Selecting a Solar Hot Water System

Introduction

- This presentation provides the minimum requirements when confirming size of a solar water heater.
- It represents the information present in the Solar Water Heaters – Selection and Installation Guidelines based on the range of systems/products typically used in the Pacific Islands and as such may not cover all configurations of solar water heating systems

Types of Solar Water Heating (SWH) Systems

There are two different types of systems:

- Passive SWH (thermosiphon or close-coupled) systems
- Active SWH (non-thermosiphon, pumped or split) systems.

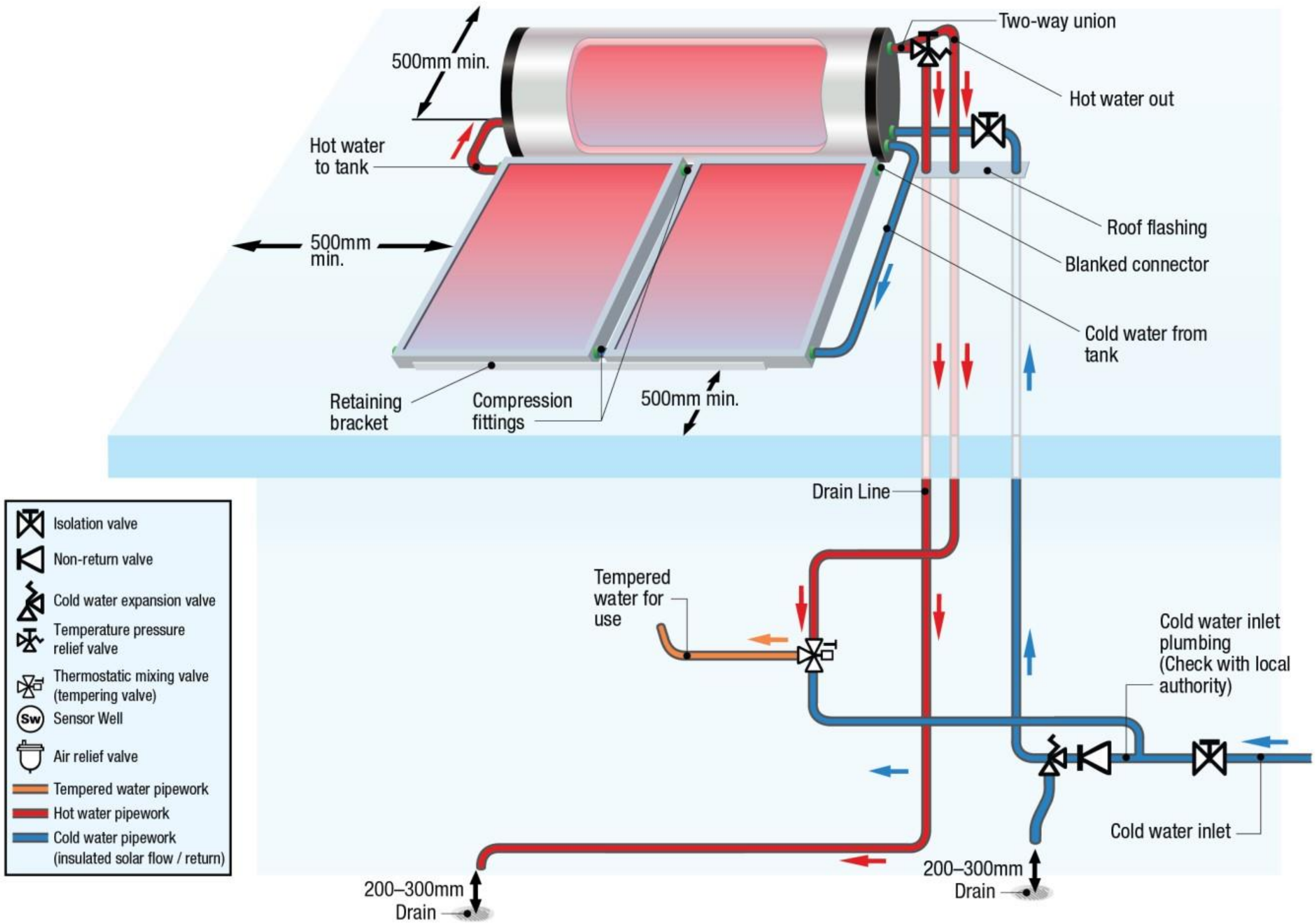
And there are two types of water heating methods used in these systems:

- Direct water heating system (heats water directly)
- Indirect water heating system (uses a heat exchanger to deliver the solar generated heat to the hot water tank)

Passive SWH Systems (Thermosiphon) or Close-coupled Systems

- Passive SWH systems have the collectors and tank close together. Both are usually located on the roof, with the tank above the collectors to take advantage of the thermosiphon effect
- The thermosiphon effect is the circulation of water that occurs naturally through the collector and storage tank due to convection. This phenomenon is used in passive SWH systems.

