Pakistan Council of Renewable Energy Technologies

Government of Pakistan

Ministry of Science and Technology

PCRET, 25, H-9, Islamabad, Pakistan

Solar Thermal Division

For further information

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Introduction

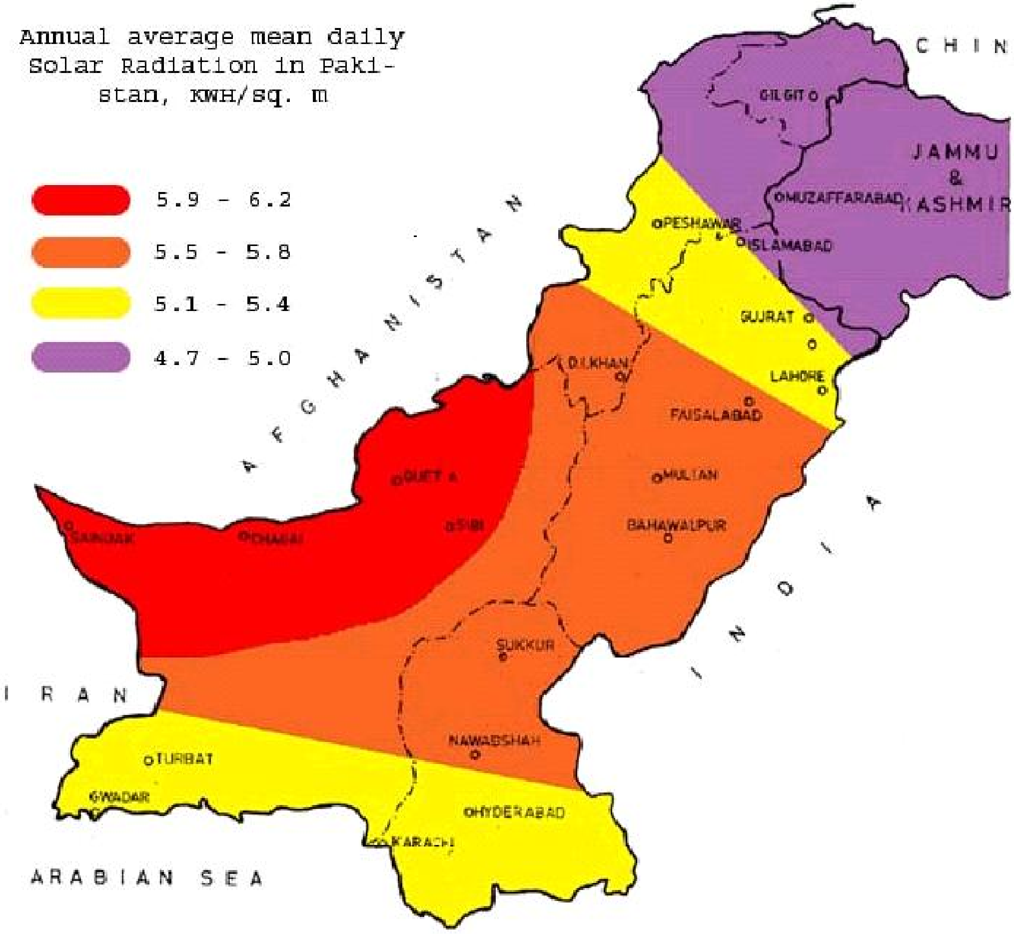
Pakistan is an energy deficient country and spends, every year, approximate 4 Billion US dollars to import oil with annual growth rate of nearly 2%. Under the present scenario of energy pattern, the renewable energy sources have become most important for Pakistan. The most viable sources of renewable energy, in the country, are solar, wind, small hydro, biogas, and biomass and these can be utilized effectively to meat the challenges of energy deficit. Realizing the importance and necessity of renewable energy technologies, Govt. of Pakistan decided to establish the Pakistan Council of Renewable Energy Technologies (PCRET) in May 2001 by merging together Pakistan Council for Appropriate Technology (PCAT) and National Institute of Silicon Technology (NIST). The council aims to take up R&D and promotional activities in different renewable energy technologies. The main objectives of the Council are to establish facilities, expertise, and to do research to develop suitable technologies to produce materials, devices, and appliances in the fields of renewable energy; to determine policies and make short and long term programs to promote renewable energy technologies in the country through research, development, conferences and demonstration projects; to establish national and international liaison in the field; and to advise and assist the government and relevant industries in the area. The council has its Headquarter at Islamabad and four regional and field offices at the four provincial headquarters. The activities of the Council are divided into a number of technical divisions and the current emphasis is on photovoltaic, solar thermal, biogas, Microhydel and wind power.

Solar Energy

Among all renewable energy sources, solar radiation is in abundance, freely available, widely distributed and can easily be converted into other forms of energy. This makes solar energy the most promising future source of energy. On reaching the earth its peak value at the sea level is 900 to 1000 W/m^2; Global irradiation falling on the horizontal surface is about 1.5-2.0 MWh/m^2 per year. This value is more than 10,000 times the current value of all type of energies that the world is using. The mean global irradiance falling on horizontal surface in Pakistan varies from 4.7 kWh/m^2 to 6.2 kWh/m^2 the number of clear sunny days in the country varies from 250 in the Northern region to above 300 days in most part of the rest of the country.

Solar Thermal

The activities here include modelling, designing and fabrication of low cost efficient solar thermal appliances such as Solar Cookers, Solar Water Heaters, Solar Room Heaters, Solar Stills, and Solar Dryers etc. Several models of solar thermal appliances like solar cookers, solar ovens, solar dryers, solar water heaters, and solar stills have been developed by this council and are being disseminated. In Public Sector Development Programme, Govt of Pakistan PCRET designed developed and installed 10 unglazed collector type hybrid (Solar + Biomass) dryer having 500 kg capacities for drying of dates in Punjab, Khyber Pakhtoonkhwa.



Current Activities

PCRET recently submitted PC-1 for **Promotion of Parabolic Solar Cookers in Rural Areas of Pakistan.** The main objectives of PCRET are to develop, acquire, assimilate, promote, propagate & disseminate Renewable Energy Technologies including solar cooker in the country. The project aims to provide 125,000 solar cookers for cooking and pasturing of water in remote area of all the provinces of Pakistan. This PC-1 is submitted according to directives of President of Islamic Republic of Pakistan

Temperature range for different solar thermal application

Temperature	Description	Application
22-24 ºC	Room temperature	Solar room heating
50-60 ºC	Most germs can't grow	Solar drying
65 ºC	Water pasteurization	Solar desalination
71 ºC	Food pasteurization	
82-150 ºC	Food cooks	Solar baking
100-120 ºC	Water boils	Solar water heating
150-250 ºC	Steam generation	Solar cooking
300-650 ºC	Heating different material for solar trough, dish stirling engine and solar tower	Solar Power Generation

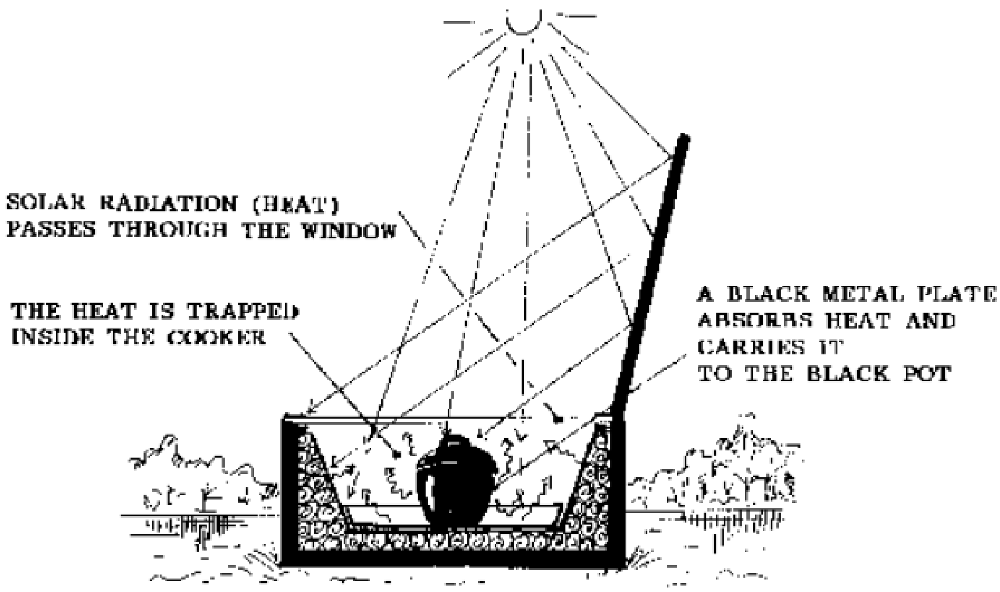
Type of collector used in solar energy application such as Solar room heating, water heating, drying

