Solar water heating
technical fact sheet

Sunlight is best!

Our sun emits massive amounts of energy - far more than we could ever use. In South Africa, solar radiation reaches up to 6.5kWh/m^2, one of the highest levels in the world. By comparison, parts of Europe only receive about 2.5kWh/m^2. So in this country, solar energy is an abundant source of renewable energy, making it an obvious candidate when seeking alternative sources of energy.

Solar water heating – how it works

Solar water heaters are based on two facts of physics: dark-coloured objects absorb heat, and hot water rises. Unlike other systems that can be very complex, a solar water heater is simple, as water is the only moving part. This is a huge advantage in terms of reliability and maintenance.

A typical system has three major components: a solar collector, a transfer medium and a storage container.

1. The **solar collector** absorbs solar radiation and transfers the energy, in the form of heat, to the fluid within it.

2. This fluid is the **transfer medium**. In a direct system, the transfer medium is the potable water from the storage container. In an indirect system, the transfer fluid is generally a mix of water and glycol, which passes the energy to the storage container via an isolating heat exchanger. In areas in South Africa where temperatures drop to below freezing (4°C), an indirect system is recommended.

3. As with a conventional geyser, the hot water **storage container** is thermally insulated to retain heat. Solar geysers are usually larger than electric geysers and better insulated. This allows you to maximise your solar gains.

Solar water heaters can be linked to existing geysers or can completely replace them. The system can be installed on top of a roof if the structure is strong enough.

The storage container can be placed elsewhere, for example, inside the roof or a cupboard, but the collector must be where sunlight can reach it.

Geysers mounted on or in the roof are usually placed horizontally, but for better thermal stratification, they should be mounted vertically. Your roofing structure must be checked to see whether it can support the weight of the storage container and collector.

Solar collector types

There are two main types: flat-plate collectors and vacuum-tube collectors.

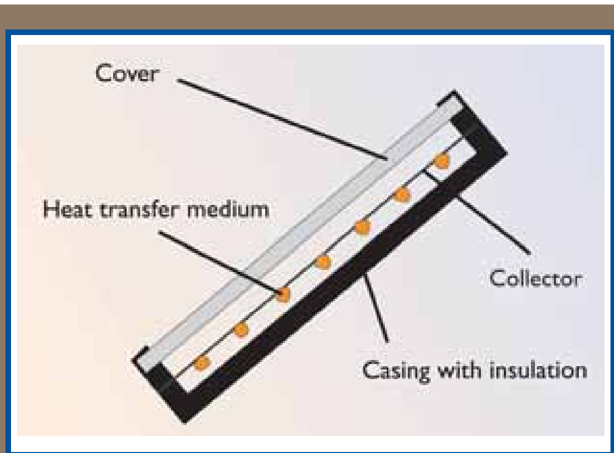


Fig1: Flat-plate collector

- A **flat-plate collector** has a transparent cover made of specially toughened glass, a coated metal absorber plate (coating is usually matt black paint), and a well-insulated weatherproof casing. Flat collectors are robust, economical, and versatile.

- **Vacuum-tube collectors** consist of a series of glass tubes connected together. The absorber strip in an **evacuated tube collector** is placed inside the toughened glass tube, which can withstand considerable pressure. The heat transfer fluid flows through the absorber directly into a U-tube or sometimes into a tube-in-tube system. Several tubes are connected to one another or to a manifold that makes up the solar collector. A **heat pipe collector** contains a special fluid that vaporises at low temperature. The hot vapour rises in the heat pipes and warms the heat transfer medium in the main pipe before condensing and recirculating. The pipes must be at a certain angle to facilitate the process. Too flat or too steep an angle and the system will not work.

  Vacuum tubes work well with low radiation. They can often produce higher temperatures in applications such as hot water heating, steam production and air conditioning.

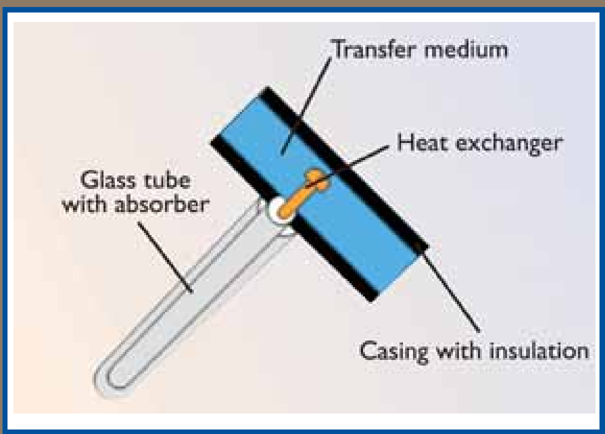


Fig2: Evacuated tube collector

Solar water heating systems

There are two main systems:

1. **Direct systems** (also called open-circuit systems) circulate water directly between the storage container and the collector(s), so the water you use in your shower is the same water that has been heated in the collector.