Passive SWH System



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Batch Water Heater

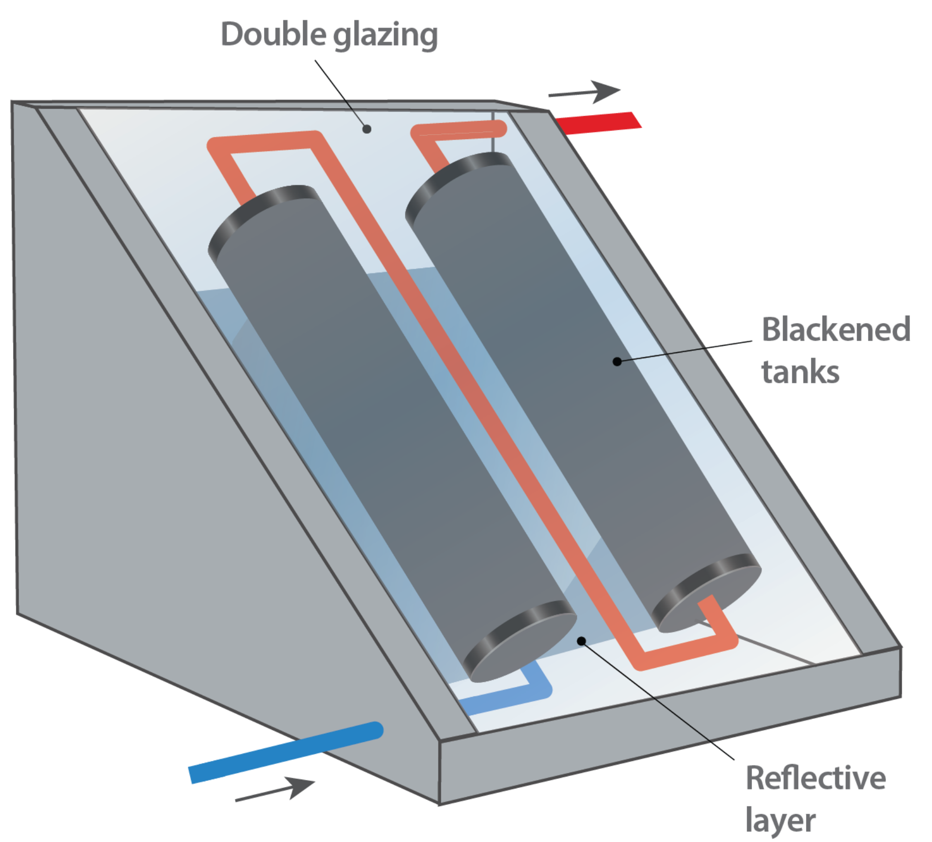
- There are also non-thermosiphon passive solar water heaters available.

- Batch water heaters as they are called, also known as ‘breadboxes’ are very simple passive systems for heating water using solar energy and have been used since the early 1900s.

Batch Water Heater

- Batch systems consist of black storage tanks contained within an insulated box that has a transparent cover. Cold water is added to the hot water stored in the tanks whenever hot water is removed. Modern batch systems are used as preheating systems, where the water is then heated further by conventional gas or electric systems.

Batch Water Heater



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Active SWH Systems

- In an active (split) system, the water tank is installed where convenient and usually is below the collectors.

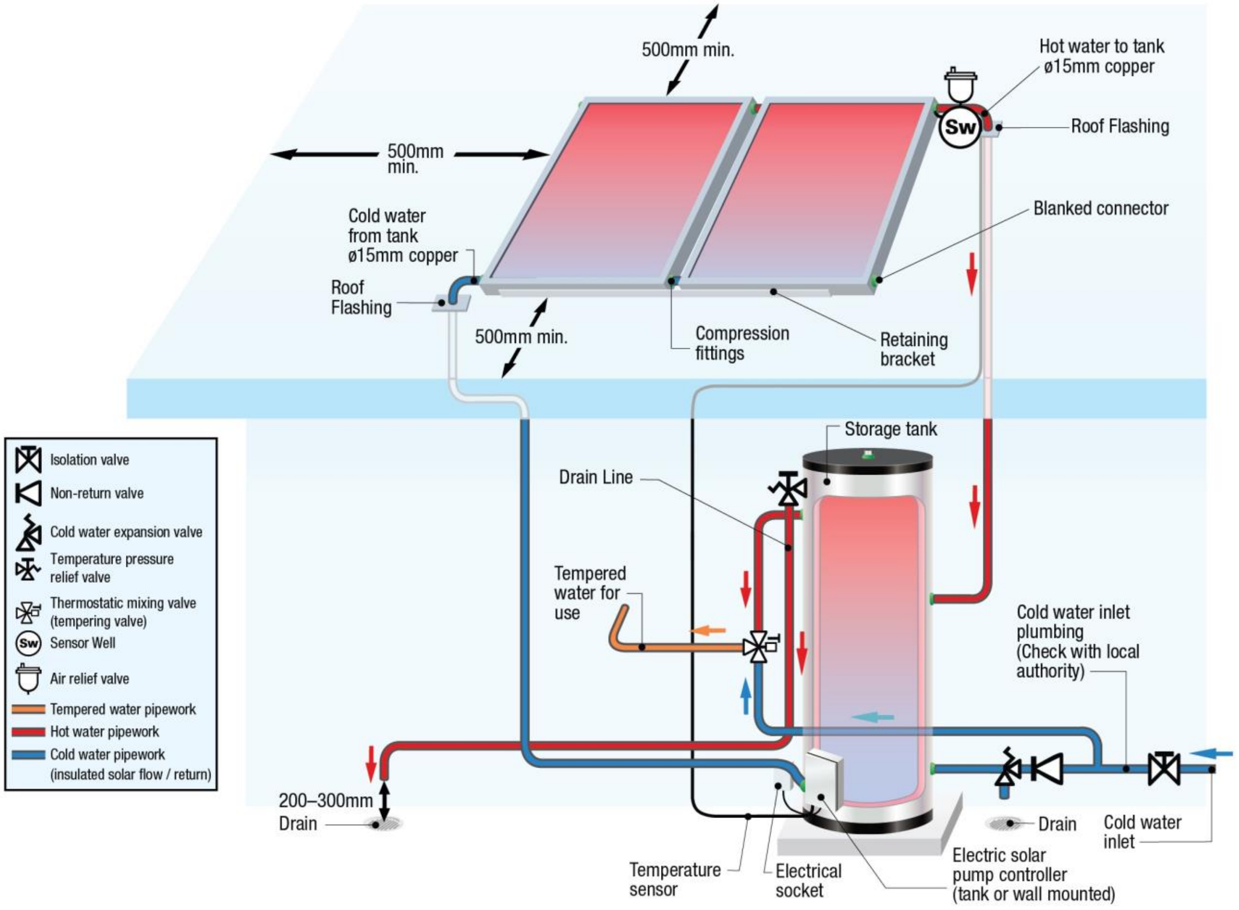
- Because there is no circulation possible by convection, a pump is used to circulate the water through the system

