

Low-energy hot water systems

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Figure 1. Domestic solar hot water system with evacuated tubes (Image: Alternative Technology Association, 2014)

ABSTRACT

Water heating accounts for around a quarter of household energy use in Australia. Low-energy water heating systems can reduce energy used for heating water by 60 to 80 per cent – or more – depending on the system type and location. This paper outlines considerations to help architects and designers to specify the appropriate system for their building. Considerations include climate, available roof space, orientation, usage, water quality and visual profile. The topic of low-energy hot water systems is especially pertinent to developments aiming to be net zero energy or energy positive.

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Introduction

Water heating is the largest single source of greenhouse gas emissions from the average Australian home, and the second largest consumer of domestic energy after heating and cooling. The majority of homes still use conventional electric resistance or gas hot water systems, which are less efficient and have higher operating costs than low-energy options, like solar and heat pump systems.

Solar and heat pump options are around 2.5 to 3 times more efficient than electric storage water heaters (DCCEE 2010). Low-energy systems can significantly reduce a home's energy use, associated energy bills and greenhouse gas emissions.

While the upfront costs of a low-energy system will be higher than a conventional one, the savings in energy costs can more than offset the capital cost (Barnes, 2014a). This is particularly important given projected increases in energy costs.

Solar hot water systems operate by using the sun's energy to heat water directly or indirectly. These systems tend to operate best with direct sunlight under clear sky conditions, and usually use a gas or electric resistance booster to supplement times when solar energy is insufficient.

With an appropriate system for the climate, solar water heating in Australia can provide 50 to 95 per cent of household hot water needs (ATA 2014).

Heat pump water heaters are electric devices that use ambient heat from the environment to heat water. As their heat source is from the ambient air, heat pumps operate more efficiently in warmer climates. Since they do not rely on sunlight to operate, they are also suitable in climates with regularly overcast skies.

With an appropriate system for the climate, solar water heating in Australia can provide 50 to 95 per cent of household hot water needs (ATA 2014).

This paper provides an overview of low-energy hot water systems and how they relate to climate, site and buildings. Specific hot water system types are discussed later. As technological designs can advance rapidly, it is recommended that design practitioners research the different options, taking into account technological advances appropriate to their project.

The scope of this paper is limited to domestic solar and heat pump hot water systems. Though they are not discussed here, there are other related water heater types for purposes such as hydronic heating and pool heating. Information on retrofits and efficient water heating options other than the solar and heat pump systems are available from other sources, including the ATA Solar Hot Water Booklet (ATA 2014 p. 53).

Costs and payback

The upfront cost of a solar or heat pump hot water system will depend on the type, model, tank size, number of panels or tubes, the capacity of the booster and the complexity of the installation. The costs will also depend on the availability of rebates or incentives offered by federal, state and territory and municipal governments.

To determine the return on investment from a heat pump or solar hot water system, the following factors need to be considered:

- climate and geographic location
- roof area and orientation
- hot water usage
- available space
- type of system
- up-front cost of system
- performance of system
- type of auxiliary heating or booster required (for solar hot water)
- installation costs and requirements
- maintenance costs and requirements
- availability of incentives or rebates
- running cost of system.

Running costs vary according to hot water system type and location. Table 1 below provides estimated running costs by system type for domestic purposes in Victoria (Sustainability Victoria, 2014). These comparative costs may differ by region.

Hot water systems	Annual cost* for 2-3 people or 150L/day	Annual cost* for 5+ people or 250L/day
Non-solar		
Electric storage (off peak)	684	1035
Natural gas instantaneous – 6 star	243	406
LPG – 5 star storage	664	991
Electric heat pump (peak rate)	426	644
Solar		
Electric boost (off-peak rate)	206	399
Natural gas boost	115	209
LPG boost	228	442

Table 1. Running costs of various hot water systems (adapted from Sustainability Victoria, 2014).

*Based on the following energy tariffs: natural gas (1.75 c/MJ), LPG (4 c/MJ), peak electricity (28 c/kWh), off-peak electricity (18 c/kWh). Based on a 70% solar contribution rated delivery. While the data presented here is the best currently available, Sustainability Victoria has commissioned a review of the running cost calculator, the results of which are expected to be available in late 2015.

Site, climate and building context for selecting the right hot water system

The hot water system most appropriate to the climate, roof characteristics and orientation, usage, available space and visual profile of the building, will also be most beneficial to the project.

Site, climate and energy

Irradiation is the energy emitted from the sun and also that energy that is absorbed by a solar collector. Any irradiation absorbed by solar collectors reduces the active energy needed to heat water. The amount of irradiation that can be absorbed by a solar collector depends on:

- latitude
- sky conditions (cloud cover)
- available utilities on site
- shading (from site obstructions like buildings or trees)
- azimuth or cardinal direction the solar collectors are oriented to
- altitude or tilt angle of the solar collectors
- atmospheric particles (like fog and smoke).

What is the latitude and predominant sky conditions on site? Latitude and sky conditions will impact the building's available solar access. With regard to sky conditions, in some areas it may also be worth finding out if there are times and seasons when fog or other localised phenomena might obstruct direct sun.

The building's site and climate will determine the solar access availability, ambient air temperature and the utilities available (electricity and gas). Sites without access to reliable electricity or gas will be limited by the selection of booster types, unless installing a new service is an option. Similarly, locations with largely overcast skies will be limited in the selection of solar heater types.

Will the roof be overshadowed by any site obstructions such as trees or neighbouring buildings? If so, at what times of the year and time of the day does this occur? If there is potential for the neighbouring sites to be developed further to obstruct direct sunlight (especially from the north) it may be worth exploring less vulnerable locations to situate solar collectors.

What are the seasonal mean air temperatures on site? Air temperature can impact the efficiency of heat pump hot water systems and any tanks located outside. Heat pump hot water systems are more efficient in warmer ambient temperatures.

Does the building have access to reliable electricity or gas? The availability of such utilities will determine the active heater or booster types that can be used.