Type of collector	Temp. Range (°C)
Air collector	20 - 50
Flat plate collector (Unglazed collector or uncovered absorber)	Up to 40
Flat-plate collector (Glazed covered with glass)	20 - 80
Evacuated tube collector	50 - 150
Heat Pipe tube collector	50 - 150
Super tube collector	50 – 150

SOLAR COOKER ((BOX TYPE)

The box cooker, which is the simplest and the cheapest solar cooker type, is still able to heat food to 150 C (300 F). It consists of an insulated box with a glass or a plastic window. The window acts as a solar energy trap by exploiting the greenhouse effect. Solar radiation passes through the window, and is absorbed by the walls, the bottom of the cooker and the cooking utensils (pots, pans, etc.). The darker the pots and the inside of the cooker are, the better they are heated. The window is not transparent to heat radiation, which means that the heat radiation coming from the walls and the pots will be trapped inside the cooker, thus heating the air. To maximise the heating effect, the cooker's walls, and the outer side (not the inner side!) of the cooking pots should be painted black. The bottom should be covered with a black metal plate to carry heat to the pots. A double window is better than a single window because it reduces heat conduction. To increase the incoming solar radiation, reflective plates can be used; and in less-than-optional solar condition, their use is essential. They should be positioned so as to reflect radiation from a wider area into the box. In addition, the box should be mad as airtight as possible, so as to minimise the flow of hot air to the outside.

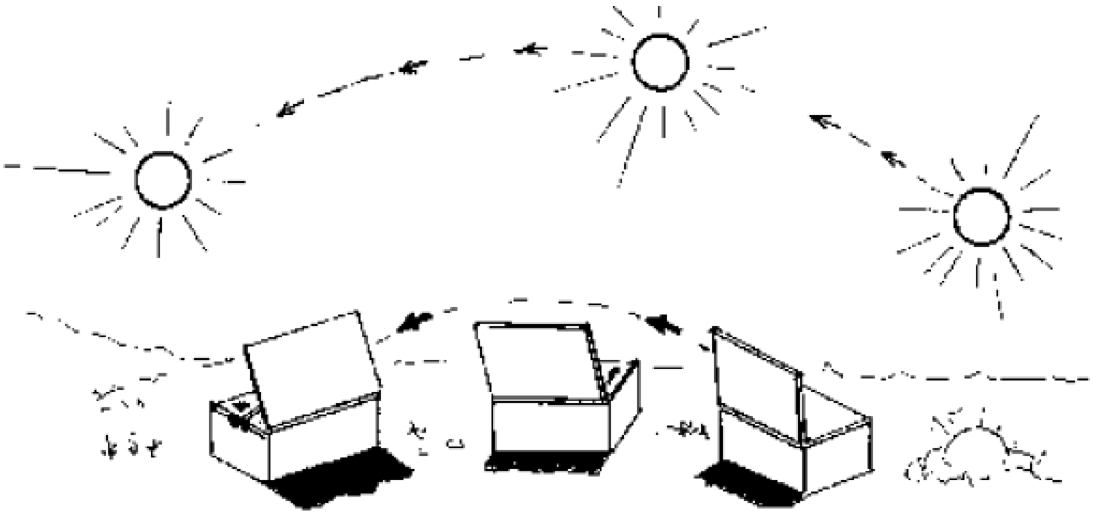
- Solar Cooking involves no recurring expenses on fuel, as the solar energy is absolutely free.
- Cost of the solar cooker gets recovered easily through savings on conventional fuel in few years.
- Regular use of a box type solar cooker may save 3-4 LPG cylinders per year.
- It saves time, as the cook need not be present during cooking in a solar cooker.
- There is no fear of scorching the food.
- It provides better and more nutritious food due to slow cooking.
- It is durable and simple to operate.
- It does not pollute the environment and conserves conventional energy.
- It is an asset to the household and a pride to its owner
- Temperature vary from 100 – 150^{o}c
- Cooking Time vary from10.00 A.M – 3:00 P.M
- Application baked and cooks rice, Vegetables, pulses, meat, cakes etc
- Weight about 14 to 15 kg.



How to use the solar box cooker

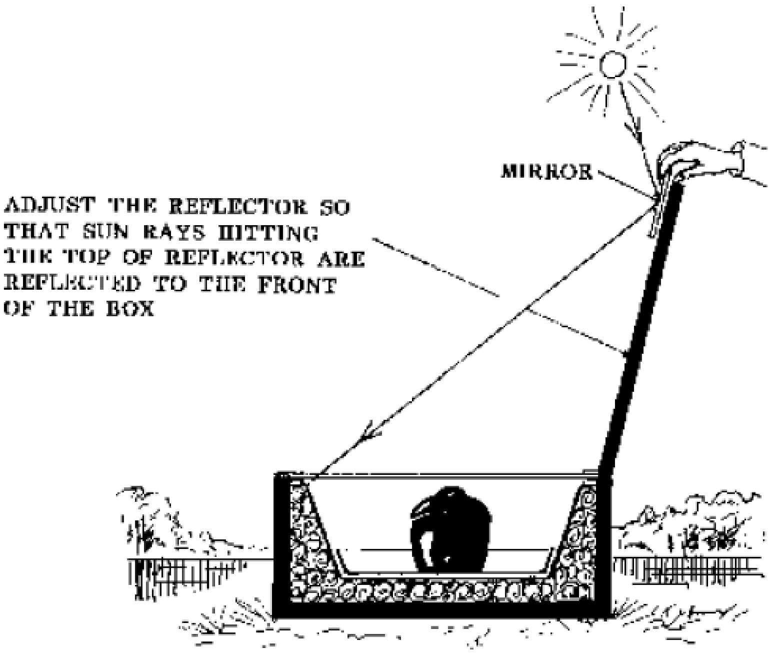
Place your solar box cooker outdoors in a sunny place, which is not windy. Choose, for example, a fenced garden, a rooftop or a balcony, because then it will be safe from animals. The nearer the cooking-place is to your house, the easier it is to prepare food and to keep an eye on the cooker. A strong wind may deposit rubbish and sand on the cooker's glass, which will slow down the heating process. Further, the outside temperature affects the temperature inside the cooker. Warm weather is always better than cold. When you use your solar box cooker for the first time, pay attention to the cooking times of different meals. With practice you can learn to estimate the time necessary for cooking, and the food will be tasty without your continuous supervision. When you lift up the glass, watch out for the burning hot steam that may rise from the box. Because pots get hot in the solar box cooker, you should use potholders when lifting them out.

Directing solar box cookers



TURN THE SOLAR BOX COOKER
TOWARDS THE SUN

It is best to use solar box cookers when the sun is shining from a cloudless sky and when the outside temperature is over 20 C (70 F). The cooker should be placed facing directly towards the sun, so that no shadows fall inside the box. In this way the cooker will get the maximum amount of sunshine, and cooks fastest. Adjust the cooker's lid to reflect all the sunshine you can inside the box. The cooker's position has to be changed so as to follow the sun's movement. If you are not in a hurry and there is a lot of sunshine, you can pre-set the cooker in the morning to the position where the sun shines at midday. Then it needs no further adjustments. Otherwise, if you are in hurry, you should change the cooker's position every 1-2 hours so that it always faces the sun. The cooker's reflecting lid should be adjusted downwards or upwards according to how high (the vertical angle) the sun is shining. Remember not to use too much force in closing the lid; otherwise you might break the glass.



