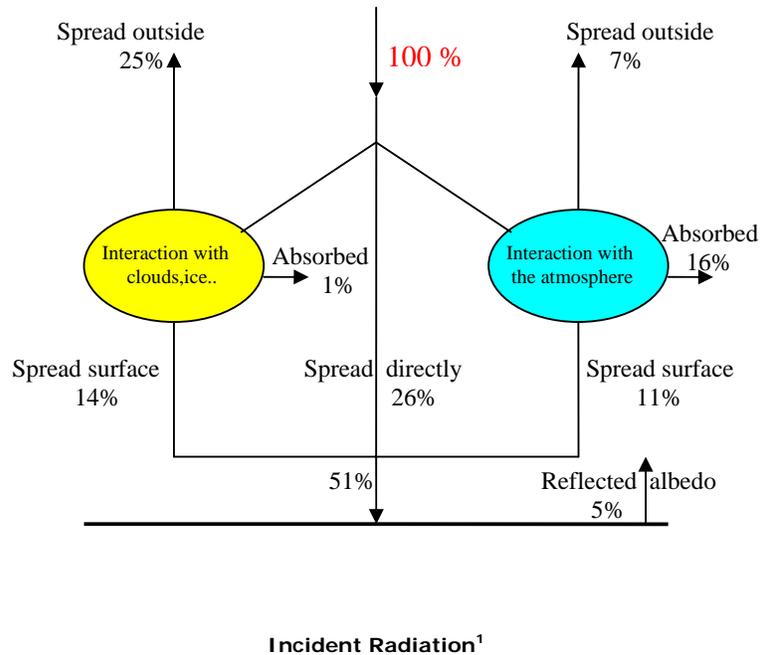
1- INTRODUCTION	3
2- SOLAR RADIATION	6
3- GEOMETRY GLOBE-SUN.....	8
4-SOLAR THERMAL ENERGY APPLICATIONS	10
5- COLLECTION SYSTEMS	15
6-ACTIVE SOLAR HEATING.....	17
7- PASSIVE SOLAR HEATING	30
8- CONCLUSIONS.....	39
9- REFERENCE LIST	41

1- INTRODUCTION

Solar power is the flow of energy from the sun. The primary forms of solar energy are heat and light. Sunlight and heat are transformed and absorbed by the environment in a multitude of ways. Some of these transformations result in renewable energy flows such as biomass, wind and waves. Effects such as the jet stream, the Gulf Stream and the water cycle are also the result of solar energy's absorption in the environment.

The Earth receives 174 petawatts (PW) of solar radiation at the upper atmosphere. While traveling through the atmosphere 6% of the incoming solar radiation (insolation) is reflected and 16% is absorbed. Average atmospheric conditions (clouds, dust, pollutants) further reduce insolation by 20% through reflection and 3% through absorption. The absorption of solar energy by atmospheric convection (sensible heat transport) and by the evaporation and condensation of water vapor (latent heat transport) drive the winds and the water cycle.

Atmospheric conditions not only reduce the quantity of insolation reaching the Earth's surface but also affect the quality of insolation by diffusing approximately 20% of the incoming light and altering its spectrum. After passing through the Earth's atmosphere approximately half the insolation is in the visible electromagnetic spectrum with the other half mostly in the infrared and ultraviolet spectrum.



Solar energy has an enormous potential like all the different prototypes have shown, and the prediction about this type of technology show that the efficiency of these systems can be increased in a significant way.

Different techniques of active solar heating and solar thermal power generation are technically feasible and cost effective, and some commercially available plants can produce up to 350MW these systems are highly dependent on the local climate and energy needs; this is a big limitation because only in certain regions these systems can be efficient enough to be implemented.

The main obstacle for the development of these systems is the low price of fossil fuels, and their high availability, like coal and biomass.

¹ <http://www.ideam.gov.co>



Solar central California (350 MW)²

The solar systems have a low environmental impact, and one of the most important benefits is that it doesn't have emissions like CO₂ or other toxic gases or radioactive material, like the ones that are produced by the current systems used to produce energy.

The costs of these energy systems consist only of the construction and maintenance of the plant, the source of energy is free and in theory unlimited. The environmental impact of these systems is practically zero.

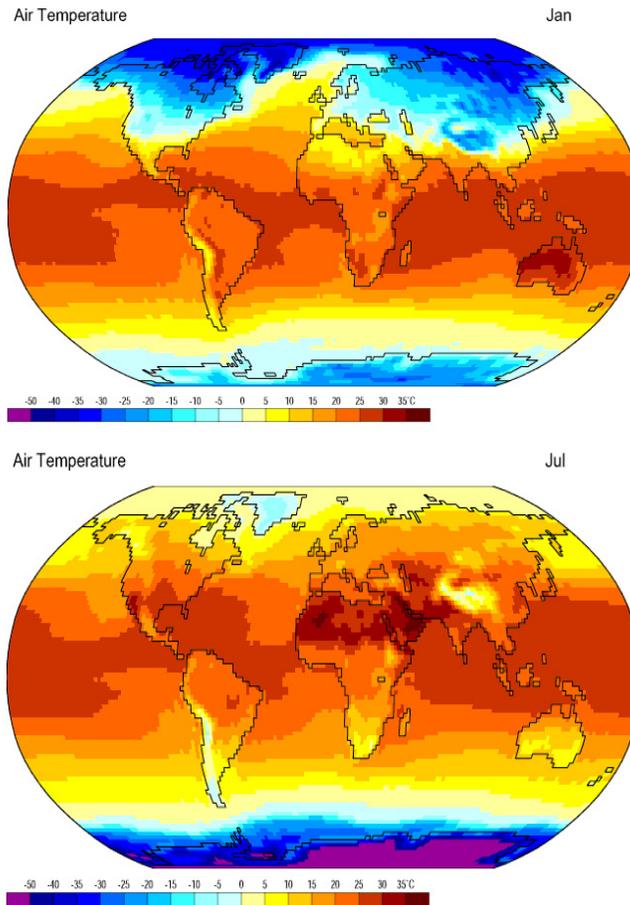
Some of the disadvantages are that these systems can only be installed in areas in which the solar radiation is longer during the days and during the year. They are also less efficient than the current energy systems

These systems can be a combination of solar energy generators and a conventional fossil fuel generator, this combination has the advantage that energy can be provided even if there is no solar energy available.

