

SOLAR & HEAT PUMP HOT WATER SYSTEMS

Plumber Training Handbook

THE PHASE-OUT OF GREENHOUSE
INTENSIVE HOT WATER SYSTEMS



a joint initiative of the Australian,
State and Territory Governments

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Due to the wide variety of products on the market, the technical diagrams illustrate the general principles of the technologies and may differ in appearance from actual products. This publication is not a substitute for independent professional advice, and readers should obtain any appropriate professional advice relevant to their particular circumstances.

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Preface

The Solar and Heat Pump Hot Water Systems Plumbers Training Handbook is a resource to assist plumbers in installing solar and heat pump hot water systems. This handbook is part of a training program for plumbers being rolled out under the National Framework for Energy Efficiency and the National Hot Water Strategic Framework.

The Solar and Heat Pump Transitional Plumber Training Program is a joint initiative of the Australian Government and state and territory governments to provide plumbers and other installers of solar and heat pump hot water systems with information on solar technologies and their installation. Correct installation of solar and heat pump hot water systems will ensure they comply with state and territory plumbing regulations and achieve high performance. This will result in good outcomes for householders and the environment.

This handbook was written by Global Sustainable Energy Solutions, who acknowledge the contributions of the ACT Planning and Land Authority, the Canberra Institute of Technology, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Construction and Property Services Industry Skills Council (CPSISC), the Australian Government Department of Climate Change and Energy Efficiency, the Queensland Office of Clean Energy, Building Codes Queensland, Media Valley, the National Plumbing Associations Alliance, the National Plumbing Regulators Forum, the Northern Territory Department of Lands and Planning, SA Water, the South Australian Department for Transport, Energy and Infrastructure, Sustainability Victoria, the Master Plumbers' and Mechanical Services Association of Australia and the Western Australian Plumbers Licensing Board.

This handbook builds on the Household Solar Hot Water and Heat Pump Installation and Maintenance Handbook 2009, developed by the Master Plumbers' and Mechanical Services Association of Australia on behalf of the Australian Government Department of the Environment, Water, Heritage and the Arts.



Chapter 1

Introduction & Overview

Introduction & Overview

This manual has been compiled to provide information on the selection, design and installation of low-emission water heating services in residential properties throughout Australia. The information will be useful to plumbers and other installers of solar and heat pump water heating technologies, and will help installers to update their installation skills and techniques.

Between 2010 and 2012, domestic electric storage water heaters are to be phased out across most of Australia. All states and territories, except Tasmania, will participate in the phase-out. As a result of the phase-out and the availability of government incentives, the number of solar water heaters (SWHs) and heat pump water heaters being installed is expected to increase. This change to the water heating market will require increased industry and public awareness of what constitutes a compliant installation and how the performance of these appliances can be maximised through good design, correct installation and an understanding by householders of use and maintenance of their water heater.

This training resource is divided into three main parts:

- 1 The first part (chapters 1–4) examines the environmental importance of moving away from electric resistive water heating to the low-emission technologies of solar, heat pump and high-efficiency gas water heaters, and the science underpinning the operation of solar and heat pump technologies.
- 2 The second part (chapters 5 and 6) covers the various components of SWHs and heat pump water heaters.
- 3 The final part (chapters 7 and 8) covers general installation requirements for SWH and heat pump systems and principles of good system design, together with important safety and site-related considerations for site work.

1.1 Why low-emission water heaters?

The amount of energy used to heat domestic water in Australia is substantial. Around a quarter¹ of the energy used in an average Australian household goes directly into water heating. Currently, almost half of Australian households use electric storage water heaters, which produce the same level of greenhouse gas emissions per year as running an average car.

Figure 1.1 shows the relative emissions intensity of different water heaters. By phasing out greenhouse-intensive water heaters, greenhouse gas emissions can be reduced by about 30 million tonnes in the period from 2010 to 2020. This is equivalent to taking 750,000 cars off the road for 10 years.

¹ Energy Use in the Australian Residential Sector 1986–2020, Department of the Environment, Water, Heritage and the Arts, 2008.