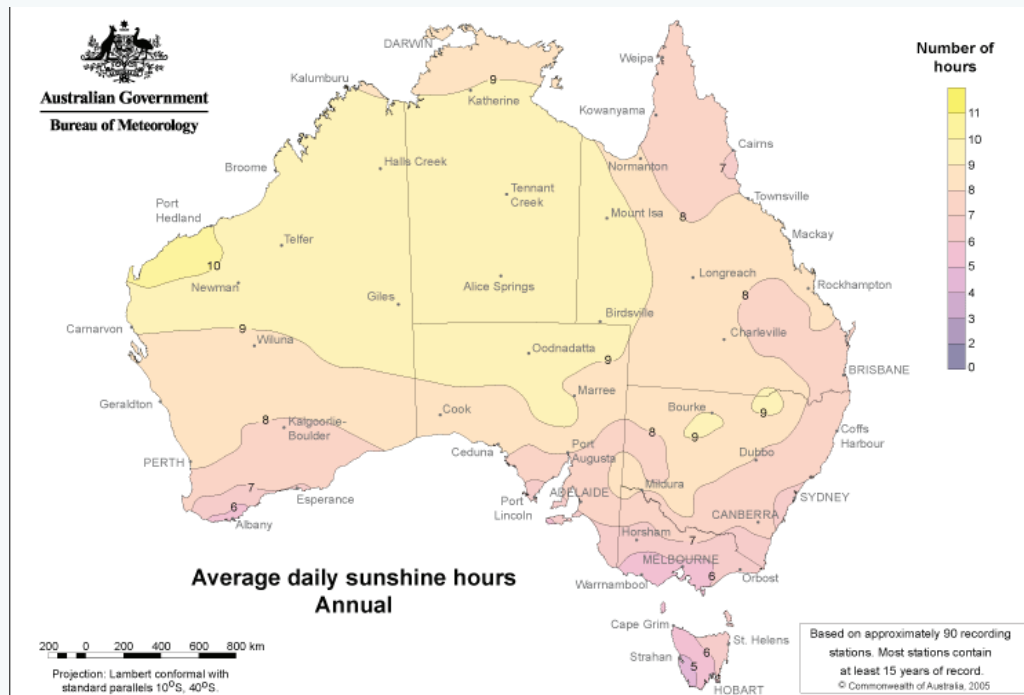


Figure 2. Average daily sunshine hours per annum in Australian cities (Source: Bureau of Meteorology, 2015a). Data in this image is sourced from the Bureau of Meteorology, refer: <http://www.bom.gov.au/data-access/3rd-party-attribution.shtml>

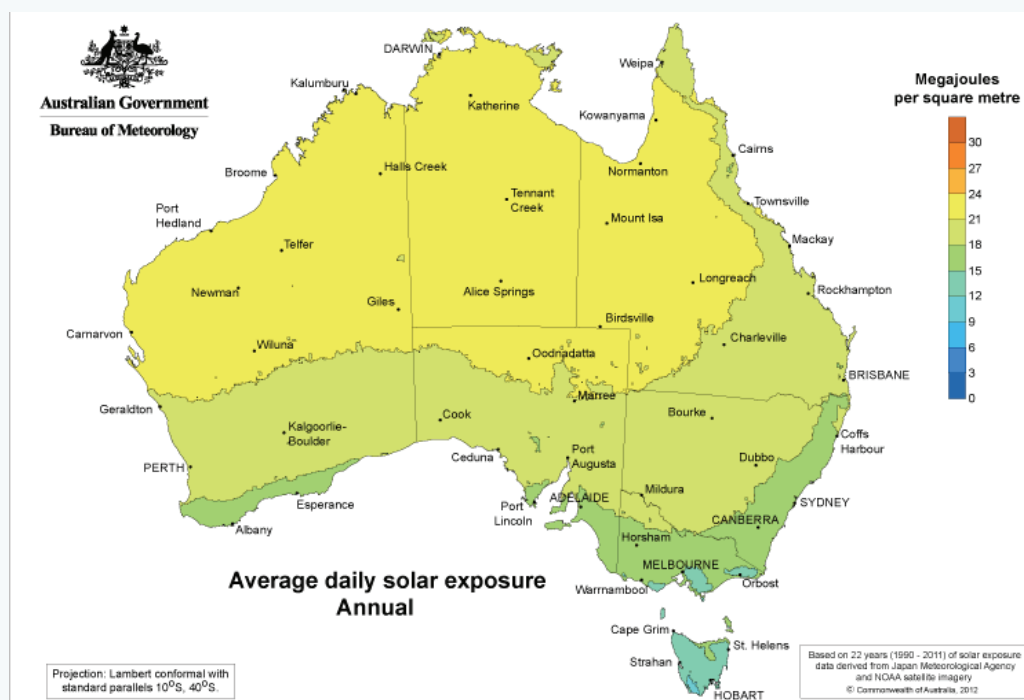


Figure 3. Average daily irradiation of Australian cities in MJ/m² (Source: Bureau of Meteorology, 2015b). Data in this image is sourced from the Bureau of Meteorology, refer: <http://www.bom.gov.au/data-access/3rd-party-attribution.shtml>

Water quality and system longevity

Water quality affects the life of solar collectors and hot water tanks. In areas where water conditions are harsh, such as those with high calcium deposits, high limestone areas, or when bore water is used, a heat exchange system can help avoid mineral clogging of solar collectors (ATA 2014, p. 21). Water with high concentrations of chloride requires careful panel and tank selection as well as regular inspections. Practitioners should carefully review the warranty for any system being considered for these conditions.

Positioning and roof characteristics for solar hot water systems

Before installing a solar hot water system, it is essential to determine where the solar collectors can be positioned to provide maximum efficiency. Since the collector is fixed, the angle of tilt to the horizontal must be selected to achieve year-round optimum heat collection. To maximise output, solar collectors should always face the sun, which in the southern hemisphere is north. If the solar collector's angle of tilt relative to the level horizon is equal to the location's latitude they will face the sun's rays directly on the equinox. While this gives optimum annual collection, for temperate climates a 'winter bias' is recommended to compensate for lower ambient temperature and colder incoming mains water.

When determining the position for the solar collectors, the structural suitability of an existing roof and possible wind issues should be carefully considered. The greatest wind problems occur when flat plate collectors are installed with tilted mounting brackets. Wind-loading, particularly from southerly winds, can dislodge collectors if the mounting is not adequately secured. Advice from a structural engineer should be sought before the installation is documented. Collector panels weigh approximately 100kg, which does not place a significant load on most roof structures. However, a typical storage tank holding 300L of water weighs around 450kg.