² <http://www.mongabay.com>

2- SOLAR RADIATION

Interest in solar energy has prompted the accurate measurement and mapping of solar energy resources of the globe.



Radiation levels through seasons of the year³

This is normally done using solarimeters. Most solarimeter measurements are recorded simply as total energy incident on the horizontal surface, other measurements separate the direct and the diffuse radiation.

³ Data: NCEP/NCAR Reanalysis project 1957-1997 Climatologies



Pyranometer:measure the global radiation⁴



Pyrliometer: measure the direct radiation⁵

Albedometer: It contains two identical pyranometers, one facing up and the other facing down. The first one measure the global radiation, and the other measure the radiation reflected by the earth.



albedometer⁶

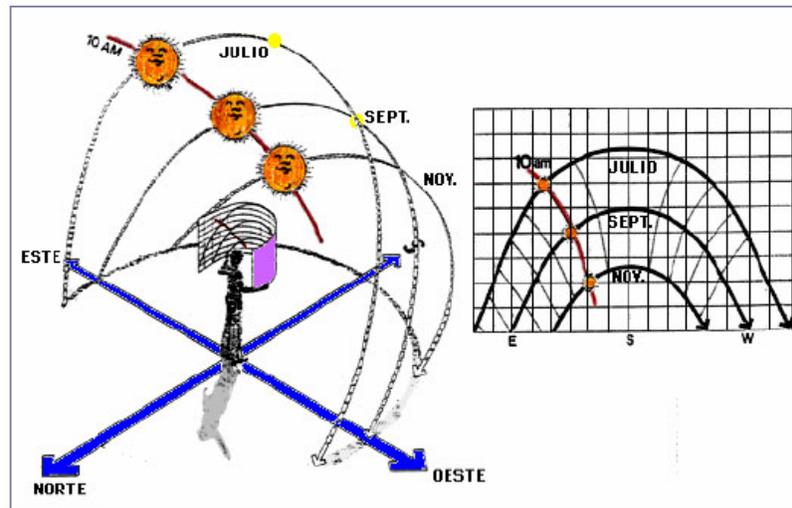
⁴ www.atmosfera.cl

⁵ www.meteochile.cl

⁶ www.directindustry.es

3- GEOMETRY GLOBE-SUN

We can use solar charts, which are a representation of the trajectories over a plane, of the sun

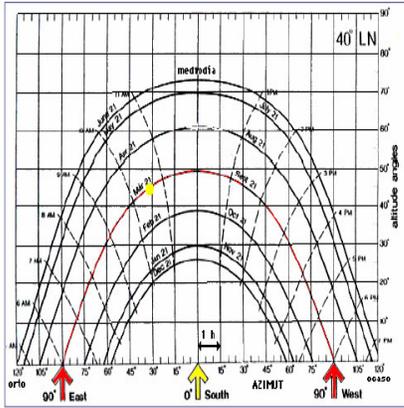


solar charts⁷

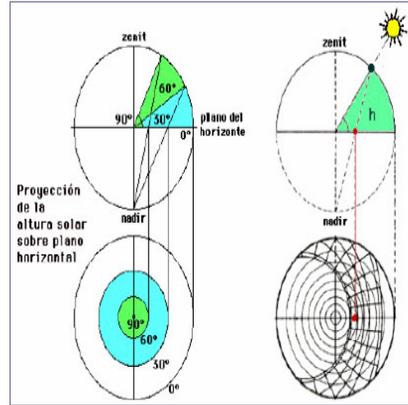
There are several types of solar charts, the most common ones are the projection charts:

- Orthogonal projection: the trajectories of the sun are projected orthogonally on an horizontal plane.
- Cylindric projection: this is a projection made over a conical surface.
- Stereographic projection: this is a conical projection over an spheric surface.

⁷ www.space.gc.ca



Cylindric projection⁸



Stereographic projection⁹

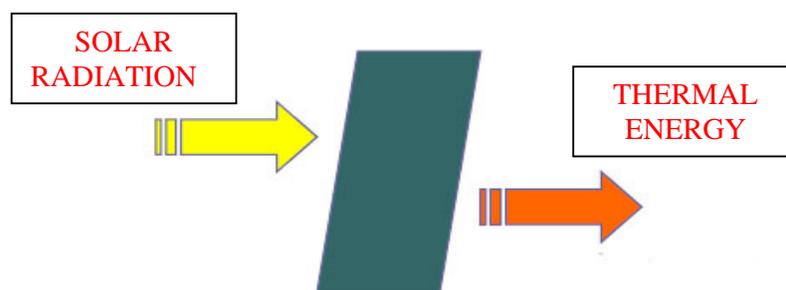
⁸ www.kesselman.com.ar

⁹ www.vitruvius.com.br

4-SOLAR THERMAL ENERGY APPLICATIONS

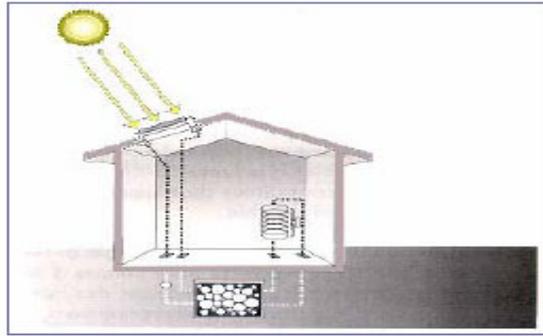
- DOMESTIC WATER HEATING

A solar domestic hot water system uses the sun's energy collected by a flat-plate solar collector and transfers the heat to water or another liquid flowing through tubes. The system then draws upon this reservoir when you need hot water inside your home. This system usually complements an existing electric or gas hot water system to reduce your utility bill and provide approximately 40-70% of your household's annual hot water needs.