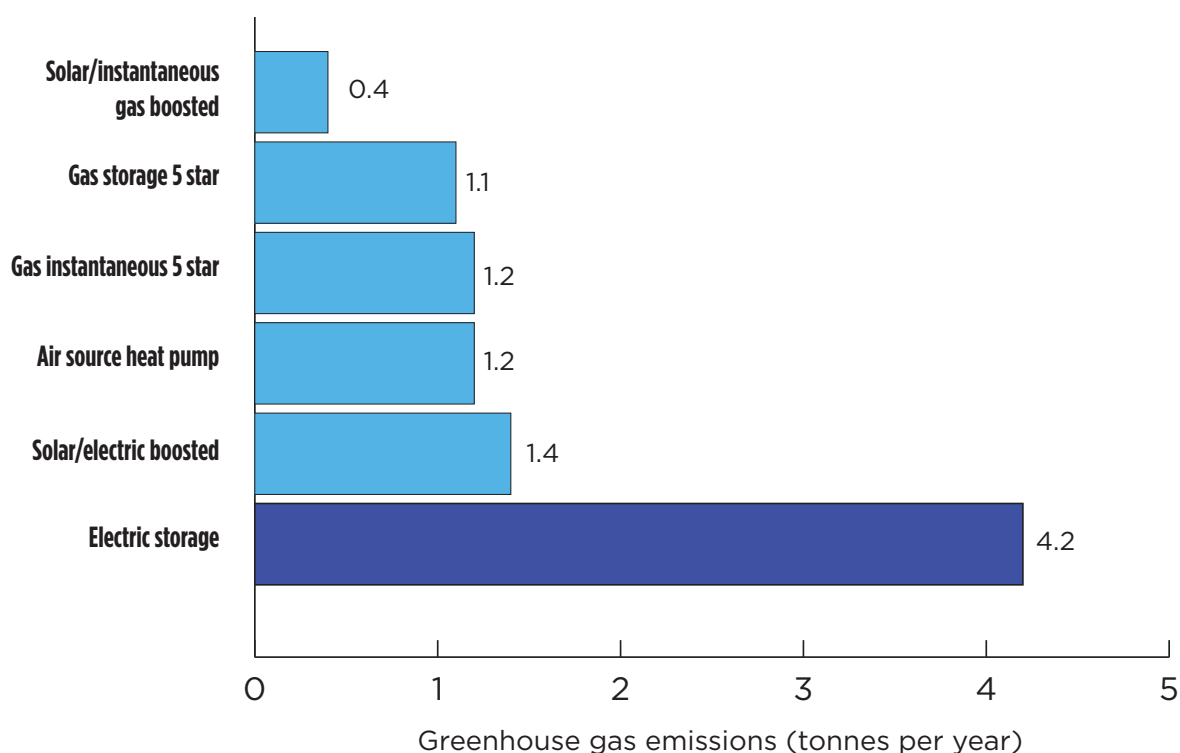
Figure 1.1 Annual greenhouse gas emissions, based on 140L of hot water per day

Table 1.1 below shows the greenhouse gas emissions in each Australian state and the Northern Territory. Differences between the jurisdictions relate to use of different generation sources for power supplies. The last column of the table shows how many kilograms of carbon dioxide are emitted into the atmosphere for each kilowatt hour (kWh) of electricity consumed for each state or territory.

Table 1.1 Carbon dioxide emissions in Australia

State	Power generation source	CO ₂ emissions (kg/kWh)
Tasmania	Hydro	0.13
Queensland	Black coal, natural gas	1.04
New South Wales	Black coal, hydro	1.06
Victoria	Brown coal, natural gas	1.31
South Australia	Natural gas, brown coal	0.98
Western Australia	Black coal, natural gas, dual fuel (gas-coal-oil)	0.98
Northern Territory	Natural gas, other fossil fuel	0.79

Source: Energy Today (energytoday.com.au); Energy Supply Association of Australia (2007).