Avoiding heat loss

A vital consideration in the reticulation of hot water is the minimising of heat loss. Short pipe runs are the most effective way of minimising heat loss from pipes. Reticulation pipes must be very well insulated and all plumbing joints should be insulated to prevent 'spots' of heat loss. Pre-insulated piping is not always sufficient, where fairly long runs are unavoidable. Thoroughly insulated pipes not only save energy, but also save water from being wasted from running cold water until the hot water from the tank reaches the tap.

In new buildings and renovations, hot water systems should be located in close proximity to end uses like kitchens, bathrooms and laundries.

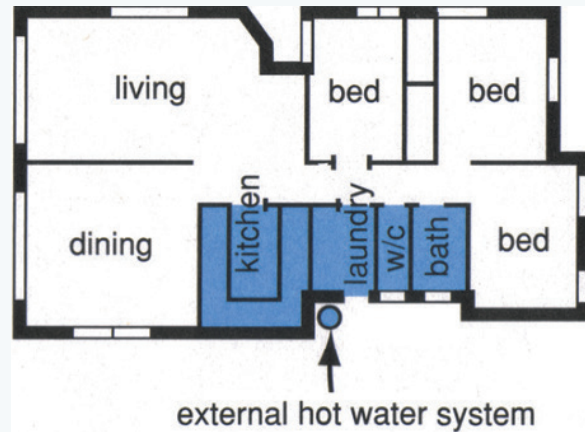


Figure 4. House plan with wet areas designed in close proximity (Source: SEAV via Your Home, Reidy et al, 2013)

Space requirements

Water tanks tend to be on the larger side, depending on the usage needs. Tanks should be kept near the areas of hot water use. In cooler climates keeping the tank(s) within the building enclosure may be a good way to conserve heating energy by reducing the tank heat loss; any heat that is lost by the tank can indirectly heat the interiors. For climates that have considerable heating and cooling needs, keeping tanks within the weather-protected, unconditioned space is another alternative.

Evacuated tube collectors take less room than flat panel collectors and will cope better with poor orientation. Some people also prefer the look of evacuated tube collectors to flat plate collectors. The greater efficiency and smaller dimensions of evacuated tubes (especially U-tubes) also means they might be appropriate for tight sites and urban settings. In some contexts, evacuated tubes may be more visually prominent than flat plate collectors.

If there is no room at ground level for tanks and the roof can withstand the added weight, a close-coupled flat plate collector system with a tank attached on the roof may be an option. If there is no available roof area, no gas for boosting, or there are concerns that a solar collector will compromise the look of the design, a heat pump may also be an option, depending on the climate type.

Hot water usage

Estimates of hot water needs will depend on occupant numbers and lifestyle, and anticipated uses, such as but not limited to, showering, dishwashing and laundry for machines without built-in hot water heaters.

Estimated capacities, like those listed below, based on the number of users and other factors can be found from various resources. While the actual hot water usage varies by household, Australians use an average of 50–70 litres of hot water per day (DCCEE 2010).

Number of people	Capacity (litres/day)
1 – 2	160 – 200
3 – 4	300 – 370
5 – 6	440

Table 2. A guide to system requirements
(Source: Sustainability Victoria 2014)

Solar hot water systems

Solar hot water systems use roof mounted collectors to harness the sun's energy, converting sunlight to heat water in a storage tank. These systems tend to operate best with direct sunlight under clear sky conditions, and usually use gas or electric resistance boosters to supplement times when solar energy is insufficient to meet demand. Solar hot water systems discussed in this paper include the following system configurations:

- System types: close-coupled and split system
- Collector types: flat plate panels and evacuated tube collectors
- Boosting: gas and electric.

Close-coupled systems

Also known as passive or thermosiphon systems

Close-coupled systems consist of a storage tank mounted above the collector, either on the roof or inside the roof space. Water circulates between the tank and the collectors by a form of convection called passive thermosiphon action – rather than by active pumping.

Close-coupled systems are most cost effective and easiest to install and do not require a pump to operate. Heat losses from the pipes are also reduced, due to the components being closer together; however, heat loss from the tank – particularly in colder climates – can be considerable. The roofs holding close-coupled solar water heaters must be structurally capable of supporting the heavy weight of the units; this may require additional structural support for existing buildings. Some councils also may not allow close-coupled systems if the tank cannot be disguised. If the system is specified for a new construction these issues are usually easily addressed during the design stage.

Split systems

Also known as active or pumped systems.

In a split system, the main components are split into two locations. Split systems are advantageous when there is insufficient structural support or roof space to place the storage tank in close proximity to the heating source.

In a solar hot water system, a split system consists of a collector panel on the roof and a tank at ground level. Note that if there is space available, the tank may also be at roof level. Water in the collector panel is heated by the sun and then pumped to the tank where it is stored. This is done by a pump connected to a controller, which only operates the pump when the water in the collector is hotter than the water in the tank. When there is insufficient solar-heated water, a booster supplies the additional hot water required. Boosting can be done by an electric element in the tank, by a gas burner at the base of the tank, or by an instantaneous gas booster which heats the water as it leaves the tank.

Split systems require less weight on the roof and tank maintenance can be easier at more readily accessible locations. The disadvantages of split systems are that they have longer pipe runs, which means more potential for heat loss and more components.