Active SWH Systems

- The pump is fitted with a controller that sends water to the collectors when the water in the collector is a higher temperature than the water in the tank.

- When the tank water reaches a temperature around 70° C (158° F), the controller shuts off the pump and so the tank temperature increases no further

Active SWH Systems



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Direct Water Heating Systems

- In a direct water heating system, the water that will be used in the building is circulated from the tank directly to the collectors where it absorbs heat from the sun's radiation. (This water is called the working fluid) Using water as the working fluid is common in both passive and active SWH systems.

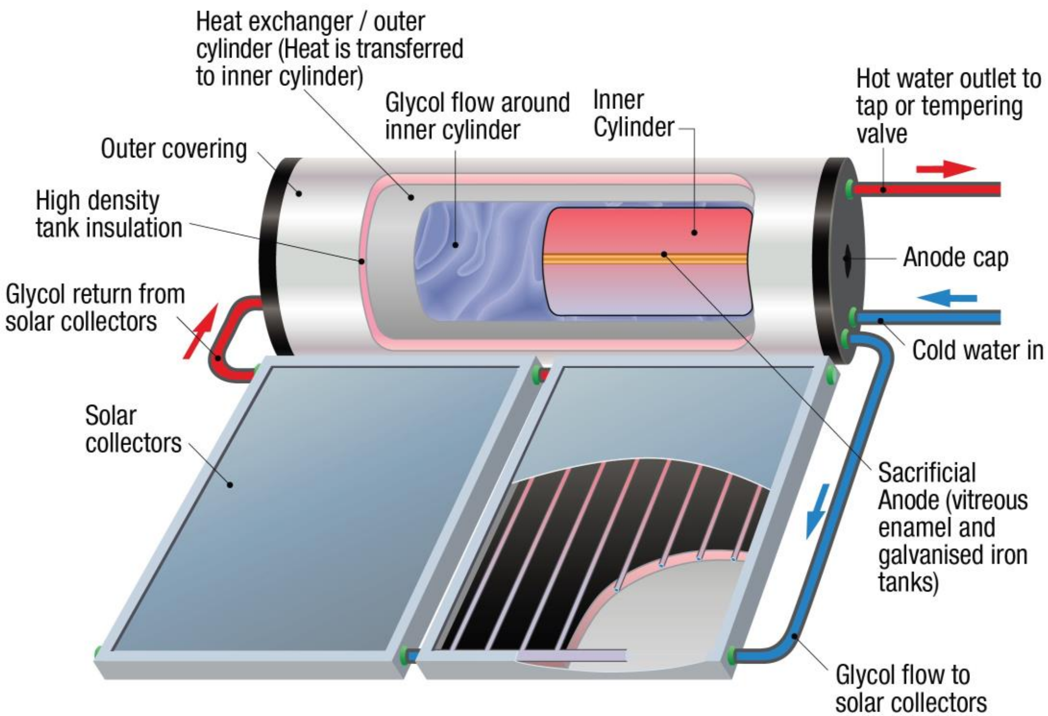
Indirect Water Heating Systems

- These systems work in a very similar way to the direct systems, but rather than ‘directly’ heating the water in the collectors, a heat transfer working fluid (e.g. propylene glycol) is used to absorb the heat of the sun’s rays and then, using a heat exchanger, the energy is transferred to the water.

Indirect Water Heating Systems

- The heat exchanger may be a jacket of working fluid around an inner tank or coils of pipe within the holding tank.
- Propylene glycol is typically chosen as the working fluid mainly because it is not toxic and provides excellent frost protection and good heat transfer

Indirect Water Heating Systems



- For sites having poor quality water supply, indirect systems would be useful in overcoming the build-up of calcium carbonate in the tank. The poor-quality water may contain sediment, which is any solid material carried by water, travels with the water through the pipes and into your home's hot water tank, causing an accumulation of minerals

Components of a Solar Water Heating (SWH) system

The main components of a Solar Water Heating (SWH) system are:

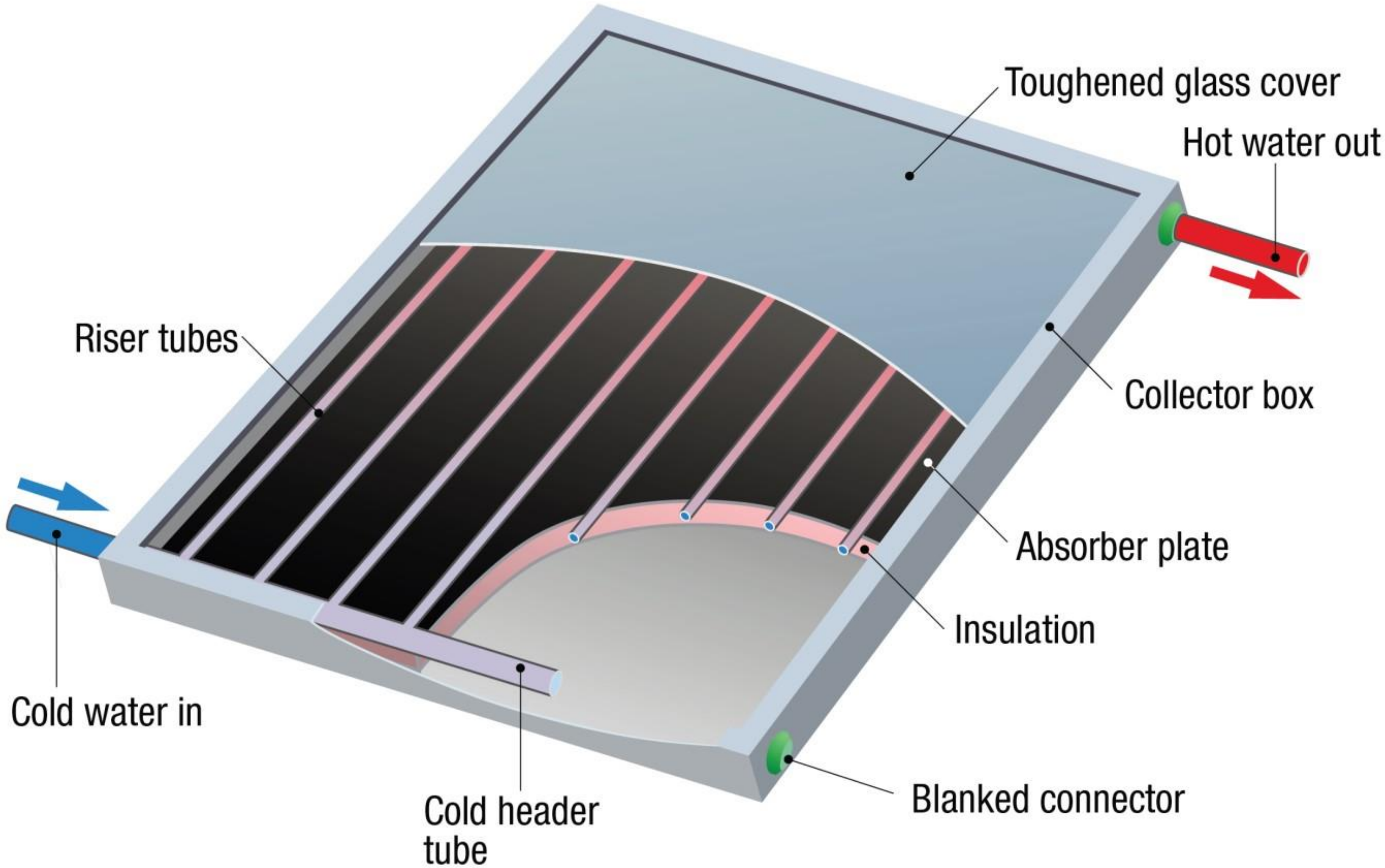
1. Collectors (flat-plate type or evacuated-tube type).
2. Mounting Structures for different types of surfaces (roofs, ground, etc.).
3. Tanks (Stainless steel, Enamel lined, Galvanized iron) and Anodes.
4. Backup water heater. (electric or LP Gas)
5. Valve types (Non-return, Pressure Reducing, Isolation Gate, Thermosiphon Restrictor, Temperature–pressure relief, Expansion Control, Thermostatic Mixing, Air bleed).
6. Pipework and Insulation.
7. Pumps and Controllers.

Collectors

- Solar collectors capture the sun's electromagnetic energy and convert it to heat energy. The solar collectors form a very important part of the SWH system.
- There are 2 main types of collectors:
- Flat-plate collectors.

- Evacuated-tube collectors.