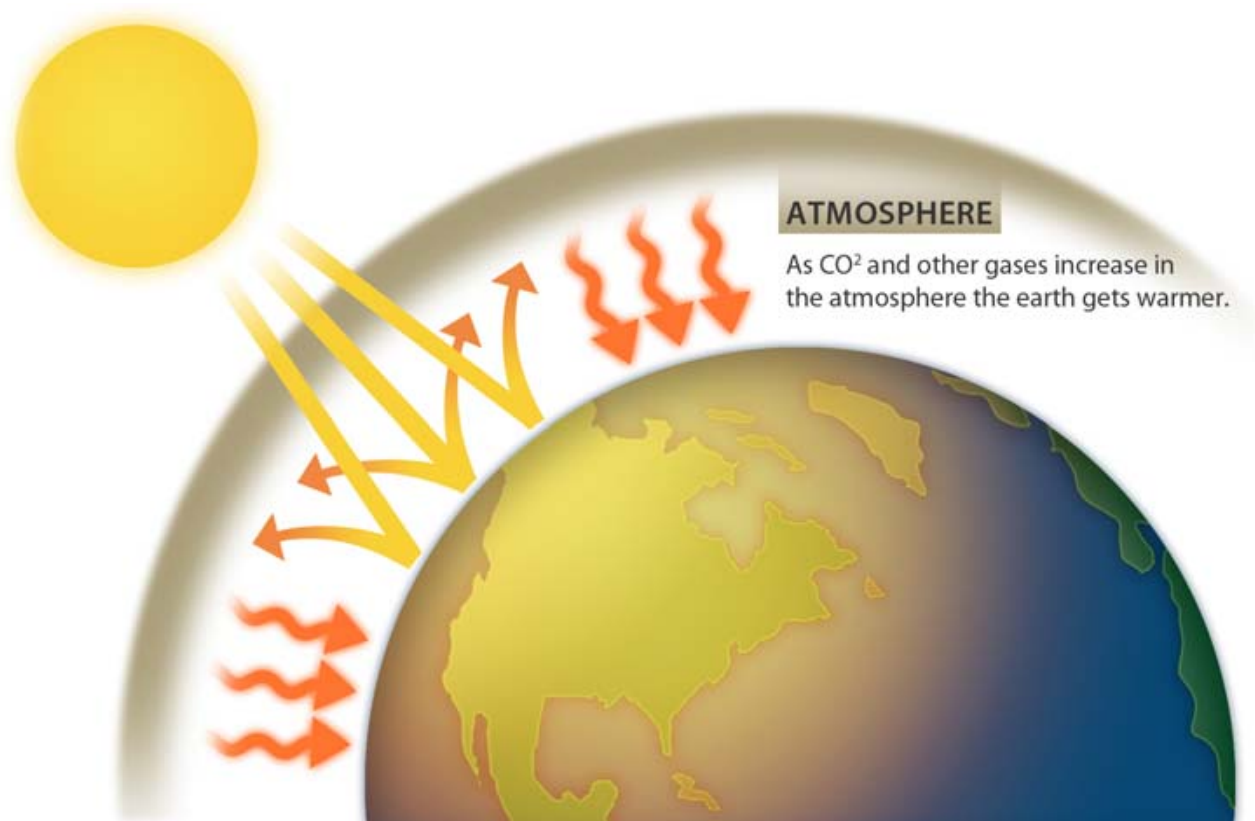
1.2 Climate change and the enhanced greenhouse effect

The most significant effect of emissions from burning fossil fuels is a change to the Earth's climate systems due to an increase in atmospheric greenhouse gases, which enhance the greenhouse effect.

The greenhouse effect is essential to life on Earth because it maintains the Earth's temperature at a level suitable for life—an average of about 14.5°C^2 . Life exists because of a balance between the rate of solar energy gained by the Earth and the rate of heat lost back to space, as shown in Figure 1.2. The use of fossil fuels is changing this balance. Burning of fossil fuels releases large quantities of additional carbon dioxide and methane (the principal greenhouse gases) into the atmosphere, increasing the amount of heat trapped in the atmosphere and increasing the Earth's average temperature.

There is now general acceptance by scientists that the increase in the average global temperature of 0.74°C^3 recorded in the past 100 years is largely attributable to the burning of fossil fuels. The extent of global warming is difficult to predict precisely, but scientists' modelling of the atmosphere suggests a 2°C to 6°C rise in average global temperature within the next 100 years.

Figure 1.2 The enhanced greenhouse effect



² National Climate Data Collection USA 2008

³ IPCC Fourth Assessment Report (AR4) 2007

Some of the predicted impacts of climate change are on:

- water resources, as a result of changes in rainfall patterns; this is already occurring in Australia, with all eastern states and the southwest of Western Australia receiving less rainfall
- weather—changes in weather patterns, more extreme events and associated environmental damage
- oceans—rising sea levels, flooding and more frequent and violent cyclones; coastal areas and island nations are most affected
- agriculture—changes in crop yields, with reduced yields in many areas due to changing or unreliable weather patterns, less available water and more frequent and severe droughts and floods
- health—more temperature-related deaths as a result of extreme weather patterns and very hot or very cold periods, particularly deaths of the very young and elderly who do not cope well with such extremes; the spread of infectious diseases is also likely to increase as warming environments allow insects and other disease carriers to increase their range
- natural environment—changes to forest cover and composition, displacement of species and increased loss of species as their habitats change too quickly for them to adapt.