Box type Solar
(Body: wooden and Iron sheet
Reflecting material: Ordinary glass and transparent glass
Heat retaining material: glass or rock wool)

Box type Solar
(Body: wooden, and iron sheet
Reflecting material: Ordinary glass and transparent glass
Heat retaining material: glass or rock wool)

SOLAR COOKER (PARABOLIC / CONCENTRATOR TYPE)

Solar cooking is the simplest, safest, most convenient way to cook food without consuming fuels or heating up the kitchen. Many people choose to solar cook for these reasons. But for hundreds of millions of people around the world who cook over fires fuelled by wood or dung, and who walk for miles to collect wood or spend much of their major incomes on fuel, solar cooking is more than a choice — it is a blessing.

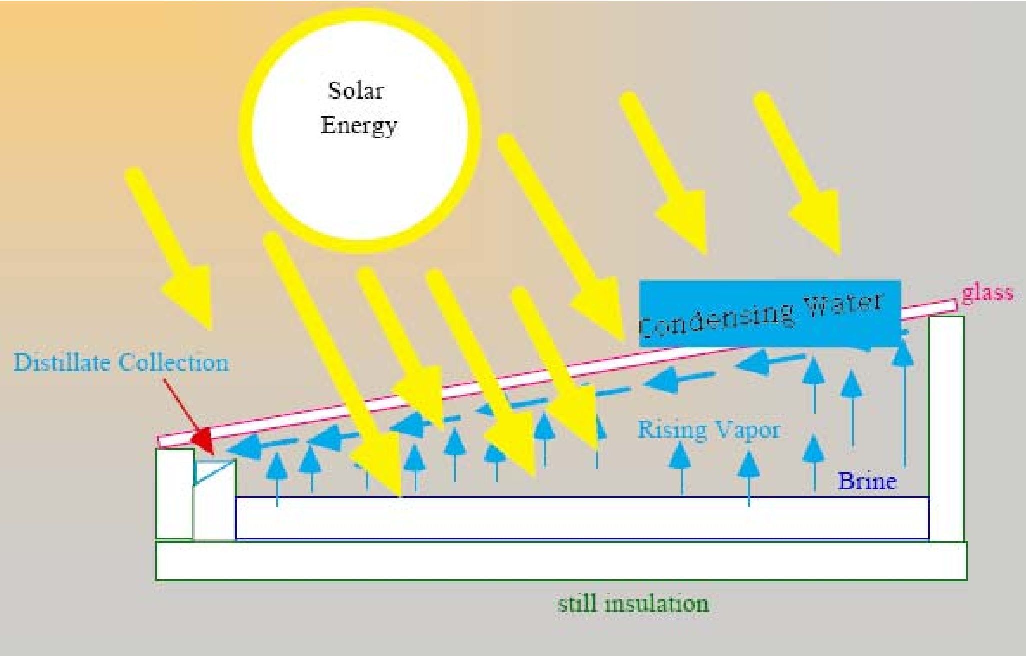
The concentrating type parabolic dish solar cooker will be useful for individuals in rural as well as urban areas. The reflecting material used for its fabrication is anodized aluminum sheet that has a reflectivity of over 75 %. The tracking of the cooker is manual and so has to be adjusted in 15 to 20 minutes during the cooking time. The temperature achieved at the bottom of the vessel could range from 300 to 400^{o}C, which is sufficient for roasting, frying and boiling. A cooker with about 40% thermal efficiency can meet the needs of around 15 people and can be used from one hour after sunrise until one hour before sunset on clear days. It can be easily dismantled and assembled and therefore can be transported anywhere in the country. It can also be placed at a convenient level for its users. The cooker can save up to 10 LPG cylinders a year on full use in small establishments. The metallic structure reflecting sheets may, however, have to be replaced once in 2 year.

Parabolic type solar cooker
(Reflecting material: aluminium foil
Dish material: fibreglass and cement
Stand made of angle iron)

Parabolic type solar cooker
Reflecting material looking glass
Dish material fibreglass and cement
Stand made of angle iron

Solar Stills

Introduction



The basic principles of solar water distillation are simple yet effective, as distillation replicates the way nature makes rain. The sun's energy heats water to the point of evaporation. As the water evaporates, water vapour rises, condensing on the glass surface for collection. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. The end result is water cleaner than the purest rainwater.

The distilled water still does not acquire the "flat" taste of commercially distilled water since the water is not boiled (which lowers pH). Solar stills use natural evaporation and condensation, which is the rainwater process. This allows for natural pH buffering that produces excellent taste as compared to steam distillation. Solar stills can easily provide enough water for family drinking and cooking needs.

Solar distillers can be used to effectively remove many impurities ranging from salts to microorganisms and are even used to make drinking water from seawater. Many users, both rural and urban, from around the globe, have received solar stills. Solar distillers can be successfully used anywhere the sunshine.

The Solar stills are simple and have no moving parts. They are made of quality materials designed to stand-up to the harsh conditions produced by water and sunlight. Operation is simple: water should be added (either manually or automatically) once a day through the still's supply fill port. Excess water will drain out of the overflow port and this will keep salts from building up in the basin. Purified drinking water is collected from the output collection port.

Supply Fill Port:
Water should be added to the still via this port. Water can be added either manually or automatically. Normally, water is added once a day (in the summer it's normally best to fill in the late evening and in the winter, in the early morning).

Overflow Port:
Once the still basin has filled, excess water will flow out of this port. It is recommends three times daily-distilled water production to be allowed to overflow from the still on a daily basis to prevent salt build-up in the basin. If your still produced 2 gallons of product water then you should add 6 gallons of fresh feed water through the fill port. If flushed like this on a daily basis, the overflow water can be used for other uses as appropriate for your feed water (for example, landscape watering).

Distilled Output Collection Port:

Purified drinking water is collected from this port, typically with a glass collection container. Stills that are mounted on the roof can have the distillate output piped directly to an interior collection container. For a newly installed still, allow the collection trough to be self-cleaned by producing water for a couple of days before using the distillate output.

Operation

A solar still operates on the same principle as rainwater: evaporation and condensation. The water from the oceans evaporates, only to cool, condense, and return to earth as rain. When the water evaporates, it removes only pure water and leaves all contaminants behind. Solar stills mimic this natural process.

A Solar single basin solar still has a top cover made of glass, with an interior surface made of a waterproof membrane. This interior surface uses a blackened material to improve absorption of the sun's rays. Water to be cleaned is poured into the still to partially fill the basin. The glass cover allows the solar radiation (short-wave) to pass into the still, which is mostly absorbed by the blackened base. The water begins to heat up and the moisture content of the air trapped between the water surface and the glass cover increases. The base also radiates energy in the infrared region (long-wave), which is reflected back into the still by the glass cover, trapping the solar energy inside the still (the "greenhouse" effect). The heated water vapor evaporates from the basin and condenses on the inside of the glass cover. In this process, the salts and microbes that were in the original water are left behind. Condensed water trickles down the inclined glass cover to an interior collection trough and out to a storage bottle

The still is filled each morning or evening, and the total water production for the day is collected at that time. The still will continue to produce distillate after sundown until the water temperature cools down. Feed water should be added each day that roughly exceeds the distillate production to provide proper flushing of the basin water and to clean out excess salts left behind during the evaporation process.

The intensity of solar energy falling on the still is the single most important parameter affecting production. The daily-distilled water output (M e in kg/m^2 day) is the amount of energy utilized in vaporizing water in the still (Q e in J/m^2 day) over the latent heat of vaporization of water (L in J/kg). Solar still efficiency (n) is the amount of energy utilized in vaporizing water in the still over the amount of incident solar energy on the still (Q t in J/m2 day). These can be expressed as:

Solar still production: $M_e = Q_e / L$
Solar still efficiency: $n = Q_e / Q_t$

Typical efficiencies for single basin solar stills approach 60 percent. General operation is simple and requires facing the still towards solar noon, putting water in the still every morning to fill and flush the basin, and recovering distillate from the collection reservoir (for example, glass bottles). Stills are modular and for greater water production requirements, several stills can be connected together in series and parallel as desired.