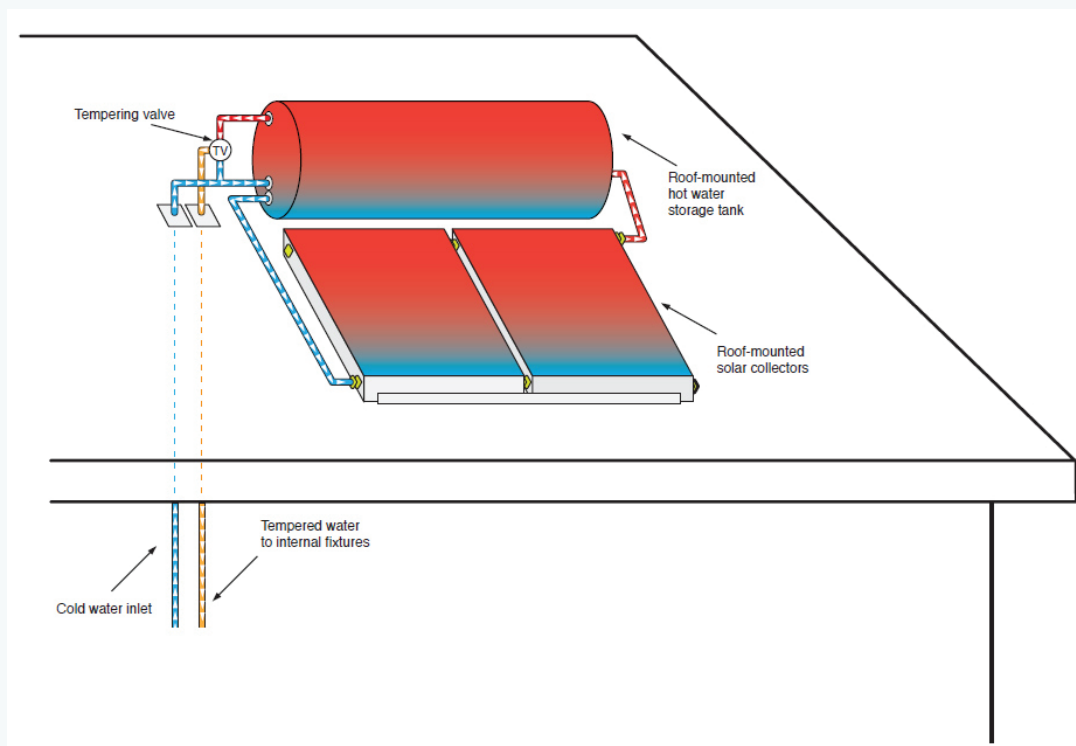


Figure 5. A flat plate, close-coupled thermosiphon system [Source: DCCEE 2010]
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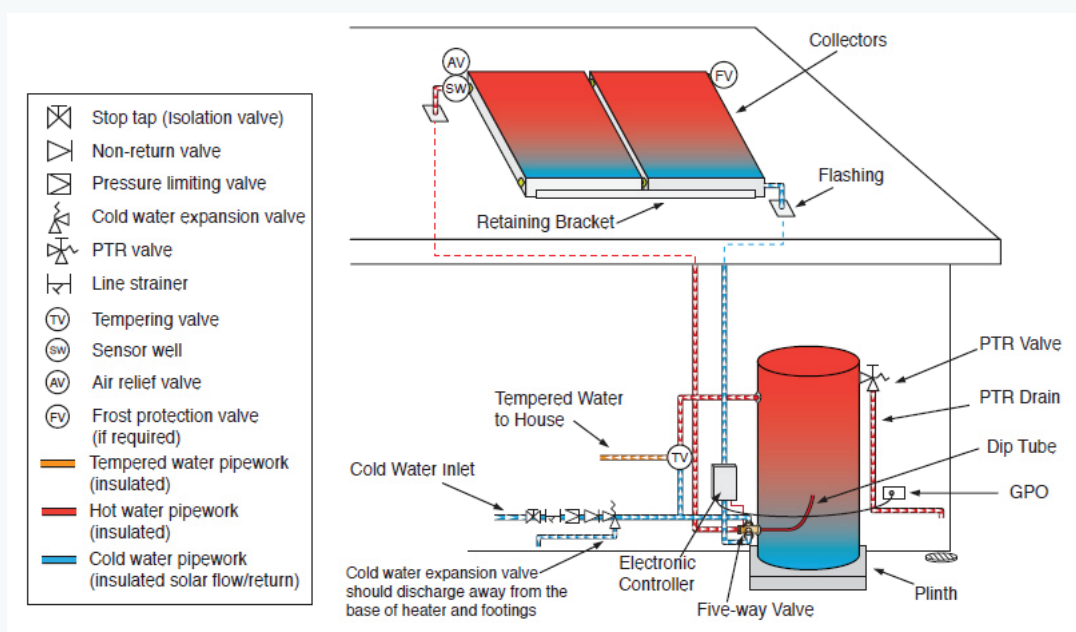


Figure 6. A typical split system for solar hot water [Source: DCCEE 2010]
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Solar collectors

Solar collectors trap solar heat to raise the temperature of water. In the southern hemisphere, solar collectors should face north in a position that avoids overshadowing for the majority of the day. The main types of solar collectors in common use in Australia are:

- flat plate collectors
- evacuated tube collectors.

Flat plate and evacuated tube collector sizes vary by manufacturer. A typical single flat plate or 15-tube array will be approximately two metres by one metre, while a solar water heater system will typically use between one and four flat-plate collectors, or between 10 and 40 evacuated tubes.

Solar fraction is an indicative measure of the relative energy performance benefit of solar water heaters. It represents the proportion of the hot water energy demand met by the solar collectors as compared to the energy required to 'boost' the water to a set point temperature.

Variables that impact the amount of solar fraction are (DCCEE 2010):

- level of solar irradiation (i.e. solar access)
- temperature of water at inlet
- system sizing and type
- actual hot water consumption
- ambient air temperature around tank, collector and system
- pipework and tank insulation
- energy needed for boosting and circulating pump.

Detailed solar radiation data can be obtained from the Bureau of Meteorology.

Flat plate collectors

Flat plate collectors are the most commonly used type. They generally consist of an insulated metal box with a transparent cover. Inside is an absorber plate – which is a metal sheet with high solar radiation absorption – attached to riser tubes that carry the water. The absorber plate collects solar radiation, converts it into heat and transfers the heat to the liquid in the tubes.