Chapter 2

Phase-out

Phase-out

Electric water heaters are being phased out across Australia in new and existing detached houses, terraced houses, townhouses and hostels, commencing during 2010. For hot water installations in **new homes**, requirements are specified in the Building Code of Australia and are to be regulated through state and territory building regulations. Installations in **existing homes** will be regulated through state and territory plumbing regulations.

2.1 Timing

The Australian and state and territory governments are working together to phase-out greenhouse-intensive water heaters.

In 2010 (Stage 1), the program is being implemented by the individual states and territories. Each participating state and territory is responsible for determining the commencement date, eligibility criteria and exemptions for the phase-out.

By 2012 (Stage 2), the program for existing homes will cover all detached, row and terraced houses, townhouses and hostels.

A working hot water system will not need to be replaced but, when a system does need to be replaced, it will be with a low-emission alternative.

The phase-out will be implemented in two stages.

2.1.1 Stage 1

Commencing during 2010, the phase-out of greenhouse-intensive electric water heaters will be implemented on a state-by-state basis for Class 1 buildings. Class 1 buildings are new and existing detached houses, terraced houses, townhouses and hostels where such requirements do not currently exist.

Programs for new homes are already in place in South Australia, Queensland, Victoria, Western Australia and New South Wales.

Programs are already in place for existing homes in South Australia and Queensland.

More detail on the programs in a specific area is available from state and territory governments. Information about the programs already in place can be obtained from:

- **Queensland**
New homes
www.dip.qld.gov.au/resources/laws/plumbing/current/qpw-code-feb09.pdf
Existing homes
www.dip.qld.gov.au/sustainable-housing/electric-hot-water-system.html
- **South Australia**
New homes
www.planning.sa.gov.au/index.cfm?objectid=1F05F9AC-96B8-CC2B-69EDFC96729A710F
Existing homes
www.energy.sa.gov.au/waterheaters
- **Victoria**
New homes
www.pic.vic.gov.au/www/html/249-5-star-standard.asp
Existing homes
www.new.dpi.vic.gov.au/energy/policy/efficiency/water-heaters

- **Western Australia**
New homes only
www.5starplus.wa.gov.au
- **New South Wales**
New homes only
www.basix.nsw.gov.au
- **Australian Capital Territory**
www.actpla.act.gov.au/customer_information/community
- **Northern Territory**
Stage 1 will not apply in the Northern Territory as less than 1% of the Territory has access to reticulated gas.

2.1.2 Stage 2

During 2012, the phase-out will be extended so that greenhouse-intensive water heaters will no longer be able to be installed in Class 1 buildings and new Class 2 buildings with access to piped/reticulated gas, except where an exemption applies. Class 2 buildings are any new flats or apartments.

2.1.3 Post 2012

For new apartments without access to reticulated gas, the phase-out will occur between 2012 and 2015, depending on further investigation into the feasibility of low-emission water heating options.

Table 2.1 shows the schedule of the phase-out.

Table 2.1 General schedule of phase-out

Building class	New	Existing
Class 1a and b*	2010: All dwellings	2010: Dwellings in a piped/reticulated gas area 2012: All dwellings
Class 2**	2012: New dwellings with access to piped/reticulated gas	Exempt

*Class 1a: Detached and semi-detached houses, row houses, townhouses, maisonettes, single storey units and flats (including 'granny flats').

*Class 1b: Small hostels (not exceeding 300m² and not more than 12 people reside)

**Class 2: Apartments and flats where one dwelling is above another.

State and territory government programs will:

- not force any households to replace an existing, operating hot water heater; the phase-out will apply to new buildings, and where the hot water system in an existing building breaks down or ages and needs to be replaced with a new system
- give home owners options to choose the low-emission alternative that best suits their home, climate and budget; the choice is not limited to gas (where a home has access to piped/reticulated gas)—householders may choose from any of the low-emission technologies, including solar, heat pump or gas
- include some exemptions; these are yet to be finalised, but will apply where appropriate alternative technologies are not yet available, or in situations where there are significant additional costs.