As water evaporates from the solar still basin, salts and other contaminants are left behind. Over time, these salts can build to the point of saturation if the still is not properly maintained and flushed on a regular basis. Properly operating a still requires about three times as much make-up water as the distillate produced each day. If the still produced 3 gallons of water, 9 gallons of make-up water should be added, of which 6 gallons leaves the still as excess. The excess water flushes the still basin through the overflow to prevent salt buildup. If this is done on a daily basis, the flushed water is of approximately the same quality as the original feed water that was added to the still. The excess water is of suitable quality that it can be used to water landscaping, wash pots and pans, etc. No sediment or sludge will buildup if the still is properly operated and flushed daily.

Still Water Production

Solar still production is a function of solar energy (insolation) and ambient temperature. Production rates in the Pakistan can average about 4 liters per day in the winter to over 6 liters per day during the summer, per square meter.

Distillation Purification Capabilities

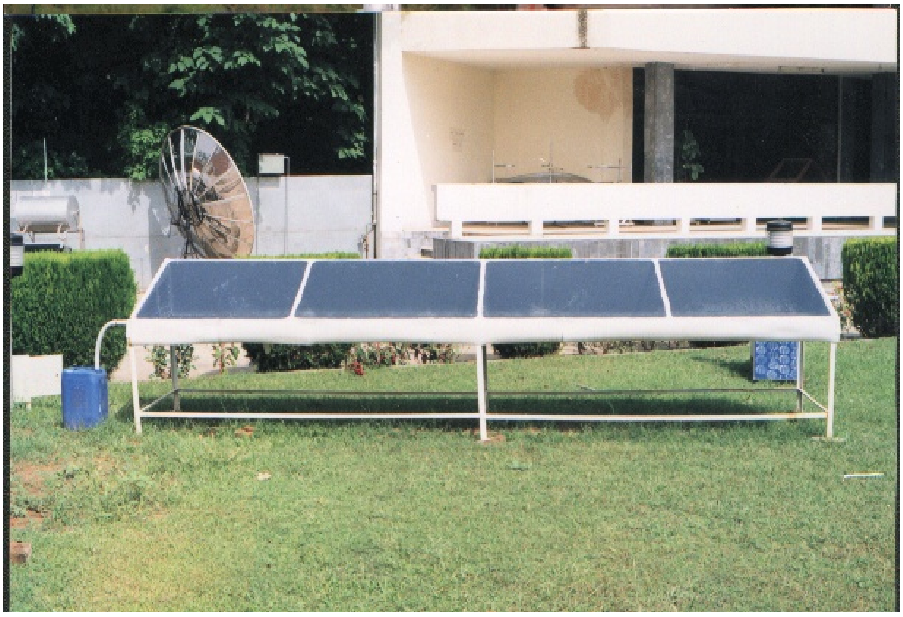
Solar stills have proven to be highly effective in cleaning up water supplies to provide safe drinking water. The effectiveness of distillation for producing safe drinking water is well established and recognized. Most commercial stills and water purification systems require electrical or other fossil-fueled power sources. Solar distillation technology produces the same safe quality drinking water as other distillation technologies; only the energy source is different: the sun.

Solar Stills are effective in removing:

- Salts/Minerals (e.g., Na, Ca, As, Fl, Fe, Mn)
- Bacteria (e.g., E. Coli, Cholera, Botulinus)
- Parasites (e.g., Giardia, Cryptosporidium)
- Heavy Metals (e.g., Pb, Cd, Hg)
- Stills can effectively purify seawater and even raw sewage

Solar Distilled Water Taste:

- Equivalent or superior taste to commercially available bottled water
- Water only comes in contact with food grade materials and glass
- Natural bicarbonate buffering produces excellent taste compared to steam distillation



Ordinary Solar Stills

Parabolic type solar stills output will double
As compare to natural solar stills

EVACUATED TYPE SOLAR WATER HEATERS

Introduction:

There are basically three types of thermal solar collectors: flat-plate, evacuated-tube and concentrating.

Flat-Plate collectors comprise of an insulated, weatherproof box containing a dark absorber plate under one or more transparent or translucent covers. Water or heat conducting fluid passes through pipes located below the absorber plate. As the fluid flows through the pipes it is heated. This style of collector, although inferior in many ways to evacuated tube collectors, is still the most common type of collector in many countries.

Evacuated Tube solar water heaters are made up of rows of parallel, glass tubes. There are several types of evacuated tubes.

Type 1 (Glass-Glass) tubes consist of two glass tubes, which are fused together at one end. The inner tube is coated with a selective surface that absorbs solar energy well but inhibits radiative heat loss. The air is withdrawn ("evacuated") from the space between the two glass tubes to form a vacuum, which eliminates conductive and convective heat loss. These tubes perform very well in overcast conditions as well as low temperatures. Because the tube is 100% glass, the problem with loss of vacuum due to a broken seal is greatly minimized. Glass-glass solar tubes may be used in a number of different ways, including direct flow, heat pipe, or U pipe configuration.

Type 2 (Glass-Metal) tubes consist of a single glass tube. Inside the tube is a flat or curved aluminium plate, which is attached to a copper heat pipe or water flow pipe. The aluminium plate is generally coated with Tinox, or similar selective coating. These types of tubes are very efficient but can have problems relating to loss of vacuum. This is primarily due to the fact that their seal is glass to metal. The heat expansion rates of these two materials glass tubes although not quite as efficient glass-metal tubes are generally more reliable and much cheaper.

Type 3 (Glass-glass - water flow path) tubes incorporate a water flow path into the tube itself. The problem with these tubes is that if a tube is ever damaged water will pour from the collector onto the roof and the collector must be "shut-down" until the tube is replaced.

Concentrating collectors for are usually parabolic troughs that use mirrored surfaces to concentrate the sun's energy on an absorber tube (called a receiver) containing a heat-transfer fluid, or the water itself? This type of solar collector is generally only used for commercial power production applications, because very high temperatures can be achieved. It is however reliant on direct sunlight and therefore does not perform well in overcast conditions.

Types of Solar Water Heating Systems

Solar water heating systems (SWHS) can be either active or passive. An active system uses an electric pump to circulate the fluid through the collector; a passive system has no pump and relies on thermo-siphoning to circulate water. The amount of hot water a solar water heater produces depends on the type and size of the system, the amount of sun available at the site, installation angle and orientation. SWHS are also characterized as open loop (also called "direct") or closed loop (also called "indirect"). An open-loop system circulates household (potable) water through the collector. A closed-loop system uses a heat-transfer fluid (water or diluted antifreeze) to collect heat and a heat exchanger to transfer the heat to the household water. A disadvantage of closed looped system is that efficiency is lost during the heat exchange process.

Active Systems

Active systems use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. They are usually more expensive than passive systems but generally more efficient. Active systems are often easier to retrofit than passive systems because their storage tanks do not need to be installed above or close to the collectors. If installed using a PV panel to operate the pump, an active system can operate even during a power outage.

Open-Loop Active Systems

Open-loop active systems use pumps to circulate household potable water through the collectors. This design is efficient and lowers operating costs but is not appropriate if water is hard or acidic because scale and corrosion will gradually disable the system. Open-loop active systems are popular in regions that do not experience subzero temperatures. Flat plate open-loop systems should never be installed in climates that experience sustained periods of subzero temperatures.

Closed-Loop Active Systems

These systems pump heat-transfer fluids (usually a glycol-water antifreeze mixture) through the solar water heater. Heat exchangers transfer the heat from the fluid to the water that is stored in tanks. Double-walled heat exchangers or twin coil solar tanks prevent contamination of household water. Some standards require double walls when the heat-transfer fluid is anything other than household water. Closed-loop glycol systems are popular in areas subject to extended subzero temperatures because they offer good freeze protection. However, glycol antifreeze systems are more expensive to purchase and install and the glycol must be checked each year and changed every few years, depending on glycol quality and system temperatures.

Drain back systems use water as the heat-transfer fluid in the collector loop. A pump circulates the water through the solar water heater. When the pump is turned off, the solar water heater drain of water, which ensures freezes protection and also allows the system to turn off if the water in the storage tank becomes too hot. A problem with drain back systems is that the solar water heater installation and plumbing must be carefully positioned to allow complete drainage. The pump must also have sufficient head pressure to pump the water up to the collector each time the pump starts. Electricity usage is therefore slightly higher than a sealed closed or open loop.