Location	Latitude	Flat plate collector area (m2)	Storage tank size (L)	Solar contribution fraction (%)
Adelaide	35°	4	315	74
Brisbane	27.5°	4	315	81
Canberra	35.5°	4	315	67
Darwin	12.5°	3	270	97
Hobart	43°	5	360	65
Melbourne	38°	5	360	67
Perth	32°	4	315	77
Sydney	34°	4	315	76

Table 3. Recommended collector area and storage tank size.
The figures are based on a household with three to four occupants or a water usage of 150-200 litres per day.
(Adapted from CSIRO by Cole, 2004)

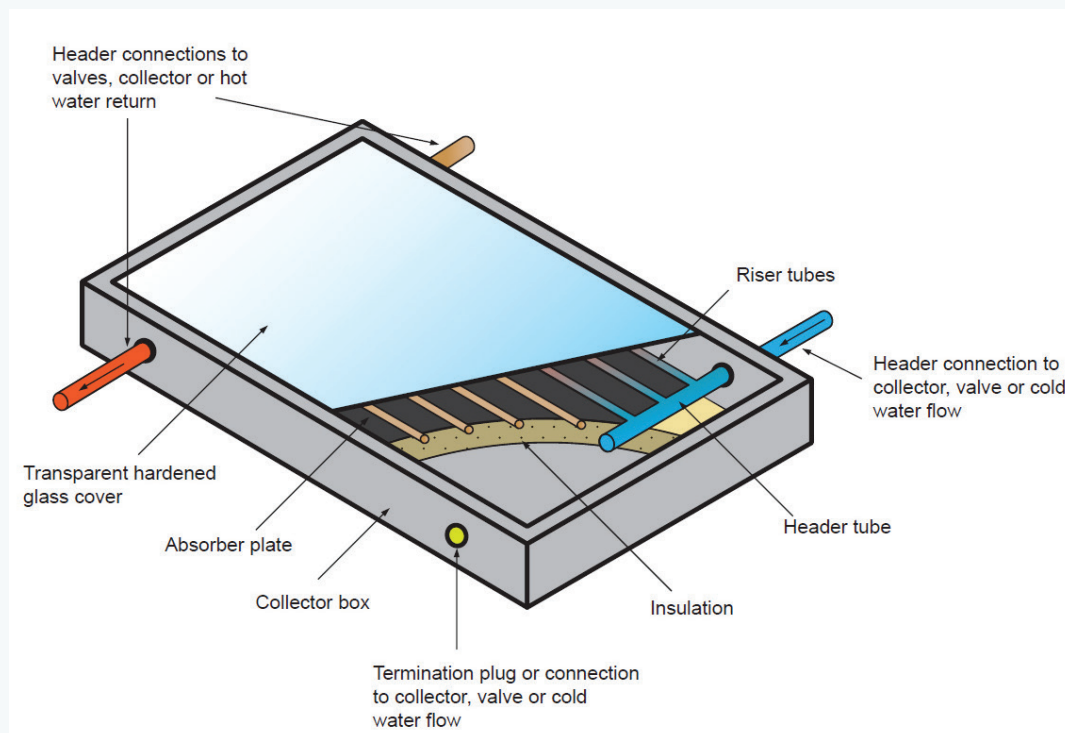


Figure 7. Flat plate collector (Source: DCCEE 2010)
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Frost protection and closed-loop systems

In areas that are prone to frost, frost protection measures are essential. Water expands when freezing and if not correctly specified, flat plate collectors can be subject to frost damage. Water can freeze in the collector channels and damage the collector. Methods of frost protection include the following:

- Selective surfaces and double glazing give some protection, provided frosts are not severe.
- A closed-loop circulation system allows the use of an antifreeze solution, circulated through the collector panels, which does not mix with the potable water in the storage tank. Closed-loop circulation systems, although generally more expensive, can be more efficient compared to open-loop systems which use mains water that may contain impurities and eventually degrade the system.
- Thermostat controllers for built-in frost protection work by pumping hot water from the storage tank through the collector, switching off when the collectors have been sufficiently warmed to avoid freezing. Thermostat controllers may alternatively be used to activate drain-down systems in close-coupled thermosiphon collectors. These allow the water in the collector to be drained via a 'dump valve'.
- Knock valves, or mechanical drain-down valves can also be employed, though these can be problematic as they can fail to operate or reclose once operated, causing damage.

Evacuated tube collectors

Evacuated tube collectors consist of an array of double-walled glass tubes attached to a header pipe or manifold, which acts as a heat collector. Between the glass layers, a partial vacuum provides a high degree of insulation. Within the inner glass layer, a heat-absorbing coating converts sunlight to heat, which is then transferred to the water in the storage tank in one of several ways, as outlined in the three basic types of evacuated tube units below:

1. The heat pipe unit has a sealed copper pipe with heat transfer liquid inside the evacuated tube. This transfers heat up to a copper bulb heat exchanger at the top of the tube. The heat from the bulb is then transferred to a copper header pipe along the top of the collector, which water passes through. The water passes through this pipe, absorbs the heat and is then stored in a tank.
2. The U-tube unit comprises a thin, U-shaped copper pipe which runs down and then up each glass tube, and over to the next tube. Water runs directly through the pipes. The heat collected by this type of evacuated tube heats the water inside directly.

3. In the Water-in-glass unit design, the glass tube is inserted directly into the manifold, with water being allowed to flow directly between the manifold and the inner glass cavity. Using a thermosiphon effect, hot water rises directly to the top of the tube and into the manifold. Such collectors operate at low flow rates and cannot operate at mains pressure due to the limitations of the seal between manifold and glass. This is a very low-cost approach which is common in China, however has limited applicability in Australia due to issues of overheating and of water loss in case of glass breakage.

Because heat does not conduct through a vacuum, evacuated tubes are very efficient at retaining heat collected. The resulting higher efficiency of evacuated tube collectors makes them more effective than flat plates in cold climates or at higher temperatures.