Flat Plate Collectors



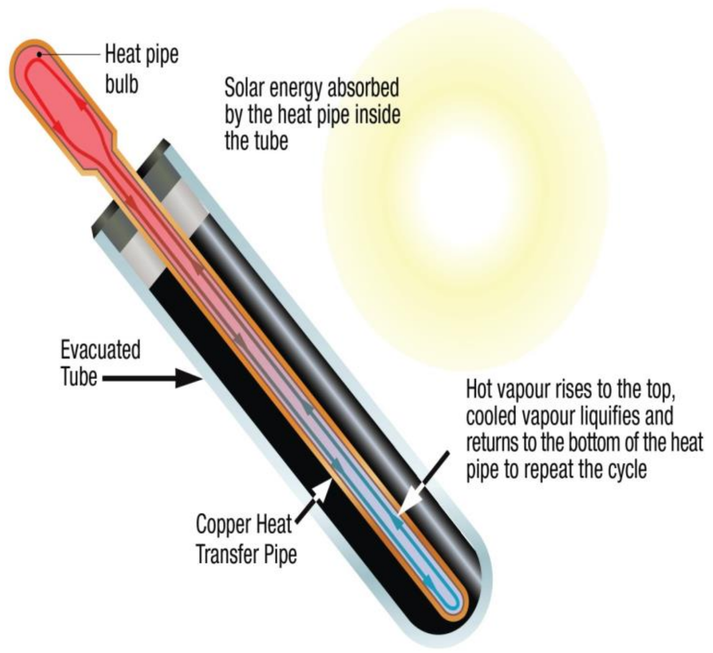
Evacuated-tube collectors

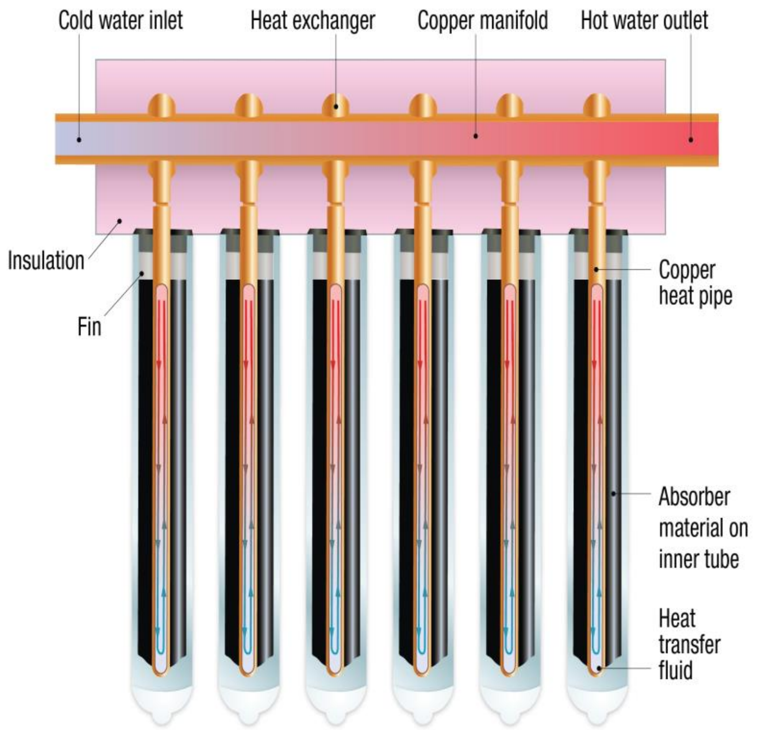
- Evacuated-tube collectors generally have a smaller solar collecting surface because that surface must be encased by an evacuated glass tube.
- They are designed to work at higher temperatures (approximately 150°C) within the heat pipes. Common sizes of collectors are around 10, 20 and 30 tubes per collector.

Evacuated-tube collectors

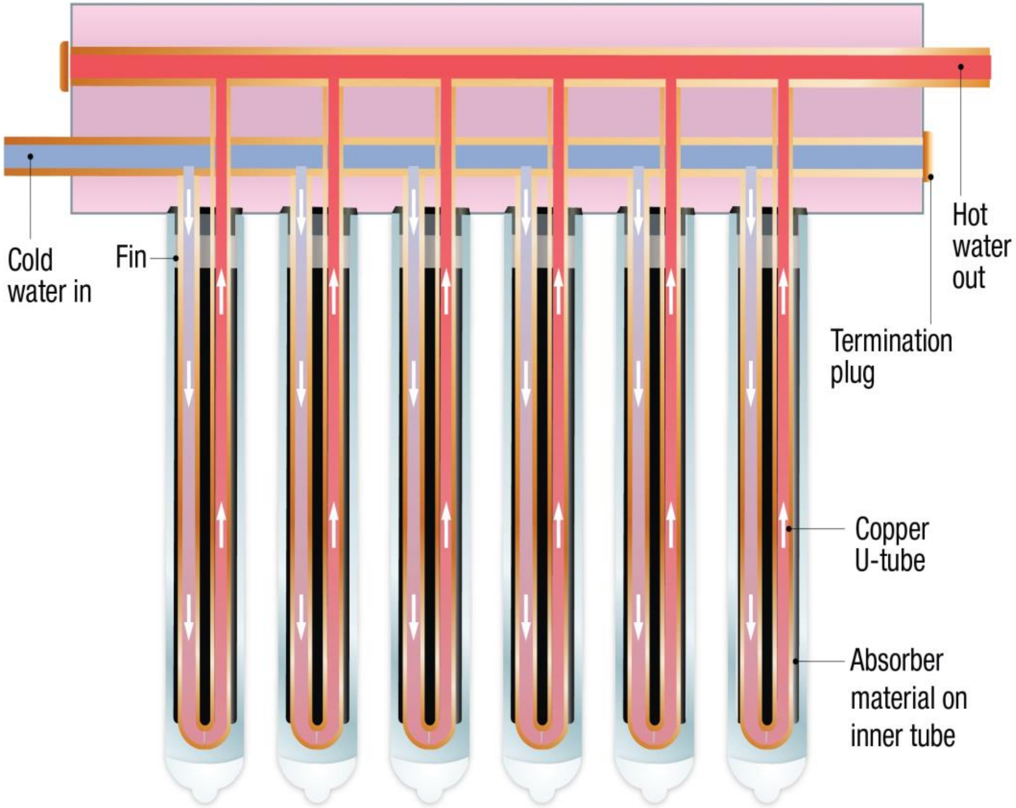
- Each tube includes the following elements:
  - Highly tempered Glass vacuum tube.
  - A metal tube with an absorber surface placed inside the vacuum tube.
- The common principle in the two types of evacuated-tube systems (described below) is that the glass tubes have a vacuum that very effectively protects against heat loss