2.2 Consumer information

Information has been developed on the phase-out of electric water heaters and the range of low-emission technologies available. This will assist householders in their selection of a replacement for their electric storage hot water heater.

Householders can be referred to www.climatechange.gov.au for the following information:

- 1 Water heating, the environment and you
- 2 Hot water systems—what you need to know
- 3 Low-emission water heating technologies

2.3 Complementary state programs for new and existing buildings

2.3.1 Queensland

The Queensland Plumbing and Wastewater Code⁴ states that from 1 January 2010 **existing** houses and townhouses (Class 1 buildings) located in a natural gas reticulated area must install a greenhouse-efficient hot water system (i.e. gas, solar or heat pump) when the existing electric resistive system needs replacing. Householders will not need to replace their existing electric resistive water heaters that are in good working order. Replacement of an electric hot water system with a low-greenhouse hot water system is not required when the initial system has failed within the warranty period. Temporary arrangements are available in Queensland to give the consumer time to consider which low-greenhouse gas hot water system to install.

This follows action by the Queensland Government to ban installation of electric resistance water heaters in all **new** houses and townhouses (Class 1 buildings only), which came into effect on 1 March 2006.

From 1 January 2010, hot water in existing Class 1 buildings must be supplied by:

- a solar water heater (SWH) system
- a heat pump system
- a gas hot water system with an energy rating of at least 5 stars.

Up-to-date information is available from the Queensland Government at:

www.dip.qld.gov.au/sustainable-housing/electric-hot-water-system-replacement.html

2.3.2 South Australia

South Australia has introduced requirements for water heaters where construction work is required, such as in new homes or renovations requiring development applications. For applications lodged after 1 May 2009, a number of requirements apply, depending on building classification:

- Class 1a and 1b in metropolitan or regional South Australia (by postcode)
 - o SWH (electric boost) or heat pump
 - o SWH (gas boost)—any system
 - o gas storage/instantaneous—minimum 5 stars
- Class 2 (single apartment)
 - o SWH (electric boost) or heat pump—any system
 - o gas storage/instantaneous—more than 2.5 stars
 - o SWH (gas boost)—any system

⁴ www.dip.qld.gov.au/resources/laws/plumbing/current/qpw-code-feb09.pdf

- Class 2 (multiple apartments)—exempt
- Class 1 (remote South Australia), Class 1 (metropolitan, where heaters are either inside or outside or in shed or garage, and less than 3 metres from neighbouring windows and doors)—same as for as Class 2:
 - o SWH (electric boost) or heat pump—any system
 - o gas storage/instantaneous—more than 2.5 stars
 - o SWH (gas boost)—any system.

Up-to-date information on the South Australian phase-out program is available from the South Australian Government, at energy.sa.gov.au/?a=30372

2.4 Existing state programs for new buildings only

Table 2.2 summarises the requirements in each Australian jurisdiction for sustainable housing rating systems.

Table 2.2 Summary of requirements for sustainable housing rating systems in Australia

Region	System	Comments
Australia	Building Code of Australia 2008 (BCA)	On 1 May 2008, the requirement for alterations to achieve 5-star energy efficiency came into effect in the BCA (www.buildingcommission.com.au), the new standard for renovations or relocations. This applies to the thermal performance of a home and does not require a solar hot water system. In 2010, governments agreed to increase energy efficiency requirements for all residential buildings to a minimum of 6 stars and introduce new requirements relating specifically to hot water systems. These are to be implemented by May 2011.
	Website	www.abcb.gov.au/go/thebca/aboutbca
ACT	ACTHERS	The ACTHERS program requires a minimum 5-star rating as part of the current BCA requirements.
	Website	www.actpla.act.gov.au/topics/design_build/
NSW	BASIX	BASIX, the Building Sustainability Index, ensures that homes are responsible for fewer greenhouse gas emissions by setting energy and water reduction targets for houses and units. Since 1 October 2006, BASIX applies to all new residential dwellings and any alteration or addition throughout NSW. Water heaters listed in BASIX are: <ul style="list-style-type: none"> • solar (gas or electric boosted) • electric heat pump • gas instantaneous or storage (with appropriate star rating).
	Website	www.basix.nsw.gov.au
NT	None identified	Check local responsible regulatory authority; otherwise NT must comply with the BCA.
	Website	www.nt.gov.au/lands/building