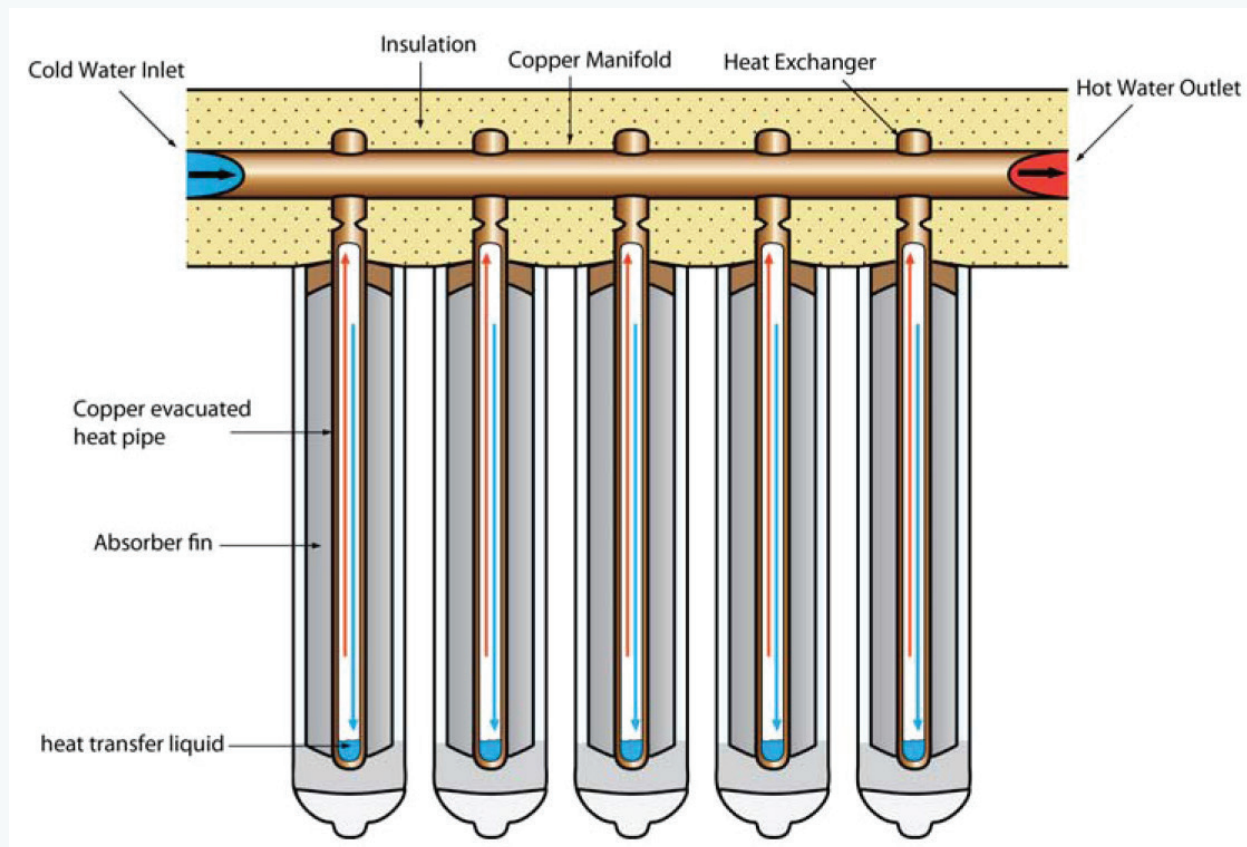


Figure 8. Evacuated tube collector [Source: DCCEE 2010]

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Heat pump systems

Heat pumps extract heat from the air using a similar mechanism to a domestic refrigerator, but in reverse. Air is used to heat a refrigerant which expands and is converted into gas. A motor and pump then compresses the gas, creating heat which is then transferred to the water. The refrigerant is then expanded into gas as it loses heat to the water, then absorbs more heat from the outside air and the cycle is repeated.

Heat pump systems are generally 50 to 75 per cent more efficient than electric resistance hot water systems, depending on climate and type (ATA 2014). Since they can operate in most weather these systems do not require separate boosting systems, as solar hot water systems do. However heat pump hot water tanks often have a back-up electric resistance heating element.

The heat pump performance efficiency depends on factors including:

- ambient air temperature
- relative humidity (more humidity increases the rate of heating)
- cold water inlet temperature
- storage tank capacity.

A drawback with heat pumps is that many do not work well in very cold climates. Trying to extract heat from already cold air can result in frosting of the evaporator, creating the need to use an electric element to provide hot water. They can also be quite noisy in operation (from around 38 to 50 dB), which is comparable to modern small air conditioning compressors. Project-specific research is especially recommended for heat pump selection, as there are purportedly newer system models that have been designed to operate more efficiently in cold climates.

The choice of refrigerant is important. Selection should consider the global warming potential (GWP) and/or ozone-depletion effect, which can be quite high for some refrigerants, and toxicity in case of leakage. Some heat pumps use low GWP refrigerant types such as carbon dioxide, known as R744, which has been commonly used in Japan, or propane, known as R290 (ATA 2014). For project sites near seaside or regional locations, or dusty activities, further research is also encouraged as these factors can impact the selection and maintenance of heat pumps (ATA 2014, p. 48).

As is the case with solar hot water systems, heat pumps can be configured as integrated systems or split systems.