Evacuated heat pipe collector





Evacuated U-tube collector



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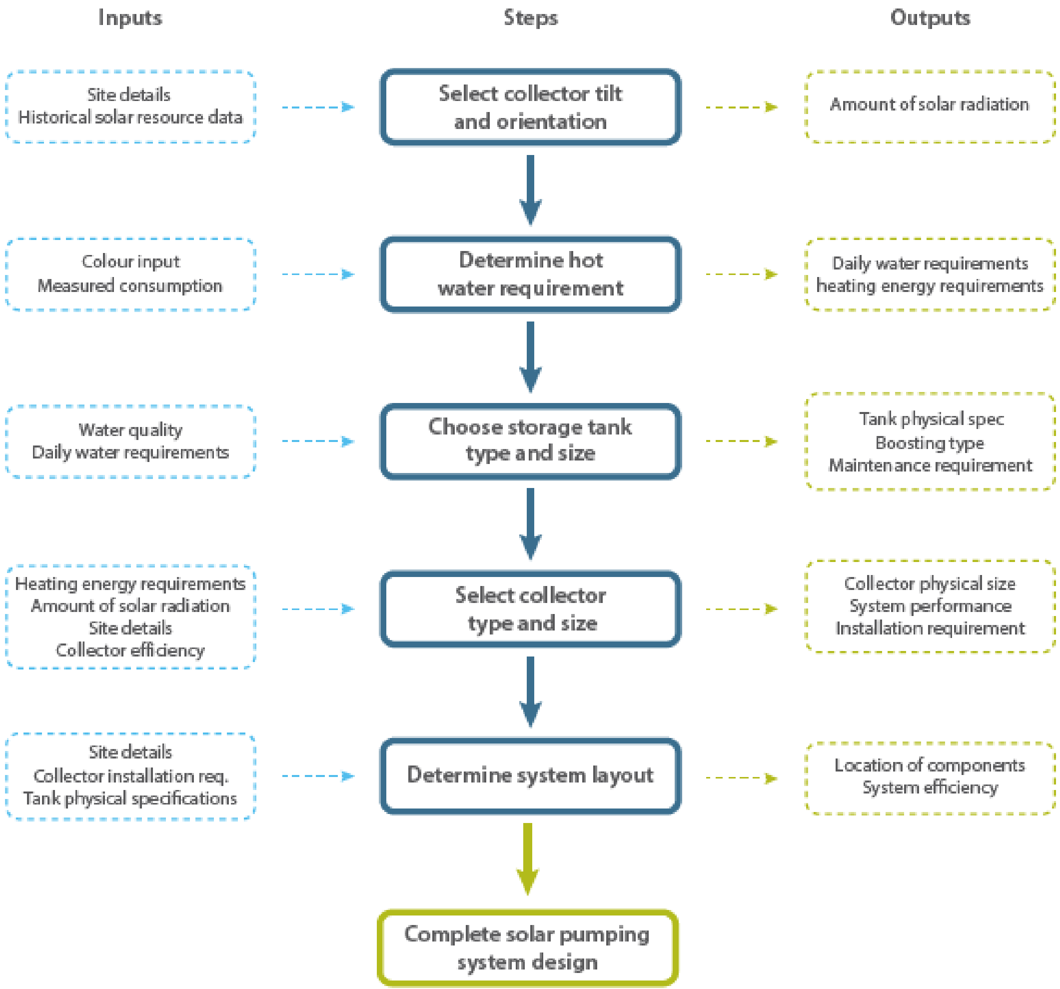
Evacuated-tube vs Flat-plate Collectors

Advantages	Disadvantages
Evacuated-tube collectors are able to retain more heat than the flat-plate collectors and are more efficient in cooler climates.	The evacuated-tube collectors are more prone to damage from severe weather (like hail, strong winds etc.) and handling due to their more delicate construction.
The shape of evacuated-tube collectors ensures that the solar radiation is always perpendicular to the surface of the outer glass tube.	The evacuated tubes do not work efficiently at low tilt angles so they often have to be mounted such that the tubes cannot lie flush with the roof.
There are no problems with clogging of the collector due to minerals in the water being deposited inside the collector tubes. The actual water that is heated does not pass through the collector pipes.	For them to deliver hot water under pressure, a much more complex (and expensive) system using heat exchangers must be constructed
Repairs are limited to replacing just the tubes that are damaged, there is no need to remove the entire system for repairs. It is usually not even necessary to disconnect any of the plumbing.	

Design Approach and Sizing



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Site Visit and Customer Hot Water Requirements

Customer Site Visit

The site survey should reveal at least the following:

- Number of residents, any special hot water needs
- Condition, slope and type of roof. Any shading issues and best direction for solar.
- Information on the existing plumbing and hot water tank, if any.
- Information on the local water pressure and quality and whether the residence has an elevated storage tank for mains water and/or a pressure pump

Some Important Considerations

- A passive SWH system with direct water heating and tank connected to the collector to form a thermosiphon loop is by far the most common and practical choice for residential applications.

Some Important Considerations

- However, other considerations when selecting the type of system include:
  - Is the roof strong enough to hold the weight of a tank?
  - If not, where is the most suitable place on the ground for a tank, given that the existing hot and cold-water plumbing must be connected?
  - Is there a section of the roof that is positioned to make it possible for the collectors to have a suitable orientation to the sun?

Some Important Considerations

- Are there nearby shading considerations that may require extra collectors to be used?
- Is the roof tilt suitable or will a tilted mounting frame be required?

Some Important Considerations

- Does the quality of the local mains water (clean, suspended dirt, high mineral content, etc.) affect the choice of tank and collector material or would a propylene glycol based indirect heating system be more suitable?
- For commercial installations: where is the best location for tank(s) and collectors given the higher volumes of hot water required.
- Wind loading issues: these are very important to consider for the safe operation of the SWH system particularly in locations where cyclones/typhoons are likely.