Passive Systems

Passive systems move household water or a heat-transfer fluid through the system without pumps. Passive systems have the advantage that electricity outage and electric pump breakdown are not issues. This makes passive systems generally more reliable, easier to maintain, and possibly longer lasting than active systems. Passive systems are often less expensive than active systems, but are also generally less efficient due to slower water flow rates through the system.

Thermosiphon Systems

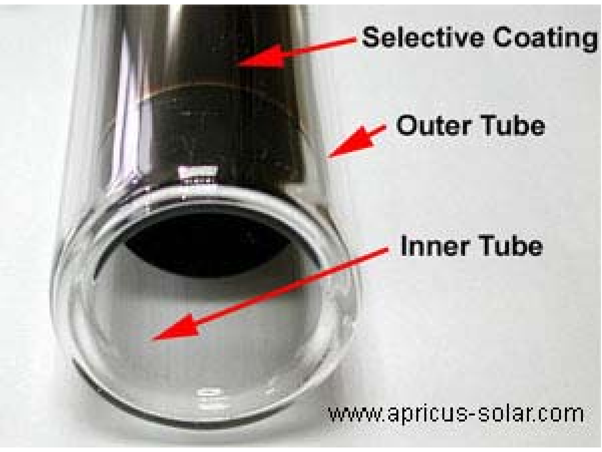
A thermosiphon system relies on warm water rising, a phenomenon known as natural convection, to circulate water through the solar absorber and to the tank. In this type of installation, the tank must be located above the absorber tubes/panel. As water in the absorber heats, it becomes lighter and naturally rises into the tank above. Meanwhile, cooler water in the tank flows downwards into the absorber, thus causing circulation throughout the system. This system is widely used with both flat plate and evacuated tube absorbers. The disadvantages of this design are the poor aesthetics of having a large tank on the roof and the issues with structural integrity of the roof. Often the roof must be reinforced to cope with the weight of the tank.

Batch Heaters

Batch heaters are simple passive system consisting of one or more storage tanks placed in an insulated box that has a glazed side facing the sun. Batch heaters are inexpensive and have few components, but only perform well in summer when the weather is warm. Evacuated tube solar collectors are now an affordable and much more efficient alternative to either batch or flat plate collectors.

Evacuated tubes

Evacuated tubes are the absorber of the solar water heater. They absorb solar energy converting it into heat for use in water heating. Evacuated tubes have already been used for years in Germany, Canada, China and the UK. There are several types of evacuated tubes in use in the solar industry.



Each evacuated tube consists of two glass tubes made from extremely strong borosilicate glass. The outer tube is transparent allowing light rays to pass through with minimal reflection. The inner tube is coated with a special selective coating (Al-N/Al), which features excellent solar radiation absorption and minimal reflection properties. The tops of the two tubes are fused together and the air contained in the space between the two layers of glass is pumped out while exposing the tube to high temperatures. This "evacuation" of the gasses forms a vacuum, which is an important factor in the performance of the evacuated tubes.
Please

Why a vacuum? As you would know if you have used a glass-lined thermos flask, a vacuum is an excellent insulator. This is important because once the evacuated tube absorbs the radiation from the sun and converts it to heat; we don't want to lose it!! The vacuum helps to achieve this. The insulation properties are so good that while the inside of the tube may be 150°C / 304°F, the outer tube is cold to touch. This means that evacuated tube water heaters can perform well even in cold weather when flat plate collectors perform poorly due to heat loss (during high Delta-T conditions).

In order to maintain the vacuum between the two glass layers, a barium getter is used (the same as in television tubes). During manufacture of the evacuated tube this getter is exposed to high temperatures, which causes the bottom of the evacuated tube to be coated with a pure layer of barium. This barium layer actively absorbs any CO, CO_2, N_2, O_2, H_2O and H_2 out-gassed from the evacuated tube during storage and operation, thus helping to maintaining the vacuum. The barium layer also provides a clear visual indicator of the vacuum status. The silver coloured barium layer will turn white if the vacuum is ever lost. This makes it easy to determine whether or not a tube is in good condition. See picture below.

The Getter is located at the bottom of the evacuated tube.

Left Tube = Vacuum Present
Right Tube = Faulty

Evacuated tubes are aligned in parallel; the angle of mounting depends upon the latitude of your location. In a North South orientation the tubes can passively track heat from the sun all day. In an East West orientation they can track the sun all year round.

The efficiency of a evacuated water heater is dependent upon a number of factors, one important one being the level of evacuated radiation (insolation) in your region. To learn more about insolation and the average values for your area

The multiple deposition selective surfaces absorb the full visible and infrared light radiation wavelengths from 0.3 to 1.3 ***u***. First deposition is a **copper metal** layer, M-AL-N / CU which has low emission ratio and high thermal transmission through inner glass wall to the refrigerant heat pipe. Effective work range of 572 to 662 deg F

Second deposition is layer of **AL2 O3** film to prevent cross migration. This entrainment allows the copper molecular layer to be very stable at temperatures in excess of 750 deg F

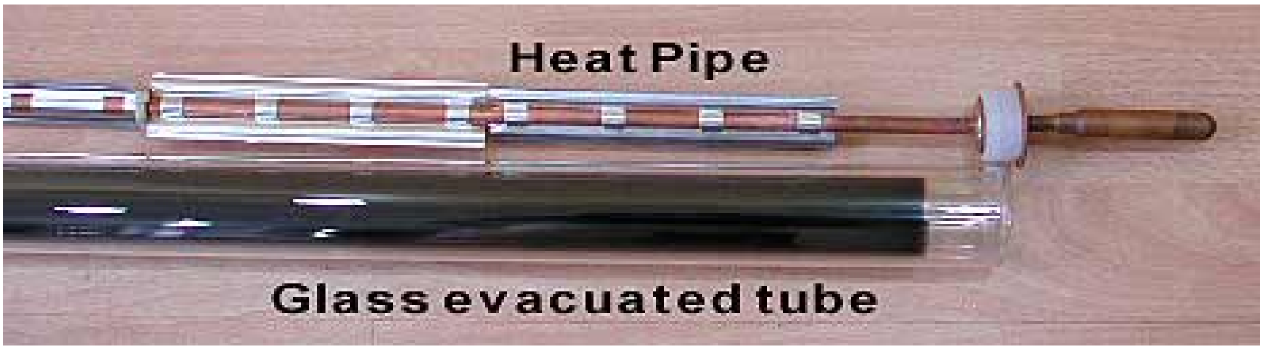
Third deposition is a cermet **aluminium nitride** AL-N/M-AL-N sputtered simultaneously in gas mixture of argon and nitrogen to produce which absorbs solar radiation at very low emissivity, a = 95%; e = 5%.

Operating principles of double wall vacuum tube with selective surface coating

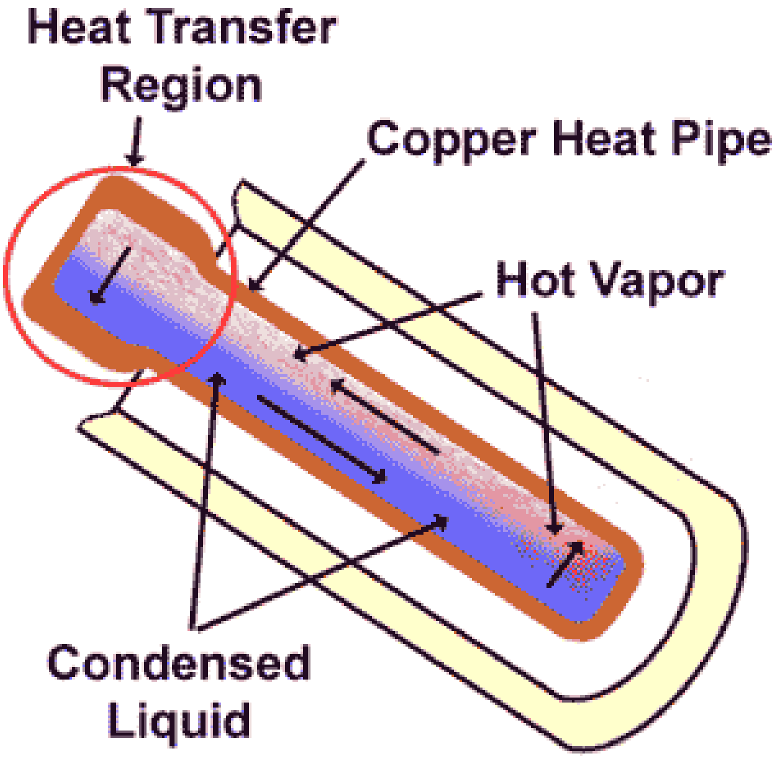
The key component of the solar collector is the double wall vacuum tube. It is made by two concentric transparent borosilicate glass tubes (Pyrex) able to resist impact from hail up to 25mm in diameter. The inner glass tube is coated with a selective coating of Al-N/Al, which absorbs and converts the maximum of solar radiation & infrared light into heat and reduces emissivity. A barium getter is used at bottom of the inner evacuated tube. This barium layer actively absorbs all CO, CO_2, N_2, O_2, H_2O the "tube" is one continuous piece with no metal embedded which makes the vacuum tube have longer service life time.