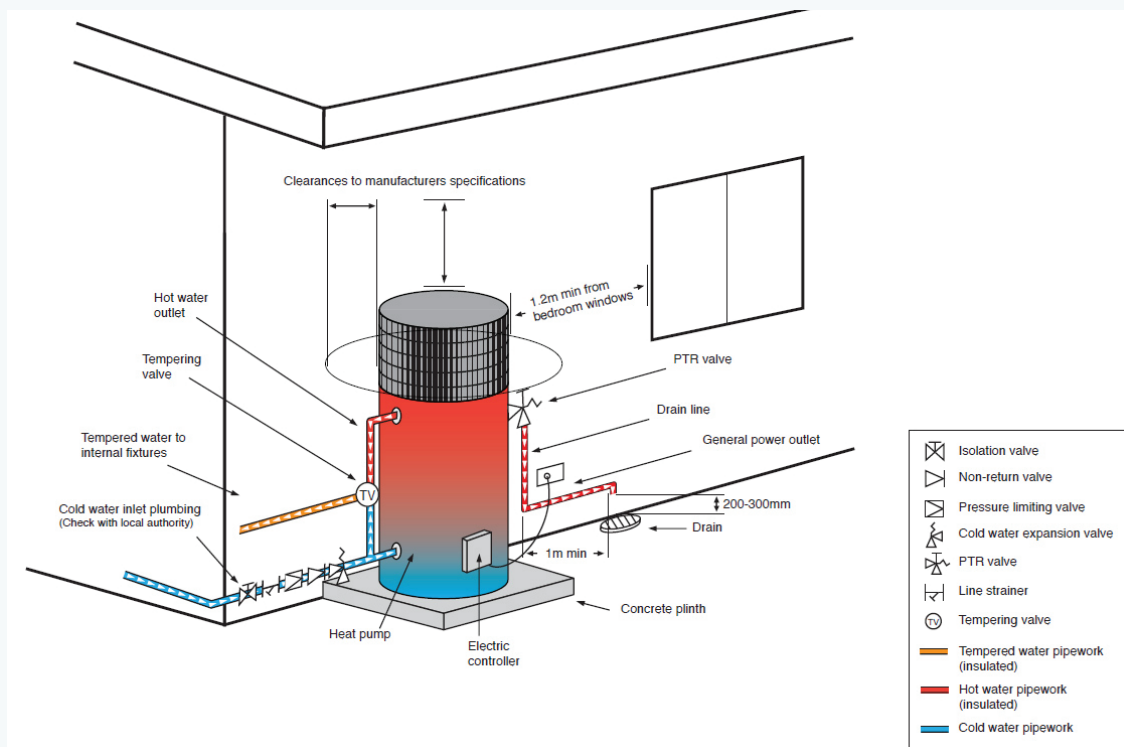


Figure 9. Integrated heat pump system showing clearances (Source: DCCEE 2010)
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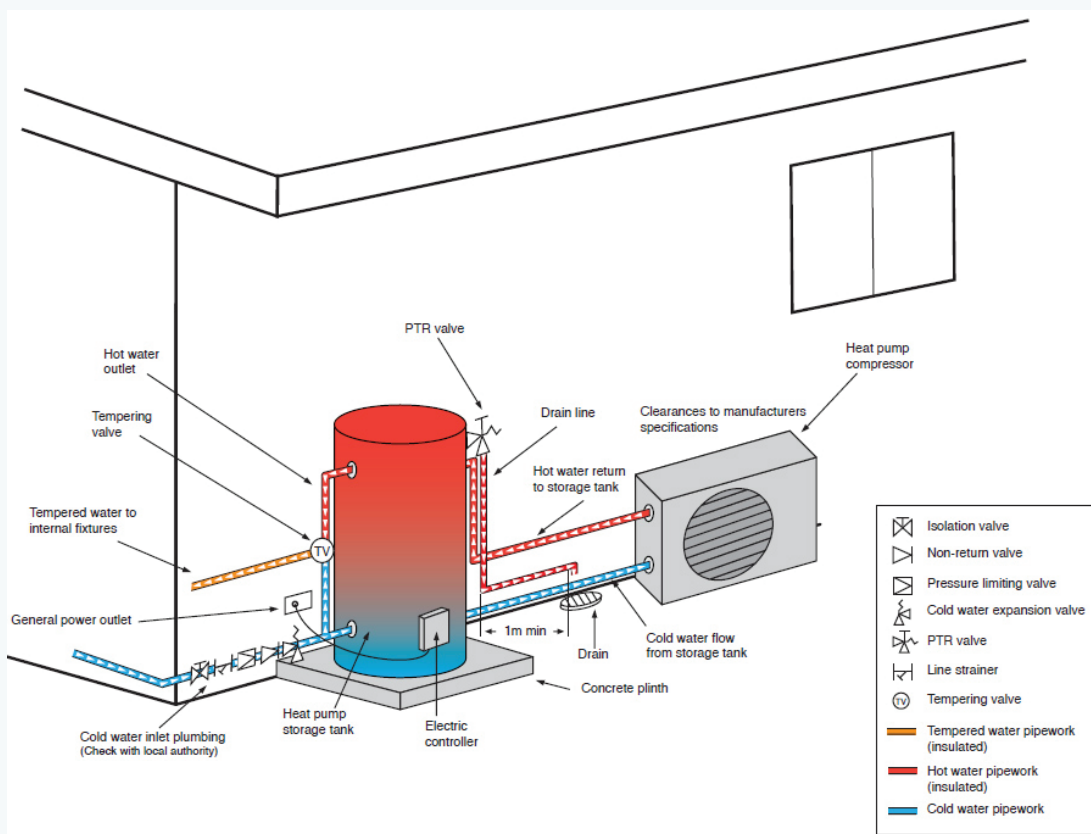


Figure 10. Split heat pump system [Source: DCCEE 2010]
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Integrated systems

In integrated systems, the heat pump compressor is mounted above or beside the tank as a single unit.

Split systems

A split heat pump system consists of a heat pump mechanism that is plumbed to a storage tank in a separate location. Depending on the type, the pipes between the tank and unit can convey refrigerant or water.

A split heat pump system has more flexibility in the locations of the two components, such as indoors for the tank and outdoors for the heat pump mechanism.

Water storage

Heated water from the solar collector array is circulated to a storage tank. Since solar hot water tanks undergo repeated cycles of heating, they tend to be prone to fatigue and corrosion; this is why sacrificial anodes are key in mild steel tanks. In harsh water conditions, in the event steel is exposed to water, the anode, usually made of magnesium or aluminium, is designed to corrode before the tank material does.

Vitreous Enamel Tanks

Vitreous enamel tanks are the same mains pressure tanks commonly used in homes for the last 50 years. They consist of a mild steel cylinder with a baked enamel lining on the inside. The repeated heating and cooling cycles in the tank cause fatigue stresses and can corrode the enamel lining. A sacrificial anode is usually fitted to reduce corrosion of the steel. This anode is a metal bar, usually of magnesium alloy, which is immersed in the water and is in electrical contact with the steel support cylinder. The anode is designed to corrode before the steel does. Since it is 'sacrificial' the anode must be periodically checked and, when necessary, replaced. Vitreous enamel tanks typically last 8 to 15 years, depending on quality and water conditions.

Stainless Steel Tanks

Stainless steel tanks tolerate the higher temperatures of solar water heating systems better than vitreous enamel tanks. While they are more expensive, they can also last up to twice as long as vitreous enamel tanks.

Sizing Storage Tanks

Some of the factors influencing the size of the storage tank are:

- average daily hot water usage
- available solar radiation
- cold water temperature
- cost of booster heating.

Typical system sizes can be selected according to Table 4. The consumption will vary with lifestyle and appliances usage (such as dishwashers and laundry washing machines that do not heat their own water).

Storage tanks should generally be sized to provide one and a half to two days' supply, in case of poor weather. It is essential that the tank be very well insulated, to carry hot water through times of low or no solar contribution.