Region	System	Comments
QLD	Queensland Development Code (QDC), Queensland Plumbing and Wastewater Code (QPW)	<p>The QPW Code has been amended to set installation requirements for the replacement of electric resistance water heaters in existing houses (Class 1 buildings) located within a gas-reticulated area. This amendment commences on 1 January 2010.</p> <p>Existing systems that need replacement must be replaced with a system that has a low greenhouse gas emissions impact (i.e. gas, solar or heat pump system) from 1 January 2010.</p> <p>Current requirements in QDC (MP4.1) for the installation of gas, solar or heat pump water heaters in new Class 1 buildings have also been placed in the amended QPW Code.</p>
	Website	www.dip.qld.gov.au/resources/laws/plumbing/current/qpw-code-feb09.pdf
	Queensland Cleaner Greener Buildings Initiative	<p>All new houses and renovations must be 6 star (out of 10) by the end of 2010, and all new units must be 5 star from March 2010. This policy overrules any existing covenants or body corporate rulings relating to SWH for a particular property.</p>
	Website	www.climatechange.qld.gov.au/pdf/factsheets/3planbuild-e1.pdf
	Queensland Sustainable Homes	<p>This imposes additional requirements for all new houses to have greenhouse-efficient water heaters. Queensland requires that building body corporates must approve energy efficiency building measures, and there is a mandatory sustainability declaration. From 1 January 2011, plumbers must have a 'solar and heat pump' endorsement on their trade licence to be able to install low greenhouse gas hot water systems.</p>
	Website	www.sustainable-homes.org.au/
SA	SA2 and SA7 variation to BCA (Vol. 2)	<p>From 1 July 2008, new and replacement water heaters installed into most homes in South Australia will need to be low-emission types, such as high-efficiency gas, solar or electric heat pump:</p> <ul style="list-style-type: none"> • a solar or heat pump water heater that achieves (i) in a home with three or more bedrooms, at least 22 renewable energy certificates in zone 3, or (ii) in a home with one or two bedrooms, at least 14 renewable energy certificates in zone 3 • a gas water heater with an energy rating label of 2.5 stars or greater.
	Specification SA80B Website	<p>For houses located in areas not serviced by reticulated gas</p> <p>www.planning.sa.gov.au/go/hot-water-services</p>
TAS	None identified Website	<p>Check with local responsible regulatory authority.</p> <p>www.wst.tas.gov.au/industries/building</p>
VIC	5 Star	<p>The 5 Star standard for all new houses in Victoria came into full effect on 1 July 2005. This means it is compulsory for new houses to have a rainwater tank for toilet flushing, or a solar hot water system. If reticulated gas is available, the solar water heater must be gas boosted.</p>
	Website	www.5starhouse.vic.gov.au

Region	System	Comments
WA	5 Star Plus	<p>In May 2007, Western Australia adopted the 5-Star Plus system, which is an extension to the 5-star energy efficiency provisions of the BCA. This system is based on the Energy Use in Houses Code and the Water Use in Houses Code.</p> <p>Energy Use in Houses Code</p> <p>Performance requirement 3—water heaters</p> <p>A building's water heater systems, including any associated components, must have features that produce low levels of greenhouse gases when heating water.</p> <p>Deemed to satisfy performance requirement 3—water heaters</p> <p>A hot water system must be either:</p> <ul style="list-style-type: none"> • a solar hot water system, complying with AS 2712:2002, that has been tested in accordance with AS 4234:1994, and achieves a minimum energy saving of 60% for a hot water demand level of 38MJ per day for climate zone 3; or • a gas hot water system, complying with AS 4552:2005, that achieves a minimum energy rating of 5 stars; or • a heat pump hot water system, complying with AS 2712:2002, that has been tested in accordance with AS 4234:1994, and achieves a minimum energy saving of 60% for a hot water demand level of 38MJ per day for climate zone 3. <p>Water Use in Houses Code</p> <p>Performance Requirement 3—hot water use efficiency</p> <p>A building must have features that, to the degree necessary, facilitate the efficient use of hot water appropriate to:</p> <ul style="list-style-type: none"> • the geographic location of the building • the available hot water supply for the building • the function and use of the building. <p>DTS 3 (Energy Efficiency Declaration)—hot water use efficiency</p> <p>All internal hot water outlets (taps, showers, washing machine water supplies) must be connected to a hot water system or a recirculating hot water system with pipes installed and insulated in accordance with AS/NZS 3500:2003 (Plumbing and drainage, Part 4, Heated water services). The pipe from the hot water system or recirculating hot water system to the furthest hot water outlet must not exceed 20 metres in length or 2 litres of internal volume.</p> <p>Source: 5-Star Codes brochure: www.cockburn.wa.gov.au/documents/CouncilServices/Building/5starplus_Brochure_GREEN.pdf</p> <p>Website www.buildingcommission.wa.gov.au/bid/5starplus.aspx</p>