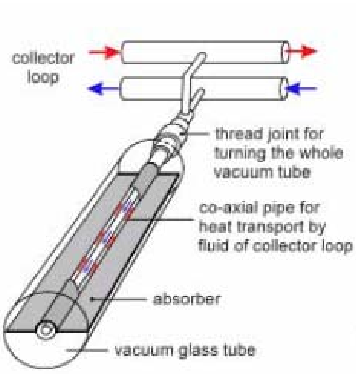
Heat Pipe Evacuated Tube System

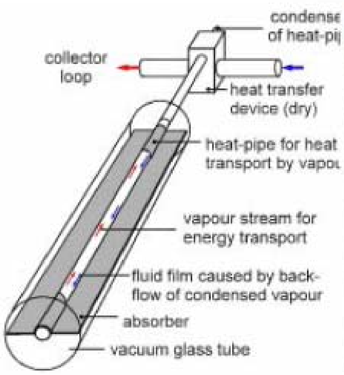
The heat pipe evacuated tube consists of the glass-evacuated tube described above. In addition a copper heat pipe is installed within the tube. The copper heat pipe transmits heat to its tip, which is plugged into the collector's heat transfer manifold. As water runs through the manifold heat is transferred from the copper heat pipe to the water. The heat pipe is a very efficient means of transferring heat from within the evacuated tube to the water. The following diagram shows both the glass evacuated tubes and the copper heat pipe. The heat pipe is simply inserted into the glass tube, held in place with high quality silicon based glue. There is no need for a air tight seal between the glass tube and heat pipe, in fact air must be able to move in and out of the tube as the air inside heats up and cools down.

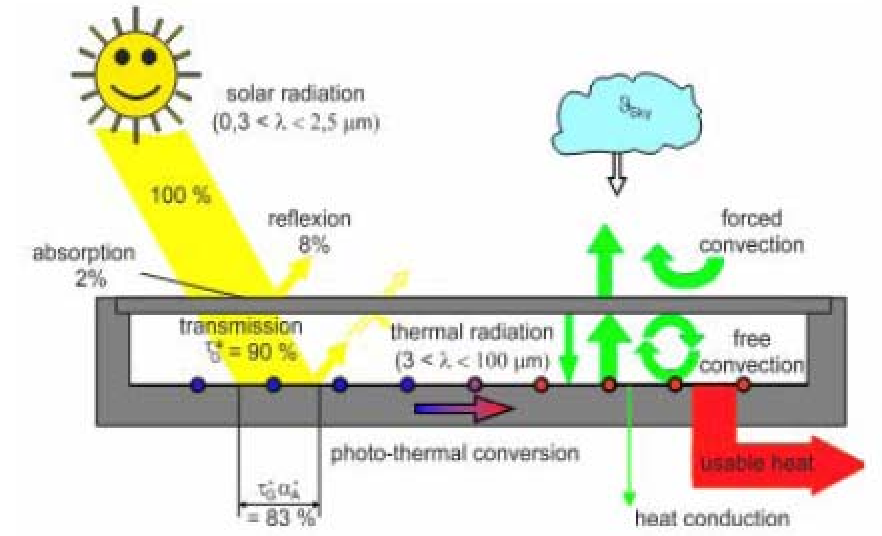


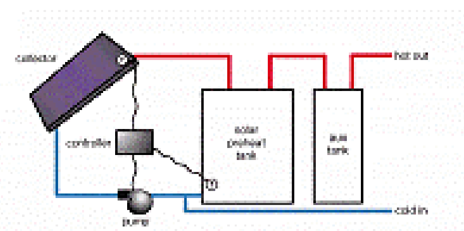
The heat pipe transfers the heat to the manifold by a very simple method. The copper heat pipe is hollow and contains acetone. The hollow center of the heat pipe is a vacuum, so that at even at temperatures of around 40°C the acetone will vaporize (boil). The vapor rises to the tip (condenser) of the heat pipe where the heat is transferred to the water flowing through the manifold. The loss of heat causes the vapor to condense and flow back down the heat pipe where the process is once again repeated. This method of heat transfer is thousands of times more efficient than a solid copper rod. Heat is therefore very efficiently transferred from the glass-evacuated tube to the water.