Number of people	Capacity (litres/day)	Solar collector size (m ²)
1 - 2	160 - 200	2
3 - 4	300 - 370	4
5 - 6	440	6

Table 4. Sustainability Victoria's estimate of the hot water needs and solar collector size, based on the number of users (Sustainability Victoria, 2014).

Safety

Hot water storage tanks are fitted with a Pressure and Temperature Release (PTR) valve. A PTR valve releases a small amount of water from the tank to release the pressure produced as the tank water heats and expands.

The PTR valve will also release water if the tank reaches a very high temperature (typically above 95 degrees C), in order to protect the system from overheating. In this instance, a large amount of very hot water may be 'dumped' by the system, and for this reason the PTR valve outlet must be positioned to drain in a safe manner. Plumbing regulations in each jurisdiction will provide guidance on the drainage requirements.

Boosters

A booster is simply the back-up source of heating for the solar hot water system when the rate of insolation has been low, such as during cloudy weather, or when hot water usage has been greater than the tank's supply of solar-heated water.

Insufficient solar gain is rarely a problem for an adequately sized system in the tropics.

A booster will ensure the availability of hot water, as well as protect the system from the growth of legionella in the storage tank – a risk in circumstances where the storage tank does not reach a high enough temperature to kill off legionella bacteria.

Solar hot water units are usually connected to gas or electric supplementary heaters. Selection of the booster largely determines the greenhouse gas emissions associated with the units' operation. Electrically boosted systems produce between five (national average) and 7.5 times (for brown coal fuelled Victoria) as much CO₂ emissions per unit of hot water than efficient gas boosted systems. Therefore, assuming boosting provides a conservative 25 per cent of system energy, specification of a new electrically boosted solar hot water unit in preference to a high-efficiency instantaneous gas system will result in greater greenhouse gas emissions.

In Victoria's case, with the greater CO₂ emissions associated with electricity production and less available energy from the sun, electrically boosted solar hot water systems are to be avoided unless it is possible to couple them with green power or directly coupled with solar photovoltaics (PV). This latter type of system is sometimes called direct PV water heating (ATA 2014, p.56).

Storage boosters

The timing and duration of the boosting is critical to maximizing the system's solar contribution. If the element is on for hours overnight, the tank may already be hot at the start of the day, and unless this water is used in the morning, the solar collectors would make little contribution. For this reason the best time to boost the tank is at the end of the day, so that the booster effectively 'tops up' the hot water already heated by the sun. That way the usage for cooking, washing up and showers will leave plenty of capacity in the tank the next morning for the sun to heat.

For all storage systems, an override switch should be placed in a central part of the house (such as the kitchen) so that the occupants have the choice of when the booster is used.

During summer and other periods of high insolation, or when the house will be unoccupied for any length of time, the booster unit should be turned off to avoid unnecessary heating of the water.

Electric storage booster

The simplest way to boost a solar water heater is with an electric element, which is typically located at the base of the tank and controlled with a timer. The sun works to heat the water during the day, while the timer typically activates the electric booster at night, essentially 'topping up' or heating the sun-warmed water to the desired temperature.

Gas storage booster

Gas storage boosters consist of a burner in the base of the tank used to boost the temperature of the water stored in the tank. These are basically standard gas storage water heaters with a control system that avoids over-heating the water and rendering the solar panel ineffective. Like the electric boosted tank, the timing of the burner operation is critical - see 'Efficient storage booster usage', below.

Because gas storage boosters can be challenging to control with timers, and the heat loss from this type of storage tank is high, they have largely been displaced by instantaneous gas boosting (ATA 2014).

Efficient storage booster usage

The booster has a significant influence on the overall performance of a system. Inefficient booster use will tend to increase the power bill such that a solar hot water system is no longer cost-effective, or takes longer to pay back.

If hot water is used mainly in the evening for showering, dishwashing, clothes washing etc, the storage tank will be largely emptied of hot water by the evening's end. If the system has a storage boost, with water constantly kept hot, then the booster will cut in after the tank has been emptied of hot water.

By morning the water will be hot again, and all the solar hot water panels can do is keep it warm during the day, ready for use in the evening. This means the booster does most of the heating work and the solar panels do little. This pattern of use ensures you do not get maximum benefit from the solar hot water unit.

Rather than boosting after the hot water has been used, it would therefore be more efficient for the storage boost to be timed just before the regular evening use, leaving the largest portion of colder water available for solar heating.

If a booster is left on automatic, on the other hand, it will not only tend to boost at night but it will switch on whenever the thermostat registers a drop below normal operating temperature such as on cloudy days, and in the morning just before the sun starts to heat the water. Therefore, to get the most out of a storage booster:

- have the booster timed just before the regular heaviest use (e.g. 4pm, before 6pm showers commence)
- turn the booster off during summer and other periods of high insolation.

Of course with an instantaneous booster and a tank that is sized correctly to the household needs (see Table 4), booster timing and manual overrides cease to be an issue.

Instantaneous gas boosting

An instantaneous water heater can be attached to the output of the solar hot water storage tank to boost the water temperature when necessary. This is the most efficient boosting configuration, as the instantaneous heater monitors the temperature of the water coming from the solar water heater and turns on to boost the water temperature only if needed. This configuration also avoids the risk with storage tanks that booster-heated water will displace solar-heated water.

One disadvantage of gas instantaneous systems is that they often need gas supply pipe upgrades, as they consume large amounts of gas over a short period. This adds to the installation cost (a rule of thumb is \$50 per linear metre of pipe). Also be aware that instantaneous boosters require a minimum 1.5 metre clearance around openable windows and doors.

Summary

Using low-energy water heating is one of the most effective ways of reducing the energy, carbon and water impacts of a domestic or small project building. It is an important element that needs to be considered in any new building design. Solar hot water in particular is a reliable, tried and tested technology which can be easily integrated into new building designs. Adopting low-energy hot water systems can achieve long term reductions in energy costs with savings that will increase as energy prices rise.

Glossary

Global warming potential (GWP): a numerical index that allows effects on global warming of various greenhouse gases to be compared; GWP uses the 100-year global warming potential (GWP) of carbon dioxide as a reference point, where it has a GWP of 1.

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