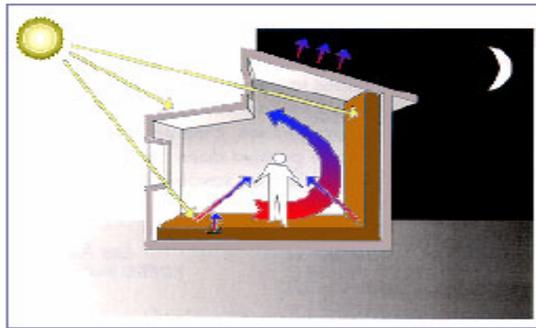
Two basic solar systems exist to produce hot water: active and passive.

An active pumped system can be either an open loop where the water is directly heated by the solar collector, or closed loop where antifreeze or glycol mixture is heated before transferring its heat to the water by a heat exchanger. A popular design of the closed loop system is known as a drain back system. This freeze-proof design drains water back into a small holding tank when freezing temperatures occur.



building – equipment - environment¹⁰

A passive solar system relies on natural sources to transfer heated water for domestic use, which is more prevalent in warmer climates with minor chance of freezing periods.



building - environment¹¹

-DOMESTIC SPACE HEATING

A solar space heater collects the sun's energy by a solar collector and directs the energy into a "thermal mass" for storage later when the space is the coldest. A thermal mass can be a masonry wall, floor or any storage drum used specifically to absorb and store the energy. Many systems involve a distribution system and control devices to circulate the heat throughout the space and to prevent loss from the collector area. These systems may be combined with a solar hot water

¹⁰ www.ar.utexas.edu

¹¹ www.solarenergyltd.net

system and sized to accommodate both uses. Solar space heaters are more economical when it replaces an electrical heating systems.

-SOLAR COOKING

Solar cooking is a technology which has been given a lot of attention in recent years in developing countries. The basic design is that of a box with a glass cover. The box is lined with insulation and a reflective surface is applied to concentrate the heat onto the pots. The pots can be painted black to help with heat absorption. The solar radiation raises the temperature sufficiently to boil the contents in the pots. Cooking time is often a lot slower than conventional cooking stoves but there is no fuel cost.

Many variations have been developed on this theme but the main restriction has been one of reducing costs sufficiently to permit widespread dissemination. The cooker also has limitations in terms of only being effective during hours of strong sunlight. Another cooking stove is usually required for the periods when there is cloud or during the morning and evening hours. There have been large, subsidised solar cooking stove dissemination programmes in India, Pakistan and China.

-CROP DRYING

Controlled drying is required for various crops and products, such as grain, coffee, tobacco, fruits vegetables and fish. Their quality can be enhanced if the drying is properly carried out. Solar thermal technology can be used to assist with the drying of such products. The main principle of operation is to raise the heat of the product, which is usually held within a compartment or box, while at the same time

passing air through the compartment to remove moisture. The flow of air is often promoted using the 'stack' effect which takes advantage of the fact that hot air rises and can therefore be drawn upwards through a chimney, while drawing in cooler air from below. Alternatively a fan can be used. The size and shape of the compartment varies depending on the product and the scale of the drying system. Large systems can use large barns while smaller systems may have a few trays in a small wooden housing.

Solar crop drying technologies can help reduce environmental degradation caused by the use of fuel wood or fossil fuels for crop drying and can also help to reduce the costs associated with these fuels and hence the cost of the product. Helping to improve and protect crops also has beneficial effects on health and nutrition.

-SPACE COOLING

The majority of the world's developing countries, however, lie within the tropics and have little need of space heating. There is a demand, however, for space cooling. The majority of the world's warm-climate cultures have again developed traditional, simple, elegant techniques for cooling their dwellings, often using effects promoted by passive solar phenomenon.

There are many methods for minimising heat gain. These include siting a building in shade or near water, using vegetation or landscaping to direct wind into the building, good town planning to optimise the prevailing wind and available shade. Buildings can be designed for a given climate - domed roofs and thermally massive structures in hot arid climates, shuttered and shaded windows to prevent heat gain, open structure bamboo housing in warm, humid areas. In some countries dwellings are constructed underground and

take advantage of the relatively low and stable temperature of the surrounding ground. There are as many options as there are people.

-DAY-LIGHTING

A simple and obvious use for solar energy is to provide light for use in buildings. Many modern buildings, office blocks and commercial premises for example, are designed in such a way that electric light has to be provided during the daytime to provide sufficient light for the activities taking place within. An obvious improvement would be to design buildings in such a way that that the light of the sun can be used for this purpose. The energy savings are significant and natural lighting is often preferred to artificial electric lighting.

5- COLLECTION SYSTEMS

There are certain systems to collect the solar thermal energy. Most systems for low-temperature solar heating depend on the use of glazing, in particular its ability to transmit visible light but to block infrared radiation. High temperature solar collection is more likely to employ mirrors. In practice, solar systems of both types can take a wide range of forms.

➤ LOW TEMPERATURE: $T < 100\text{ }^{\circ}\text{C}$

Domestic water, swimming-pool heating

➤ MEDIUM TEMPERATURE $T < 400\text{ }^{\circ}\text{C}$

Electricity produce

➤ HIGH TEMPERATURE $T > 400\text{ }^{\circ}\text{C}$

Electricity produce, blast furnace...