Siting the Collectors and determining collector tilt and orientation

- Knowing the site-specific solar resource is important in designing SWH systems.

Roof Pitch and Collector tilt Angle

- Solar collectors are best oriented such that the collector is perpendicular to the incoming sunlight.
- Manufacturers will specify the range of tilt angles and orientations that are acceptable for the solar collectors, based on where they are installed.

Roof Pitch and Collector tilt Angle

- Typical specification is within ± 20° from latitude angle and within ± 45° from the direction facing the equator although in general they should not have a tilt less than 10° so rain will run off fast enough to keep the glazing clean
- Typically, this is 20° for evacuated tube heat pipe systems and 15° for passive flat plate thermosiphon systems

Available installation space

- The dimensions of unobstructed roof space that is facing within 45° east and west of the direction of the equator should be determined.
- The location of obstructions such as roof ventilation shafts, exhaust fans, etc. should also be noted, as well as any other areas that must be avoided.

Available installation space

- When calculating the amount of available roof space, remember that a minimum edge zone of 500 mm should be kept clear when installing the collectors on the roof.
- If the installation is in a very windy area (e.g. the top of a hill) or subject to cyclones/typhoons, a structural engineering calculation should be undertaken

Local Shading

- Solar collectors should be installed in a position that is shade-free for at least three hours both sides of solar noon, i.e. from around 9am to 3pm. This is the time of the day when the Sun is highest in the sky, throughout the year.
- Always ensure a shade analysis that considers the movement of the sun over a full year has been carried out. Shading analysis tools - Solar Pathfinder

Worked Example 1

- A house in the Pacific is being considered for solar water heater installation. The house has a flat roof. The roof does not have any obstacles (no shading) and is structurally sound for installation. Putting the SWH flat on the roof will not be a good decision as the thermosiphon effect will not operate when the solar collectors are mounted flat.

Determining Hot Water Requirements

- The daily hot water requirement is a key parameter for system sizing. The best way to obtain this data is to install an inline water meter that logs the water usage for weeks or months – this is not always practical.
- Guidelines exist on residential water usage (based usually on the number of occupants) to help estimate the hot water demand of households

Determining Hot Water Requirements

- A SOPAC Technical report (2000) estimated usage of around 38 litres per person per day in a study done on solar water heaters in Fiji and Tonga
- Average of 40-50 litres per person per day can be used as a rule of thumb.
- ALWAYS confirm with customer!!

Worked Example 2

A family of 4 people lives in a house that has 3 bedrooms. Let's estimate the hot water demand per day for this family:

Worked Example 2 Solutions

Step 1: Identify the building type

In this example it's a domestic residential house, so the daily hot water demand is assumed to be 40L per person.

Step 2: Specify the number of persons

In this case it is 4

Step 3: Multiply values from step 1 and 2: 40 L (10.6 gal) of water per person x 4 persons = 160 L (42.4 gal) per day.

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Selecting the Tank and Determining the Collector Size

- The designer needs to consider the tank material as well as the holding capacity of the storage tank.
- The tank material selected will be based partly on the water quality at the site and partly on customer budget.
- In residential systems, vitreous enamel lined tanks are the more common choice due to their affordability.

Selecting the Tank and Determining the Collector Size

- Marine grade stainless steel tanks are considered to be higher in quality as they are more resistant to corrosion
- Vitreous enamel storage tanks are recommended in areas with poor quality water due to the enamel coating inside the tank that resists damage. However, the sacrificial anode will need to be replaced regularly to combat corrosion.

Selecting the Tank and Determining the Collector Size

- Once the hot water requirement has been estimated, calculations are required to determine the size of the collectors and the tank, so that enough water will be heated and stored.

Selecting the Tank and Determining the Collector Size

- . The processes involved include:
  - Calculating the required tank capacity in relation to the daily hot water demand.
  - Matching the collector size to the storage tank size to meet the hot water requirements.
  - Understanding that the collector size may have to be increased if a non-ideal location or shading exists.
  - Assessing whether retrofitting SWH to an existing hot water tank is practical or whether a new tank must be installed.

Estimating the tank capacity for Solar Water Heating system

- The storage water tank for solar water heating systems needs to be sized to cater for the hot water needs of the customer.
- As a general rule of thumb, size the storage tank to equal 1.5 times the daily hot water requirement of the building in Litres/Gallons per day. Then round that up to the nearest equal or larger tank size.

Worked Example 3

A family of 4 people lives in a house which has 3 bedrooms. Estimate the capacity of the hot water storage tank (for one day).

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Worked Example 3 Solution

Step 1: Use the rule of thumb of sizing 1.5 times the daily hot water storage demand to get the tank size.

In worked example 2, the daily hot water requirement is 160 L per day. So, the tank capacity should be = 160 x 1.5

= 240 L (63.4 gal)

Step 2: Rounding up the obtained value to a commonly available sized tank.

We round the value obtained in Step 1 to 300L (80 gal) as this is a commonly available size.

Some typical tank sizes available are 180L (50 gal), 300L (80 gal), 330L (90 gal), 440L (116 gal), 480L (130 gal), etc., however these sizes may vary from one manufacturer to another.

Worked Example 3 Solution

We round the value obtained in Step 1 to 300L (80 gal) as this is a commonly available size.