Chapter 3

RECs, Rebates & Tariffs

RECs, Rebates & Tariffs

Two types of incentives are offered to householders to encourage them to install low-emission water heaters.

- Renewable energy certificates (RECs) are available for the installation of solar and heat pump systems for new and existing homes.
- A range of rebates on the cost of purchasing and installing a low-emission water heater to replace an electric water heater are available from the Australian and state and territory governments.

Solar water heater (SWH) and heat pump systems are typically connected to the mains electricity supply. The tariff rate for the electricity supply will affect the operating costs of these systems, and this is an important consideration in the design of an SWH or heat pump system.

The following information is current at the time of printing this handbook.

3.1 Renewable energy certificates (RECs)

When installed, an SWH or heat pump uses less electricity than a conventional hot water system. This reduces the drain on the electricity grid, including electricity produced by coal and other non-renewable sources.

SWHs and heat pumps are listed as a renewable energy technology under the *Renewable Energy (Electricity) Act 2000* and are entitled to RECs. The number of RECs is calculated by determining the amount of electricity the system displaces over a determined period (called a deeming period). Each REC is equivalent to 1 MWh of renewable electricity generated or deemed to have been generated.

In June 2010, the Federal Government announced amendments to the Renewable Energy Target (RET) scheme. As part of these changes, the scheme will be split into two parts: 1. the Small-scale Renewable Energy Scheme (SRES) which covers small scale technologies such as solar panels and solar hot water systems. 2. the Large-scale Renewable Energy Target (LRET) which covers large-scale renewable energy projects like wind farms, commercial solar and geothermal. The Small-scale Renewable Energy Scheme will provide a fixed price of \$40 (less brokerage fees) per REC effective from 1 January 2011.

The number of RECs also depends on where the system is installed because the amount of sunlight a system receives each day varies from location to location. Each postcode is allocated a zone rating based on its solar radiation levels and the water temperature in the area. A system with a higher zone rating has the potential to displace a greater amount of electricity and is entitled to more RECs. Table 3.1 shows the REC zone ratings for all Australian postcode areas.

Table 3.1 REC zones for Australian postcodes

Postcode range			Postcode range			Postcode range		
From	To	Zone	From	To	Zone	From	To	Zone
200	299	3	3750	3898	4	5231	5261	3
800	862	1	3900	3900	3	5262	5263	4
870	872	2	3902	3996	4	5264	5270	3

Postcode range			Postcode range			Postcode range		
From	To	Zone	From	To	Zone	From	To	Zone
880	909	1	4000	4419	3	5271	5291	4
1001	2914	3	4420	4420	1	5301	6256	3
3000	3381	4	4421	4428	3	6258	6262	4
3384	3384	3	4454	4454	1	6271	6318	3
3385	3387	4	4455	4468	3	6320	6338	4
3388	3396	3	4470	4475	2	6341	6341	3
3399	3413	4	4477	4477	1	6343	6348	4
3414	3424	3	4478	4482	2	6350	6353	3
3427	3451	4	4486	4488	3	6355	6356	4
3453	3453	3	4489	4493	2	6357	6395	3
3458	3462	3	4494	4615	3	6396	6398	4
3463	3465	3	4620	4724	1	6401	6439	3
3467	3469	4	4725	4725	2	6440	6440	2
3472	3520	3	4726	4726	1	6441	6444	3
3521	3522	4	4727	4731	2	6445	6452	4
3523	3649	3	4732	4733	1	6460	6640	3
3658	3658	4	4735	4736	2	6642	6725	2
3659	3660	3	4737	4824	1	6726	6743	1
3661	3661	4	4825	4829	2	6751	6799	2
3662	3709	3	4830	4895	1	6800	6997	3
3711	3724	4	5000	5214	3	7000	8873	4
3725	3749	3	5220	5223	4	9000	9729	3

Source: Office of the Renewable Energy Regulator (www.orer.gov.au/publications/pubs/register-postcode-zones-v1-1107.pdf).