Active solar heating. This always involves a discrete solar collector, usually mounted on the roof of a building, to gather solar radiation. Mostly, collectors are quite simple and the heat produced will be at low temperature and used for domestic hot water or swimming pool heating.

Solar thermal engines. These are an extension of active solar heating, usually using more complex collector to produce temperatures high enough to drive steam turbine to produce electric power.

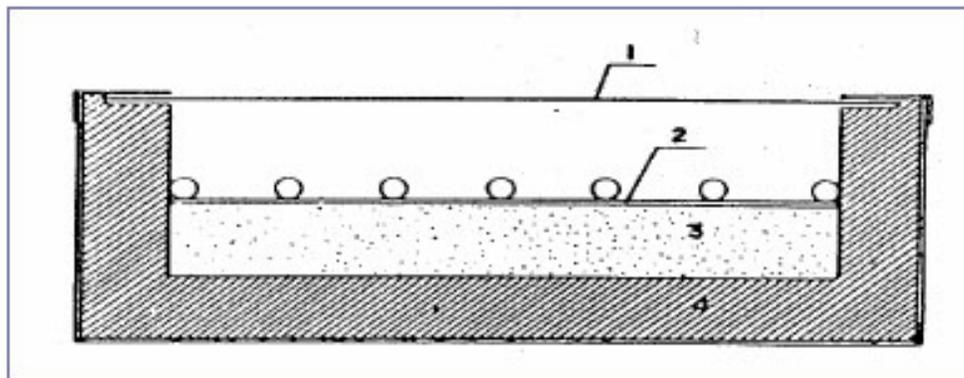
Passive solar heating systems mostly use air to circulate the collected energy, usually without pumps or fans indeed the collector is often an integral part of the building.

6-ACTIVE SOLAR HEATING

- LOW TEMPERATURE-SOLAR COLLECTOR

The solar collector plate has four principal elements:

- The transparent covert (1)
- The absorbent layer (2)
- Insulating (3)
- The casting (4)



solar collector¹²

The transparent cover should have several characteristics for the appropriate performance of the collector:

- Produce a green house effect and reduce the external losses
- Have a low coefficient of thermal conductivity
- The external surface has to be clean
- The collector must be sealed to prevent water and air to go into the system.

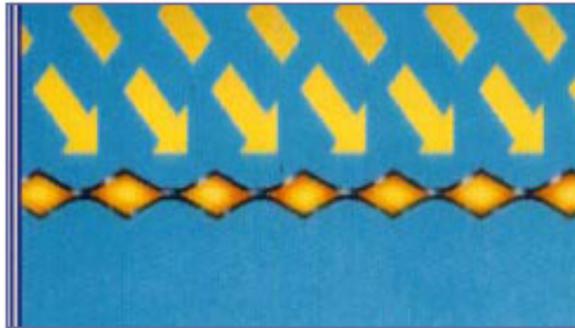
¹² shop.solardirect.com

The main materials used in the cover are:

- Glass
- Transparent plastic

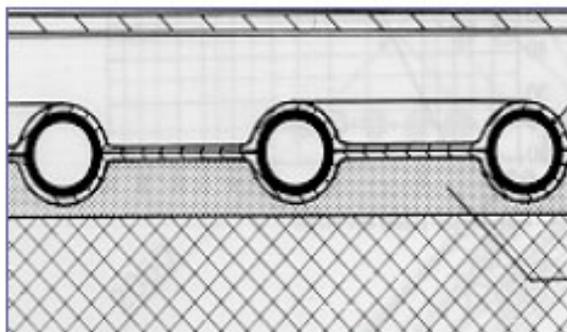
The absorbent layer receives the solar radiation that is transformed into heat and then it is transmitted to the fluid that will transport it. Two examples of these layers are:

- Two metallic sheets separated by a few millimetres.



absorbent layer¹³

- A metallic sheet that contains several tubes that carry the fluid.



absorbent layer¹⁴

¹³ www.cogeneration.net

¹⁴ www.thermomax.com

Absorber coating

There are two procedures, paintings and selective surfaces:

- The black paintings have a good absorption of solar radiation, but they have a high emission coefficient. They are cheaper than the selective surfaces but they suffer from deterioration from ultraviolet radiation.
- The selective surfaces are coatings with a high absorption coefficient and low emission coefficient. They have in general a better performance.

The absorber is protected in the back side to reduce the thermal losses. The isolators used for this are generally made from fiber glass or polyurethane. Some of the characteristics of these isolators are:

- Good performance at temperatures around 150°C
- Aging
- Good behaviour against humidity

The housing protects the different elements of the collector. It has some characteristics like:

- rigidity
- resistance to temperature variations
- corrosion resistance
- isolation from elements like water, snow and ice

-TYPES OF COLLECTOR

Unglazed panels: These are most suitable for swimming pool heating, where it is only necessary for the water temperature to rise by a few degrees above air ambient air temperature, so heat losses are relatively unimportant.



Unglazed panels¹⁵

Flat plate water collectors: Usually they are only single glazed but may have an additional second glazing layer, sometimes of plastic. The more elaborate the glazing system, the higher the temperature difference that can be sustained between the absorber and the external air.



Flat plate water collectors¹⁶

¹⁵ builditsolar.com

¹⁶ fivestarsolar.en.alibaba.com

The absorber plate usually has a very black surface with a high absorptivity. Most normal black paints still reflect approximately 10% of the incident radiation. Some panels use a selective surface that has both high absorptivity in the visible region and low emissivity in the long-wave infrared.

Generally, an absorber plate must have high thermal conductivity, to transfer the collected energy to the water with minimum temperature loss.