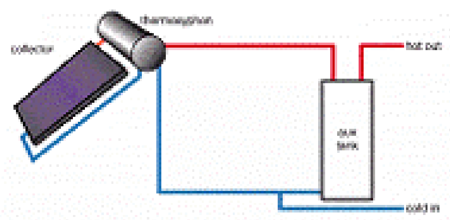




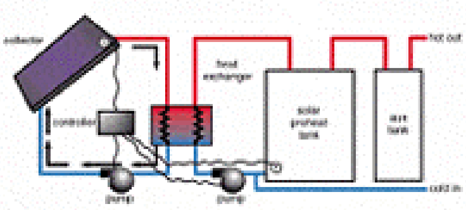




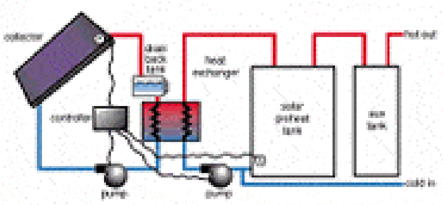
Pump, Direct Active System



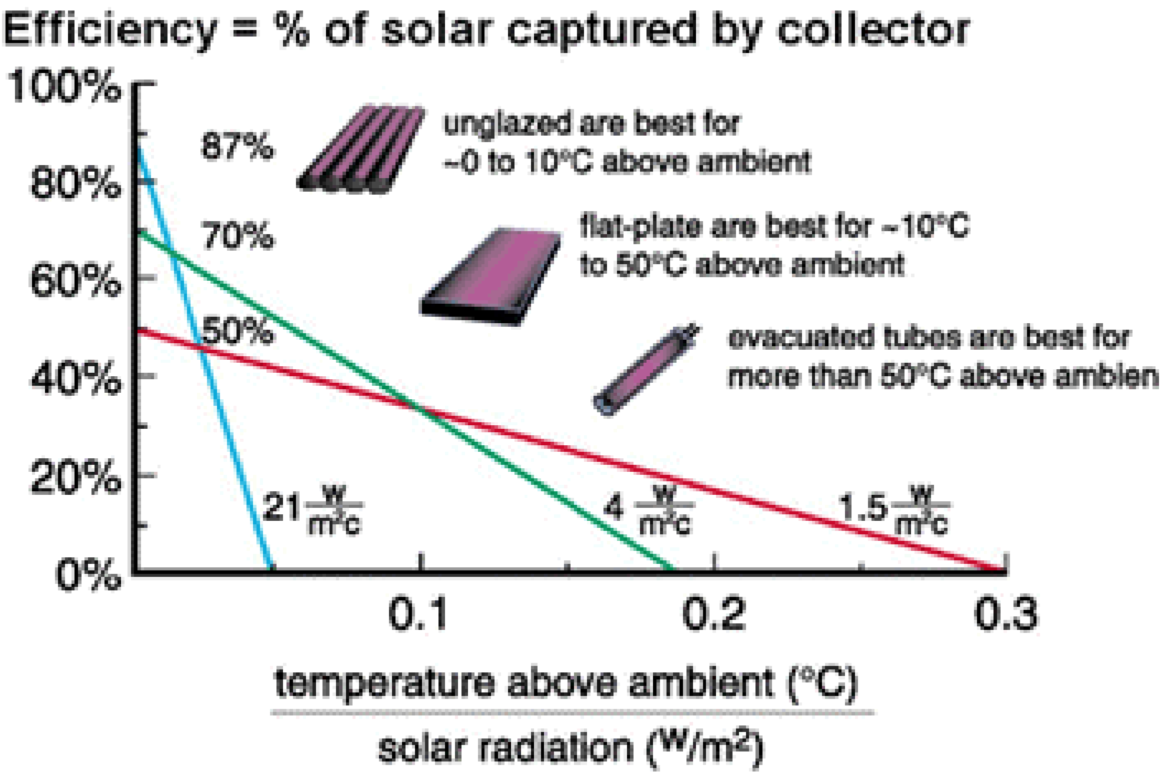
Passive, Thermosyphon, Direct System

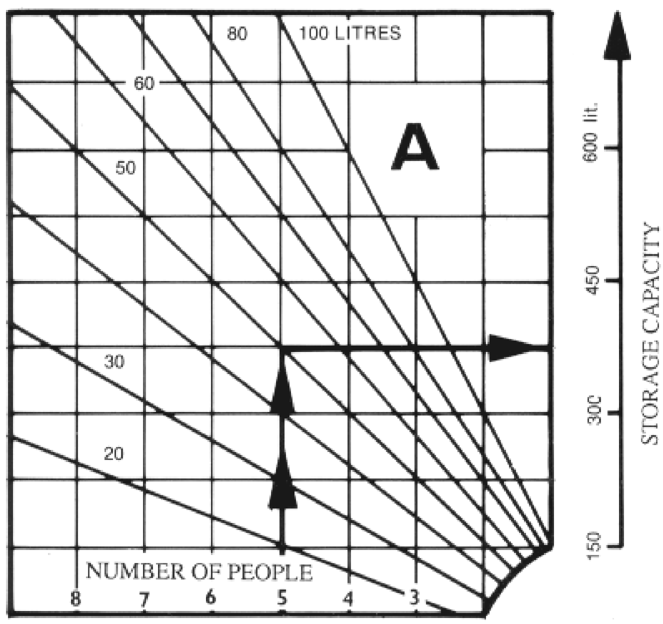


Active, Antifreeze, Indirect System



Active, Drain Back,Indirect System





Tank Size 108 Liters (24 Gallons), 135 Liters (30 Gallons), 162 Liters (36 Gallons), 180 Liters (40 Gallons), 216 Liters (48 Gallons), 270 Liters (60 Gallons), 288 Liters (64 Gallons), 306 Liters (68 Gallons), 324 Liters (72 Gallons)

SOLAR DRYER

Agriculture forms the base of the Pakistan economy, which produces large quantities of grains, fruits and vegetables. But due to the inadequate post harvest care, it is estimated that about 20-30 percent of the produce is wasted. If solar dryers are used to remove excess moisture from the product before storage, their quality will not deteriorate during storage and insect infestation will be reduced. Similarly, large quantities of excess vegetable and fruits, now being wasted, could be solar dried in a controlled manner for use during off-season.

Basic Principle

A solar food dryer consists of a flat box (frame) placed at an angle, with an open bottom and top, so that the air can circulate. Corrugated metal sheet, painted black, is placed on the bottom of the box. The black colour absorbs the sunrays and heats the air above. The frame is covered with glass, transparent plastic foil or a plain garden plastic. The warm air reaches 40 - 50°C, rises and leaves the heating box through the top opening and flows through the drying chamber with the drying screens. Cool environment air is sucked off through the bottom opening.
The dryer’s angle must be adapted to the respective geographical latitude: In Pakistan steeper (35-45°). With a flat angle, air circulation can be improved by adding a chimney. The solar dryer only works with direct solar radiation and works best during dry periods when there is little humidity in the air.

What can be dried?

The solar dryer is suitable for tomatoes, bananas, mangos, apples, plums, tea, fish etc.

How to dry?

Food to be dried is cut in halves or slices or shredded and placed on the screens. Fruit should not be too ripe and juicy to avoid dripping.

Drying time

The length of time with any drying procedure depends on the water content of the food, the temperature and the humidity in the air. Tomatoes and fruit may take several days to dry. The interruption of the drying process at night is an advantage because fast drying produces crusts that obstruct a further withdrawal of water. Any crusts are therefore soaked during the night and the next day the drying process can go on unhindered.

Cover

Food should not be exposed directly to the sun because it changes its colours. Therefore, the top drying screen should be covered with an empty screen or a lid with holes, keeping off flies at the same time.

Position of the dryer

It is not necessary to direct the solar dryer in the course of the day to the changing position of the sun. It is good enough to place it according to the highest position of the sun at midday.

Produce	Moisture Content (%)		Max. Permissible Temperature
	Initial	Final	^{o}C
Dates	80	25	50-55
Chillies	80	5	65
Onions	80	4	55
Potatoes	75	13	75
Apple	80	24	70
Apricots	85	18	65
Green Peas	80	5	65
Green beans	70	5	75
Cauliflower	80	6	65
Cabbage	80	4	55
Tomatoes	96	10	60
Brinjal	95	6	60
Peaches	85	18	65
Grapes	80	15-20	70

Maximum Permissible temperature for drying agricultural produce and their initial and final moisture contents

Solar Drying of Fruits & Vegetables

Tomatoes

Due to the increasing demand to dried tomatoes from the industry, especially from the soup manufacturers, interest in producing high quality dried tomatoes has been increasing. Therefore, it is important to establish a drying method, which yields products with higher sensory and sanitary quality in a shorter drying time compared to the conventional sun-drying method. Both 2% Na2S205 and 2% citric acid pretreatments can be used to protect the bright, red colour of tomatoes. However, citric acid did not prevent the growth of moulds and yeasts effectively. Therefore, dipping into sodium metabisulfite solution for 3 minute is the best type of pretreatment. Tomatoes can be dried at 55°C in solar tunnel dryer without a darkening in colour. At this temperature the drying takes 4-5 days to final moisture content of 11 %.

Red Pepper

Red peppers are deseeded, cut into small pieces, and washed before loading into the tunnel solar dryer. Pretreatment with 2% Na2S205 for 1 second gives the best colour. Moreover, the drying temperature and piece size of red peppers affects the final product quality. Temperatures higher than 60°C results in dark brown colour formation in red peppers, Red peppers that are cut into bigger pieces needs a longer time period to dry and therefore the colour of the final product are darker. Drying at low temperatures (45-50°C) for about 1 day gives good results. To increase the capacity of the solar dryer, a double layer system can be constructed, but with this system, drying needs a more careful control. Final moisture content of dried red peppers, which are pretreated with 2 Na2S205 for 1 second, is 3.5%. The yield is 9% for both pretreated and naturally dried peppers.

Green Pepper

Green peppers are used especially in the soup manufacturing. Therefore, establishing an efficient and economic method for peppers is important for the food industry. Green peppers are washed, deseeded and cut into small pieces before loading into the dryer. Green peppers are very sensitive to high temperatures and light. Therefore, green peppers should be dried under dark and at 45-50°C to preserve the natural green colour. 2% Na2S205 dipping for 1 sec can be applied to obtain a microbiologically safe product. Drying at 45-50°C under dark conditions takes about 1 day. Green peppers dried under these conditions have final moisture content of 6%, and a yield of 10%.

A large part of the dehydrated onion production is used as seasoning in production of catsup, chilli sauce and meat casseroles, as well as cold cuts, sausages, potato chips, crackers and other snack items. Food service outlets also use dehydrated onions because of its convenience in storage, preparation and use. Before drying, onions are peeled and sliced into desired shapes. Onions can be dried at 45-50°C for 2-3 days to a final moisture content of 15 % in tunnel solar dryers. Sodium metabisulfite dipping can be used to preserve colour. Drying temperatures of onions should not exceed 50°C in order to prevent browning of the product. The yield in onion drying is 8%.

Carrot

Before loading into the dryer, carrots are peeled, washed, cut into small cubes and treated with 2% sodium metabisulfite solution for 1s and 10s or dried as natural. Carrots can be dried at 50-55°C for 1-1.5 days to a final moisture content of 7.5 %. Naturally dried carrots loss their bright orange colour. The sodium metabisulfite treated ones preserve their colour to the largest extent.