   A direct system should only be used under certain conditions, for example, in areas where temperature never drops below freezing (4°C) and where the quality of the water supply is suitable.

   The water should not be hard (water is classified as hard when it has a high calcium/lime or mineral content). Traces of scale either on the element or on the inside of a kettle are indicators of calcium/lime in the water supply.

2. **Indirect systems** (also called closed-circuit systems) have a heat transfer fluid that circulates through the collectors via a heat exchanger that transfers heat from the collector circuit to the water in the storage container. Closed-circuit systems are essential in areas that are exposed to frost or freezing because they are resistant to the cold. They are also used where the water is hard, as the system avoids lime scale build-up in the collectors.

   Indirect systems can require maintenance, as the heat transfer fluid must be checked and might need to be topped up.

How the water circulates

Water moves around a solar heating system either by natural convection (passive circulation) or by means of pumps (active circulation).

In **natural convection** (also called thermosiphon), the water heats up in the collector and rises naturally into the storage container above it, while the cooler water in the storage container flows down to the bottom of the collector, creating an unaided circulation. For this system to work and to avoid reverse circulation at night, the collector must be below the geyser. This type of system can be given an inherent freeze resistance by using a closed circuit between the collector and the geyser.

A **forced-circulation** system works with a pump that keeps the heat transfer fluid circulating between the collectors and the heat exchanger in the storage container. The pump is controlled by a differential controller.

The system's differential controller does two things. It switches on the pump between the collectors and the heat exchanger as soon as the temperature at the collector outlet is higher than the temperature in the storage container. It also switches off the pump when the temperature of the fluid from the collectors is 5°C below the temperature in the storage container.

The pumps in forced-circulation systems are small and do not consume much power. Some pumps are powered by small photovoltaic panels that convert sunlight into electricity. However, these are not effective without a differential controller.

System configurations

In a **closed-couple** system, the storage container and collector are closely joined to each other - the storage container looks like a part of the solar collector, and both are perched as a single unit above the roof. In a closed-couple system, the thermosiphon works well and reliably.

In a split system the storage container and solar collector are separated. The storage container is usually installed in the roof, although it can be installed elsewhere, with only the collector visible externally. If the system is a thermosiphon system then the storage container must be placed above the collector to facilitate circulation.

Getting the system size right

The first step in selecting a solar water heating system is to work out the household's hot water needs. Then a supplier can recommend a suitable collector size and storage volume needed. Units that are too small will not provide enough hot water, so slightly oversizing your storage container is normally recommended. Too much oversizing, however, could be uneconomical and have a longer payback period.

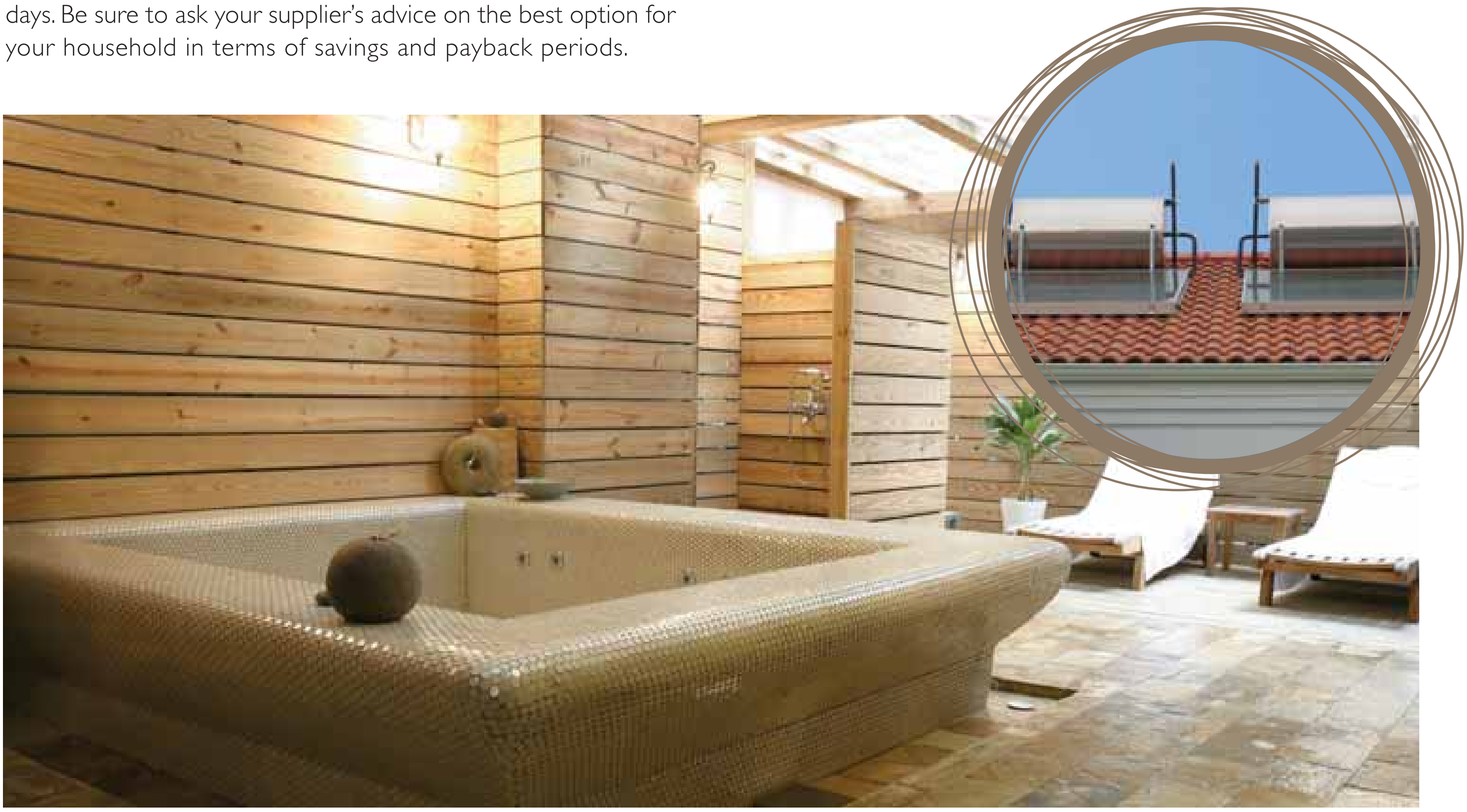
The table below gives an indication of the most appropriate tank size for a specific household size, based on achieving maximum energy savings. Household sizes are based on the number of people living in the house plus household appliances that require large volumes of hot water (every appliance counts as one extra person).