Flat plate air collectors: These are not so common as water collectors and are mainly used for space heating only. Also can combine this type of collector with a photovoltaic panel



Flat plate air collectors¹⁷

Evacuated tube collectors: The absorber plate is a metal strip down the centre of each tube. Convective heat losses are suppressed by virtue of a vacuum in the tube. The absorber plate uses a special heat pipe to carry the collected energy to the water.

¹⁷ www.eos-solar.com



Evacuated tube collectors¹⁸

Line focus collectors: These focus the sun on to a pipe running down the centre of a trough. The trough can be pivoted to track the sun up and down or east to west. A line focus collector can be oriented with its axis in either a horizontal or a vertical plane.

-MOUNTING

Solar collectors are usually roof mounted and once installed are difficult to reach for maintenance and repairs. They have to be proof against internal corrosion and very large temperature swings. A double-glazed collector is potentially capable of producing boiling water in high summer if the heat is not carried away fast enough.

¹⁸ www.azsolarcenter.com



On sloping roof



As sloping roof



On flat roof



On the ground

-ORIENTATION AND SLOPING

Orientation (general case)

One orientation to the East bring forward daily period (1 hour each 15°)

One orientation to the West put off daily period (1 hour each 15°), the performance is better because the collector can work more hours with higher ambient temperature.

Sloping

<u>Utilization</u>	<u>Degree of incline</u>
All year DWH	Latitude + 10°
Winter (heating)	Latitude+ 20°
Summer (swimming-pool)	Latitude – 5°

-MEDIUM TEMPERATURE AND HIGH TEMPERATURE

In a solar electricity generation system, the rays of the sun are used to generate heat. This systems use this energy to produce high temperatures that can boil water and drive steam machines to produce mechanical work or drive electrical generators in the same way as conventional oil, coal or nuclear power plants. We can differentiate basically two kinds of solar thermal systems: with and without concentration of solar rays.

The systems that concentrate the solar rays use mirrors or lenses to focus the light into a specific zone to produce high temperatures, this

allow the system to be very efficient energy conversion. Some examples of this type of system are:

-SOLAR TOWERS

Also called central receiver system or heliostat power plants. In this plant the sunlight is focused into a boiler at the top of the central tower by an array of moveable mirrors that track the trajectory of the sun. This boiler heats a synthetic oil or molten rock salt due to their high thermal capacity and conductivity. This heat can be stored by those elements for further use and some new designs have show that this energy can be stored from 3 to 13 hours. A solar tower can produce between 30 to 200MW.



solar tower Manzanares (Spain)¹⁹

¹⁹ www.deugarte.com



Comparison between diferents towers highs²⁰

-PARABOLIC THROUGH CONCENTRATION SYSTEMS

This system use large fields of parabolic trough shaped mirrors with a tube running across their length at the focal point. The collectors heat synthetic oil up to 390C that produce high temperature steam via a heat exchanger. This system has an efficiency of solar to electricity conversion between 14 and 22% and the thermal efficiency ranges from 60 to 80%. In absence of sun light these plants use conventional power generators. These hybrid systems need other components like condensers and accumulators. With a normal parabolic trough plant can produce between 14 and 80 MW.



Parabolic through²¹

²⁰ <http://es.wikipedia.org/wiki/Imagen:OzTowerCompare.jpg>

²¹ www.jupiterimages.com

- PARABOLIC DISH CONCENTRATOR SYSTEMS

This system puts the engine itself at the focus of a parabolic dish shaped mirror. Some modern systems can reach very high conversion efficiencies, close to 30%. The temperature at the focal point can reach 3000 °C that can be used to generate electricity, melt steel or to produce hydrogen fuel. This plant can produce between 7 and 25kW.



Parabolic dish²²

The most common way to concentrate the solar energy is with parabolic mirrors, this mirrors reflect the rays of the sun in a parallel way, this allow us to concentrate all the reflections into one point.

There are two ways in which the rays of the sun can be focused, the line focus, that concentrate the rays on a small region running along the length of the mirror, and the point focus, which concentrate the ray in a boiler, at the centre of the mirror.

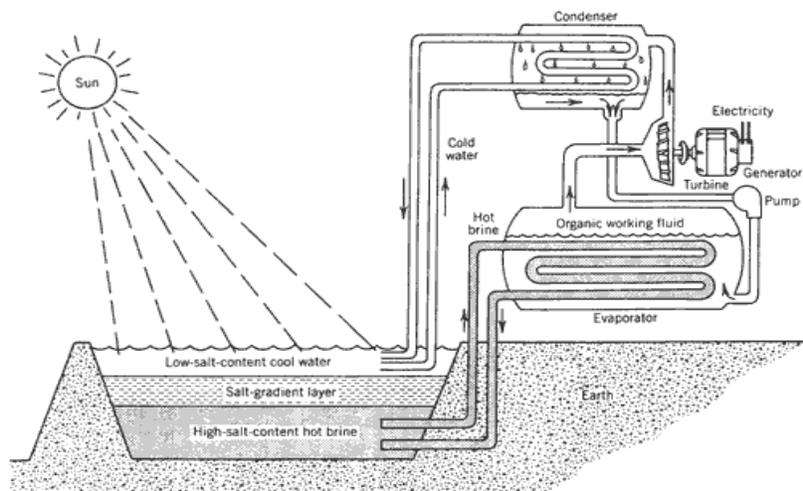
The other kind of systems are the ones that don't concentrate the solar rays, instead, the area that needs to be heated is exposed directly to the sun without any auxiliary components. This will result in less efficient systems, but they are also easier to construct and the

²² www.canren.gc.ca

possibilities of technical failures are reduced. In these systems we can find:

-SOLAR PONDS

In this system, a large salty lake is used as a plate collector. With the right salt concentration in the water, the solar energy can be absorbed at the bottom of the lake. The heat is insulated by the different densities of the water and at the bottom the heat can reach 90C, which is high enough to run a vapour cycle engine, at the top of the pond, the temperature can reach 30C. There are three different layers of water in a solar pond, the top layer that has less concentration of salt; the intermediate layer, that acts as a thermal insulator and finally the bottom layer that has a high concentration of salt. These systems have a low solar to electricity conversion efficiency, less than 15% (having an ambient temperature of 20C and a storage heat of 80C). One advantage of this system is that because the heat is stored, it can run day and night if required. Also due to its simplicity, it can be constructed in rural areas in developing countries.