Some typical tank sizes available are 180L (50 gal), 300L (80 gal), 330L (90 gal), 440L (116 gal), 480L (130 gal), etc., however these sizes may vary from one manufacturer to another.

Estimating the Collector size for a Solar Water Heating system

- The collectors heat the required daily volume of hot water during the sunlight hours and then store this in the well insulated hot water storage tank.
- For an initial estimate of the size of the collectors, a simple rule of thumb is:
- 1 m^2 (10.8 ft2) flat plate collector per 80 L (21.2 gal) of tank capacity or
- 10 evacuated tubes per 100 L (26.4 gal) of tank capacity.

Worked Example 4

- A family of 4 people lives in a house which has 3 bedrooms. Estimate the size of collector for daily hot water need for both flat and evacuated tube type solar collectors.

Worked Example 4 Solution

For Flat plate collectors:

Step 1: Use the tank value calculated in worked example 3 and utilize the rule of thumb to obtain the area of the flat plate collectors. The tank size recommended was 300 L (80 gal) per day. So, the collector size would be,

= 300 ÷ 80

= 3.75 m2 (40.4 ft2)

Worked Example 4 Solution

Step 2: Rounding up the obtained value to a commonly available size

We round the value obtained in Step 1 to 4m2 (43 ft2) as 2m2 (21.5 ft2) collectors are commonly available. Therefore 2 x 2m2 collectors can be used to satisfy this requirement.

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Worked Example 4 Solution

For Evacuated tube collectors

Step 1: Use the tank value calculated in worked example 3 and utilize the rule of thumb to obtain the area of the flat plate collectors. The tank size recommended was 300 L (80 gal) per day. So, the collector size should be, = (300 ÷ 100) x 10

= 30 tubes

Common numbers of tubes per collector are 10, 22, 30, and 44.

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Provision for collector size in a non-ideal location or if shading exists

- The above sizing for collector and tank assumes that the solar collectors are facing the equator and are at an optimum tilt angle
- The best practices for sizing, as mentioned previously will likely change if:
  - Roof does not face within 25° of the equator.
  - Roof tilt angle is greater than 20°.
  - Shading from surrounding trees or buildings is present.
  - Locations have substantially more or less solar peak sun hours than assumed.

Determining System Layout

- When locating the storage tank and collectors it is important to consider any pipe run requirements, roof integrity, as well as the location of existing water and electricity connection points.
- To reduce heat loss in pipes, the storage tank should be located as close as is practical to the points of hot water use, such as the kitchen, laundry and bathroom.
- Similarly, the length of pipework between solar collectors and tank should also be minimized in order to keep both costs and heat losses down.

Pipework Sizing

- Only copper pipes with insulation should be used on the hot water side not plastic pipes

Consider the following when sizing pipework diameters:

- Pipe diameter between the storage tank and the solar collectors needs to be sized appropriately taking the following into consideration:
  - Flow rate needed
  - pressure
  - pipework length
-

Pipework Sizing

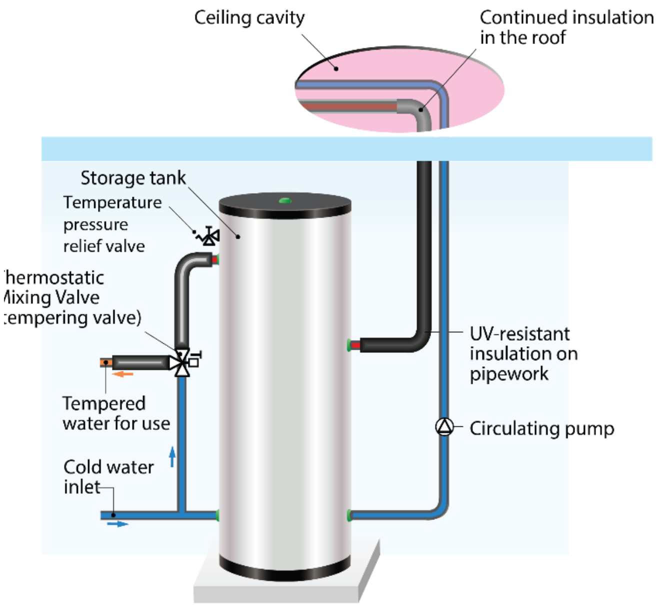
- Flow and return line diameters in a non-thermosiphon SWH system should be a minimum of 15 mm (0.6 inch) copper for mains pressure and pumped systems.
- Pipework in a system driven by thermosiphon flow needs to be larger, typically 25 mm (0.98 inch) diameter.
- The SWH system manufacturer will provide guidance on the suitable pipe diameter for the expected pressure, flow rate and pipework length.

Selection of Circulation Pump

- Similar to pipe sizing, manufacturers will provide guidance on selection of the circulation pump in split systems based on the system configuration.
- If the installation of an alternative circulation pump is desired, consult the manufacturer to ensure compatibility between the SWH system and the chosen circulation pump.

Pipe Insulation

- All exterior piping insulation must be protected from environmental and ultraviolet ray degradation by using purpose-made UV resistant coatings, paints or shielded wraps. All pipes between the hot water storage tank and collectors must be insulated for efficient operation.



Finalising Sizing and Selection

- Based on tank size, collector size and type of system appropriate, a selection can be made from the range of system sizes and types available from manufacturers.
- Consideration should be given and the selection should be made based on efficiency, quality of products, reliability, warranty, etc.
- It is recommended that the customer/installer reviews and understands all specifications prior to the purchase and installation. A thorough market survey will help determine the higher quality and more reliable systems for installation.


The End
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