Prunes

It is known that certain treatments used to modify the waxy cuticle of the surface of various fruits (prunes, grapes, cherries, etc.) accelerate the drying as a result of an increase in the skin permeability. Dipping in olive oil emulsions is a traditional practice in direct solar drying of pieces and it is recorded that this increases the drying rate of grapes approximately 30%. Different olive oil concentrations combined with sodium or potassium carbonate or ethyl esters of fatty acids are used for this purpose. Researches have found that the most effective compounds are the ethyl esters of fatty acids in the C10-C18 range with ethyl oblate being the easiest to handle. Prunes can be dried at 55-60°C in solar tunnel driers. At this temperature, prunes pretreated with 2% ethyloleate or 2% olive oil+4% potassium carbonate dried in 3-4 days.

Peach

Peaches are washed, destoned and sliced 1-2 cm thick. The thickness of the slices is very important since very thin slices causes hardening and brownish colour in the final product. Different concentrations of Na2S2O5 and citric acid can be used as pretreatment agent: 2% citric acid for 30s, 1 Na2S2O5 for 1 s, and 1 % citric acid + 0.5% Na2S2O5 for 1 s. Peaches which are consumed directly or used in recipes can be dried at 45-50°C in 2 days. The yield of the final product is 11 % and final moisture content is about 8.5%.

Okra

Okra is one of the most popular vegetables consumed in tropical and subtropical countries, because of its adaptability and resistance to hot and humid weather. Before loading into solar dryer, okra is washed and its head is removed. One of the following treatments can be applied to okra prior to solar drying: dipping in 0.2% Na2S2O5 for 20 min; 0.1% Na2S03 for 30min; 0.3% Na2S2O5 10 min; 2% Na2S2O5 for 1s, and 3 minutes of blanching followed by dipping in 0.2% Na2S03 for 15 min, and finally blanching and dipping in 0.2% Na2S03 for 15 min. On the basis of colour, flavour and microbiology of the final product, it was observed that high quality dried okra was obtained using 2% Na2S2O5 dipping as a pretreatment and drying of okra at 50-55°C in the solar dryer under dark conditions. Drying time was about 1day. Blanching of okra before drying needs ice-bath dipping. Therefore it is not considered as a practical method.

Apple

Golden apples are cleaned, cored and sliced to 3-5 mm thick. To prevent browning, the apples can be immersed for 1s in 2% citric acid or 2% Na2S2O5 solutions immediately after slicing. The apples dried under light conditions becomes a little brown but the ones that are dried without exposure to light are kept their natural, light colour. The choice of drying conditions depends on the consumer's demand. Dried apples have a water activity of 0.38 and a yield of 15%.

Solar Natural Dryer
10-kilogram loading capacity

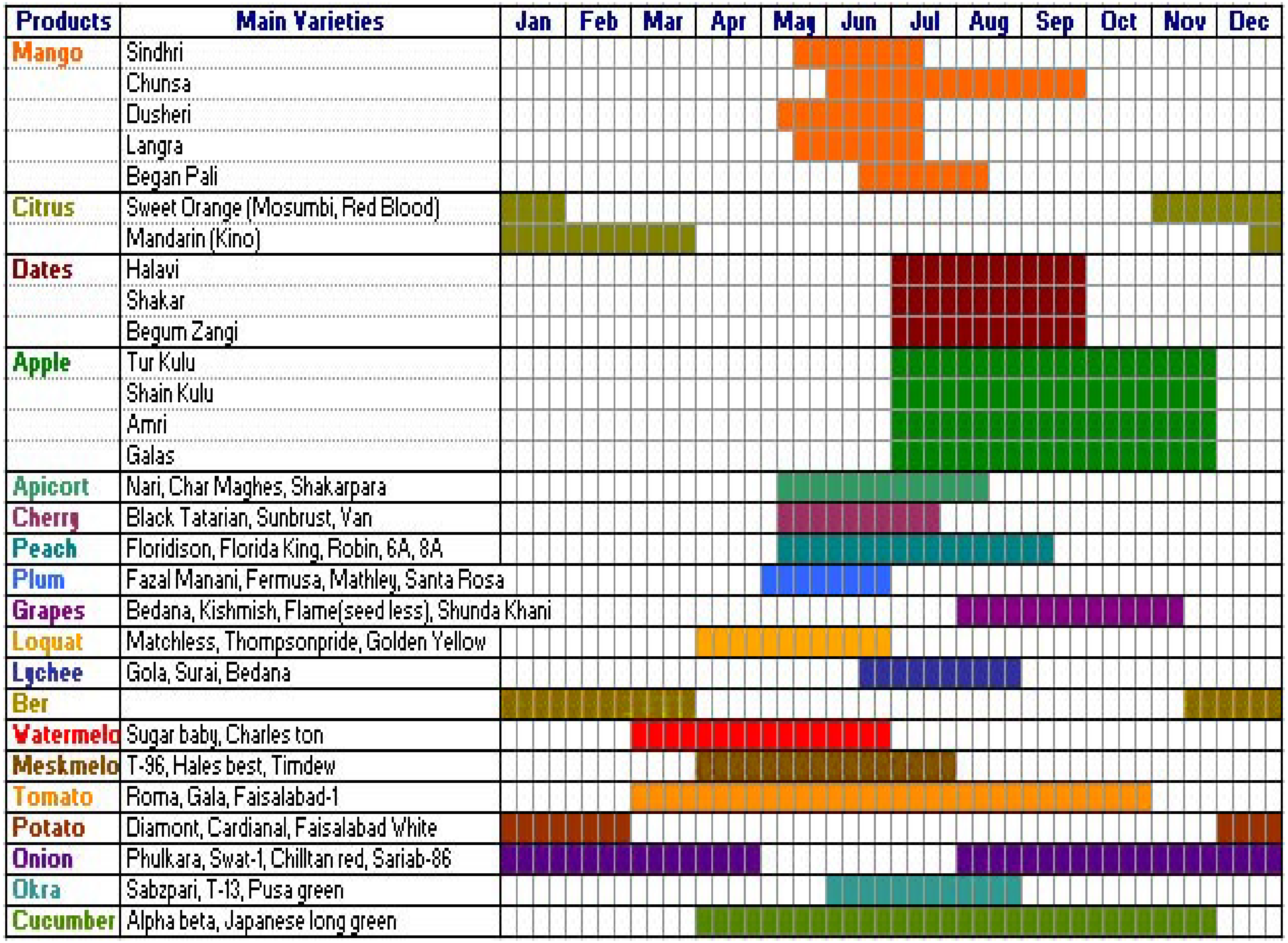
Cabinet Type Solar Dryer
15-kilogram loading capacity

Solar Tunnel Dryer
80 kilogram loading capacity

Solar Dryer
Green House type

Unglazed type transpired collector type hybrid
(Solar-biomass) dryer 150 kilogram loading capacity

Unglazed collector type hybrid (solar-biomass)
Dryer 500 kilogram loading capacity


Products
Main Varieties
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mango
Sindhri
Chunsa
Dusheri
Langra
Began Pali
Citrus
Sweet Orange (Mosumbi, Red Blood)
Mandarin (Kino)
Dates
Halavi
Shakar
Begum Zangi
Apple
Tur Kulu
Shain Kulu
Amri
Galas
Apicort
Nari, Char Maghes, Shakarpara
Cherry
Black Tatarian, Sunbrust, Van
Peach
Floridison, Florida King, Robin, 6A, 8A
Plum
Fazal Manani, Fermusa, Mathley, Santa Rosa
Grapes
Bedana, Kishmish, Flame(seed less), Shunda Khani
Loquat
Matchless, Thompsonpride, Golden Yellow
Lychee
Gola, Surai, Bedana
Ber
Watermelo
Sugar baby, Charles ton
Meskmelo
T-96, Hales best, Timdew
Tomato
Roma, Gala, Faisalabad-1
Potato
Diamont, Cardianal, Faisalabad White
Onion
Phulkara, Swat-1, Chilltan red, Sariab-86
Okra
Sabzpari, T-13, Pusa green
Cucumber
Alpha beta, Japanese long green

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