Solar ponds²³

²³ www.powerfromthesun.net

The following table show the different characteristics of the solar electricity generators:

	Parabolic Trough	Solar Tower	Parabolic dish
Size	30-320MW	10-200MW	5-25kW
Temperature C (mean value)	390	560	750
Peak Efficiency	20%	23%	30%
Energy storage	Limited	Yes	Battery
Annual efficiency	16%	20%	25%

7- PASSIVE SOLAR HEATING

Passive solar technologies convert sunlight into usable heat, cause air-movement for ventilation or cooling, or store heat for future use, without the assistance of other energy sources and presents the most cost effective means of providing heat to buildings. Generally, the amount of solar energy that falls on the roof of a house is more than the total energy consumed within the house. Passive solar applications, when included in initial building design, adds little or nothing to the cost of a building, yet has the effect of realizing a reduction in operational costs and reduced equipment demand. It is reliable, mechanically simple, and is a viable asset to a home.

Passive solar systems have little to no operating costs, often have low maintenance costs, and emit no greenhouse gases in operation. They do, however, need to be optimized to yield the best performance and economics. Energy conservation reduces the needed size of any renewable or conventional energy system, and greatly enhances the economics, so it must be performed first. Passive solar technologies often yield high solar savings fractions, especially for space heating; when combined with active solar technologies or photovoltaics, even higher conventional energy savings can be achieved.

The mechanism of heating and cooling equipment is usually referred to as a system. A building is designed (home, apartment house) and a heating/cooling system using forced air equipment with air ducts; radiant floors using hot water; etc., is specifically designed for it. In passive building designs the system is integrated into the building elements and materials - the windows, walls, floors, and roof are used as the heat collecting, storing, releasing, and distributing

system. These very same elements are also a major element in passive cooling design but in a very different manner. It should be understood that passive solar design does not necessarily mean the elimination of standard mechanical systems, although recent designs coupled high efficiency back-up heating systems greatly reduce the size of the traditional heating systems and reduce the amount of non-renewable fuels needed to maintain comfortable indoor temperatures, even in the coldest climates.

The preceding explanations show that three elements must be present in all passive solar heating designs:

- A large area of south-facing glazing to capture the sunlight;
- Thermally heavyweight construction. This stores the thermal energy through the day and into the night;
- Thick insulation on the outside of the structure to retain the heat.

-GAIN IN P.S.H.

-LOSS IN P.S.H.

- Solar Radiation

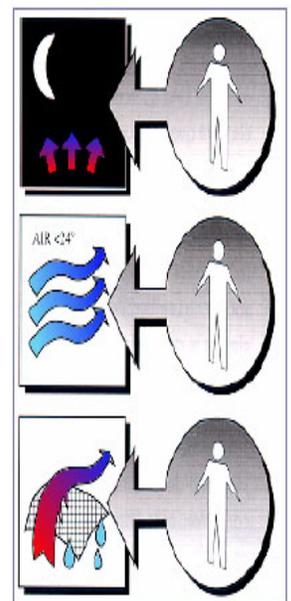
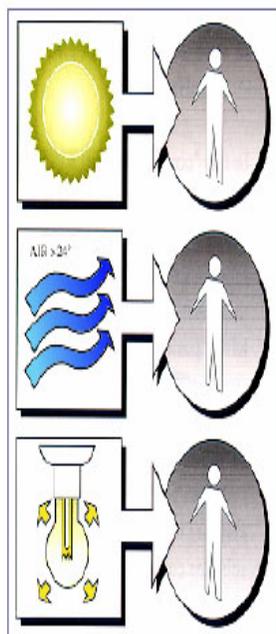
-Environment

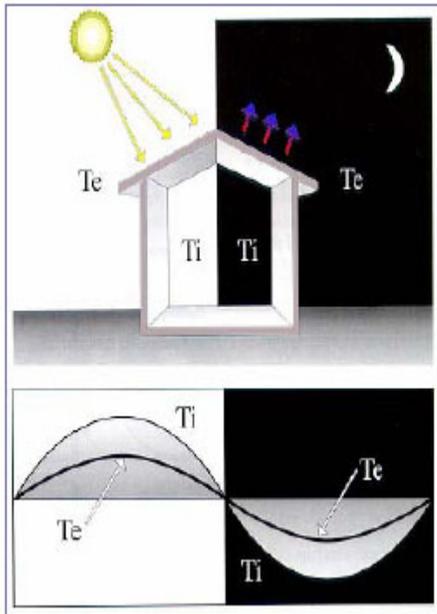
- Outside air to > 24°C

-Outside air to <24°C

- Inner gains

-Damp surface and vegetation





-DIRECT GAIN

The simplest of approaches is a direct gain design. Sunlight is admitted to the space and virtually all of it is converted to thermal energy. The walls and floor are used for solar collection and thermal storage by intercepting radiation directly, and by absorbing reflected or reradiated energy. As long as the room temperature remains high in the interior space storage mass will conduct heat to their cores. At night, when outside temperatures drop and the interior space cools, the heat flow into the storage masses is reversed and heat is given up to the interior space in order to reach equilibrium. This re-radiation of collected daytime heat can maintain a comfortable temperature during cold nights and can extend through several cloudy days without recharging.