It is wise to make the system slightly larger than the household's normal daily needs to ensure that only one reheat period a day is necessary. Extra volume also makes allowances for cloudy days. Be sure to ask your supplier's advice on the best option for your household in terms of savings and payback periods.

Ensuring system effectiveness

- Select the right system for your area. Most direct systems should not be installed in areas that experience winter temperatures lower than 4°C and also not in areas with extremely hard water, as lime scale and calcification will occur within the collector. In these areas, indirect systems are preferable. Very soft water tends to be aggressive on metals, and therefore areas experiencing this should also use indirect systems.

- A solar water heater that has a back-up element controlled by a thermostat cannot save as much electricity as one without an element or one that makes use of a timer. Optimal savings are achieved if the water in the storage container is at ambient temperature in the morning. Thus, if hot water is consumed in the morning or the late evening, the thermostat should not turn on the element in the storage container, thereby ensuring maximum solar energy contribution.



- A timer fitted to the thermostat will ensure that the water is not electrically heated when the sun begins to heat the water. Pilot studies have shown that about 44% of energy is saved when neither a timer nor a load management device is used. A timer improves this energy saving to around 66% – a significant benefit at minimal cost. Where no electrical back-up is installed, all the electricity previously used for water heating will be saved, but the household then runs the risk of occasionally not having hot water.

- Collectors must be orientated and inclined correctly during installation. In South Africa, collectors should face true north or slightly to the west to take advantage of higher irradiance in the afternoon. A deviation of 45° east or west is acceptable, but deviation greater than this will require larger collectors to compensate for solar losses.

- A rule of thumb for pitching the collectors is "latitude +10°". This gives the best uniform solar collection throughout the year. Vacuum-tube collectors are less orientation-sensitive than flat-plate collectors. Additional framework may be required to achieve the desired angle for the collector.

- Solar collectors should be placed in an area of uninterrupted sunlight. If an area is in shade between 9am and 3pm, another position should be found. A simple rule is to position your collector a distance from the obstacle that is twice the height of the obstacle. This is true for areas of higher latitudes, such as Cape Town. For Johannesburg and lower latitudes, the distance can be reduced to approximately one and a half times the size of the object. Partial shading by obstructions such as chimneys and TV antennas during daylight hours is acceptable, provided the shade does not cover more than 10% of the collector's surface area.

- Solar collectors must be clean to be effective. In very dusty areas or areas subject to dust or sandstorms, the glass panels of the collectors should be washed with clean water at least once every three months in the rainy season and once a month during the remainder of the year.

- Evacuated tube systems may require re-evacuation a few times during their expected life. Please consult your supplier for maintenance requirements.

- Energy and water saving shower heads and tap aerators are very effective to optimise energy savings and reduce hot water consumption. With or without electrical back-up, hot water piping should be insulated to minimise heat losses.

- Increased savings are incurred by limiting hot water usage to the evening rather than in the morning, for example, by showering or bathing before going to bed rather than when getting up. Also, showering generally consumes less water than bathing.

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