Direct gain design is simple in concept and can employ a wide variety of materials and combinations of ideas that will depend greatly upon the site and topography; building location and orientation; building shape; and space use.

A direct gain design requires about one-half to two-thirds of the total interior surface area to be constructed of thermal storage materials. These can include floor, ceiling and wall elements, and the materials can range from masonry (concrete, adobe, brick) to water.

Water contained within plastic or metal containment and placed in the direct path of the sun's rays has the advantage of heating more quickly and more evenly than masonry walls during the convection process. The convection process also prevents surface temperatures from becoming too extreme as they sometimes do when dark colored masonry surfaces receive direct sunlight. The masonry heating problem can be alleviated by using a glazing material that scatters sunlight so that it is more evenly distributed over walls, ceiling, and floor storage masses. This decreases the intensity of rays reaching any single surface but does not reduce the amount of solar energy entering the space.

-DIRECT GAIN – TYPES

➤ Window



window²⁴

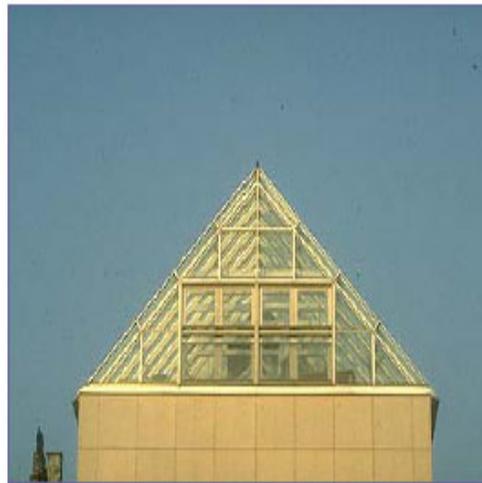
²⁴ construible.es

➤ Atrium



atrium²⁵

➤ Skylight



skylight²⁶

-INDIRECT GAIN

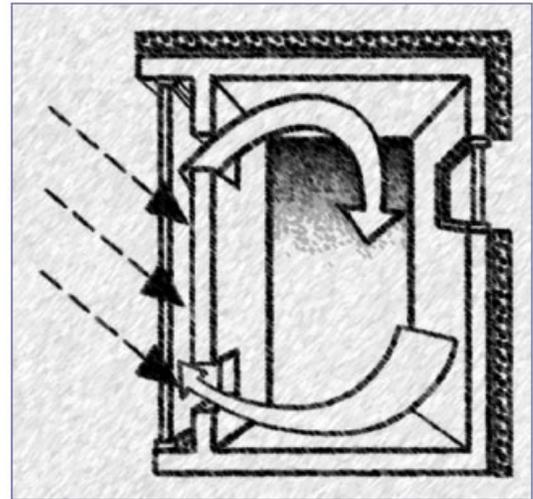
This passive solar design approach uses the basic elements of collection and storage of heat in combination with the convection process. In this approach, thermal storage materials are placed

²⁵ www.todoarquitectura.com

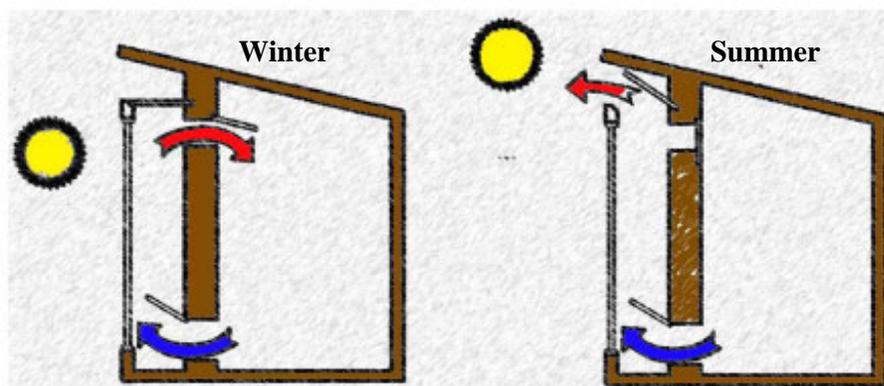
²⁶ www.iaso.es

between the interior habitable space and the sun so there is no direct heating.

Instead a dark colored thermal storage wall is placed just behind a south facing glazing (windows). Sunlight enters through the glass and is immediately absorbed at the surface of the storage wall where it is either stored or eventually conducted through the material mass to the inside space. In most cases the masonry thermal storage mass cannot absorb solar energy as fast as it enters the space between the mass and the window area. Temperatures in



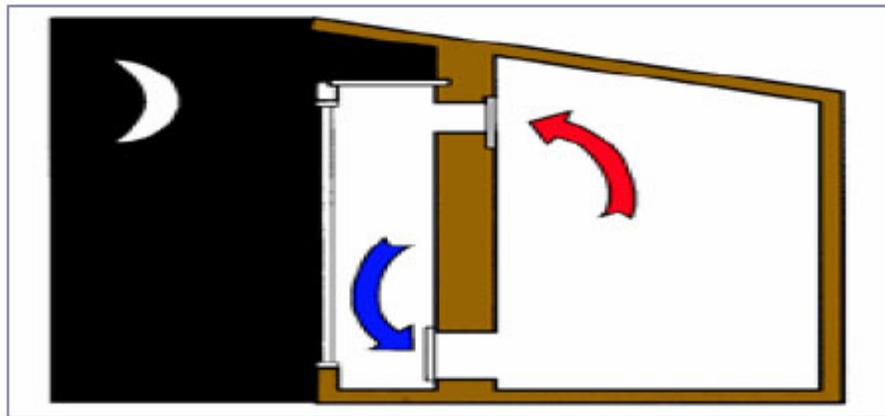
this space can easily exceed 37.78°C. This build up of heat can be utilized to warm a space by providing heat-distributing vents the top of the wall. Vents at the bottom of the wall allow cool air to be drawn into the heating space thereby replacing the outflowing hot air, and picking up heat itself.



Trombe wall during the day²⁷

²⁷ www.maslibertad.com

The top and bottom vents continue to circulate air as long as the air entering the bottom vent is cooler than the air leaving the top vent. This is known as a natural convective loop. At night the vents can be closed to keep cold air out and the interior space is then heated by the storage mass, which gives up its heat by radiation as the room cools.

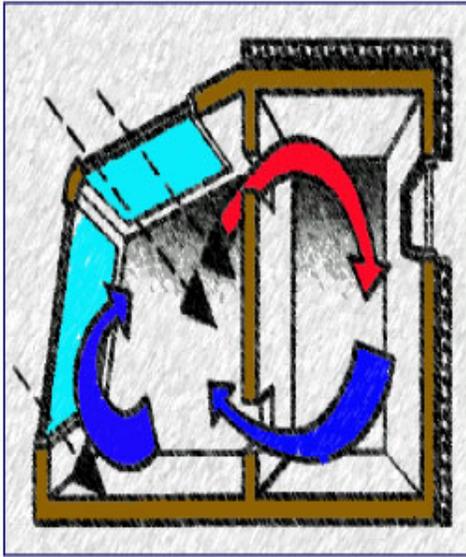


Trombe wall during the night²⁸

A variation of the vented masonry wall design is one that employs a water wall between the sun and the interior space . Water walls used in this way need not be vented at top and bottom and can be constructed in many ways. Again, as the water is heated, the convection process quickly distributes the heat throughout the mass and the interior space is warmed by heat radiated from the wall.



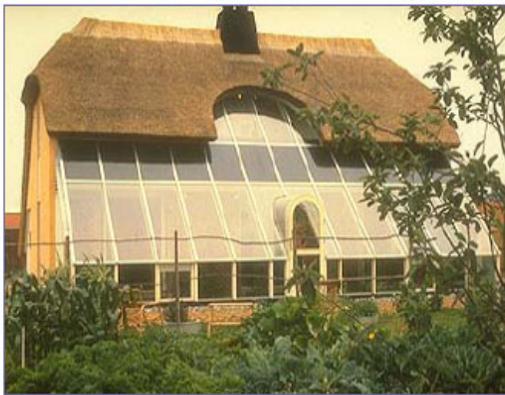
²⁸ www.maslibertad.com



greenhouse

Another design approach takes advantage of the greenhouse effect as well as the direct gain storage wall. A south facing "greenhouse space" is constructed in front of a thermal storage wall exposed to the direct rays of the sun. This wall would be at the rear of the greenhouse and the front of the primary structure. The thermal wall absorbs heat at the same time the interior space of the greenhouse is

being heated. If a vented masonry wall is used as storage, heat can also be released into the living space by convection. This combination also works with an unvented water wall. The greenhouse, then, is heated by direct gain while the living space is heated by indirect gain . The advantage is that a tempered greenhouse condition can be maintained through days of no sun, with heating from both sides of the thermal storage wall.



greenhouse²⁹

²⁹ www.construnario.com

An indirect gain design which provides both heating and cooling is the thermal pond approach, which uses water encased in ultraviolet ray inhibiting plastic beds underlined with a dark color, that are placed on a roof. In warm and temperate climates with low precipitation, the flat roof structure also serves directly as a ceiling for the living spaces below thereby facilitating direct transfer of heating and cooling for the spaces below. In colder climates, where heating is more desirable, attic ponds under pitched roof glazing are effective. Winter heating occurs when sunlight heats the water, which then radiates energy into the living space as well as absorbs heat within the water thermal mass for nighttime distribution. During the summer, a reverse process, described later, occurs. For best effect, roof ponds must be insulated (movable) so that heat will not radiate and be lost to the outside. One of the major advantages of this approach is that it allows all rooms to have their own radiant energy source with little concern about the orientation of the structure or optimal building form.

8- CONCLUSIONS

Climate change concerns coupled with high oil prices and increasing government support arriving increasing renewable energy legislation, incentives and commercialization. Solar thermal energy accounts for one of the major forms of renewable energy utilization. The mayor applications of it are heating swimming pools, heating water for domestic use and space heating of building. Current research and developement is focused on improving solar heating technologies to make them even more efficient and affordable, with special emphasis on:

- Tesitng material for durability, much research efforts include glazing and absorbers.
- Conducting thermal analysis of solar water heating technologies that function in different climates.
- Developing advanced applications such as low cost solar water heating and collectors.

Solar savings fraction is very important in dealing about solar energy, which is the amount of energy provided via the solar technology divided by the total energy required. Passive solar technologies often yield high solar saving fractions for space heating, when combined with active solar technologies even higher conventional energy savings can be achieved.

The electricity generation from solar energy is also an important feature that is available with different technologies such as solar tower and solar ponds. However solar dish/stearling engine has the highest

energy efficiency. The one installed at Sandia National Laboratories produces as much as 25kW of electricity with conversion efficiency of 40.7%. As a solar power plant does not consume any fuel, the cost mainly consists of capital cost and some operational costs. If lifetime of plant and interest are known then cost for kWh can be calculated.

Solar technologies have the potential to be mayor contributors to the global energy supply. The ability to dispatch power allows large scale central solar technologies to provide 50% or more of the energy needs in sunny regions around the world. Large scale solar technologies can provide energy price stability as well as quality jobs to the local community. Solar energy has the potential to become mayor a domestic energy resource in the 21st century.

9- REFERENCE LIST

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