The example in Table 3.2 shows the RECs produced by an SWH and heat pump system in the different zones.

Table 3.2 Example of REC allocations in different zones

System	Model	Eligible from:	Eligible to:	Zone 1 RECs	Zone 2 RECs	Zone 3 RECs	Zone 4 RECs
A: SWH, one collector, 180L tank, electric boost	ABC00001	6 Sept 2007	31 Dec 2020	30	26	30	30
B: heat pump, 250L capacity	ABC00002	15 July 2008	31 Dec 2020	21	21	21	17

Householders have two options for gaining financial benefit from their RECs:

- Agent assisted. Householders can find an agent and assign their RECs to the agent in exchange for a financial benefit. The financial benefit can be either a delayed cash payment or an up-front discount on the system. A majority of owners take this option.
- Individual trading. Householders can create the RECs themselves in an internet-based registry system called the REC Registry. It is up to the householder to find a buyer, and sell and transfer the RECs in the REC Registry.

The Office of the Renewable Energy Regulator has a register available on their website of approved SWHs and heat pumps, and a list of the RECs they generate in different climate zones.

More information is available from the Office of the Renewable Energy Regulator on, phone (02) 6159 7700, or at **www.orer.gov.au**

3.2 Rebates

Rebates are an economic incentive to reduce the up-front cost of an SWH or heat pump water heater system. The Australian Government and state and territory governments provide rebates to encourage the installation of these types of hot water system. This section indicates where to find information on current state and federal rebates.

Information provided is accurate at the time of writing but may be subject to change at short notice. Installers should check appropriate state and federal programs regularly for details.

3.2.1 Australian Government rebate

The Australian Government offers rebates for both SWH and heat pump systems. Full guidelines and eligibility criteria are available at **www.climatechange.gov.au**

3.2.2 State and territory government rebates

Table 3.3 State and Territory government rebate information availability.
(Details correct at time of printing.)

State or territory	Website
ACT	www.thinkwater.act.gov.au/tuneup_rebates.shtml
NSW	www.environment.nsw.gov.au/rebates/ccfhws.htm
NT	www.powerwater.com.au
QLD	www.cleanenergy.qld.gov.au/queensland_solar_hot_water_program.cfm
SA	www.dtei.sa.gov.au/energy/rebates_and_grants/solar_hot_water
VIC	www.resourcesmart.vic.gov.au/for_households/rebates.html
WA	www1.home.energy.wa.gov.au/pages/subsidy.asp

3.3 Tariffs

SWHs and heat pump devices can be connected to different electricity tariffs, and the connection chosen can affect the efficiency and operating costs of the system installed. The type of tariff used should therefore be carefully considered and discussed with the property owner before installation begins.

Features of the various tariffs are listed below.

3.3.1 Continuous supply

- Charged at a single price all day.
- Higher price per kWh than other options.
- Important for pump-controlled SWHs, to ensure that the pump can operate when needed (e.g. for frost protection).
- Important for heat pump systems because they are most efficient when they can access hot daytime air.
- For electric boosters, can allow the booster to come on at any time of the day, increasing reliability but possibly resulting in higher electricity bills.
- Essential for gas boosters because of their electronic ignition systems.

3.3.2 Off-peak supply

- Available for hard-wired dedicated heating circuit.
- Significantly lower cost per kWh than continuous supply.
- Provides safety for maintenance, and hard for system owner to disconnect.
- During high periods of hot water use and/or low solar heat, hot water supply may be insufficient.
- Not suitable for any system using gas boosting or a pump controller. The limited availability of off-peak supply means that the SWH system may not operate as required.
- Off-peak times are 6–12 hours per night (details available from electricity retailers).

3.3.3 Mixed mode

- Combine continuous supply and off-peak supply.
- System can be customised to suit customer but may not be appropriate for all customers as it requires input.

Table 3.4 summarises the features of these three types of tariff.

Table 3.4 Features of electricity supply tariffs for use with SWH and heat pump systems

Feature	Continuous supply	Off-peak supply	Mixed-mode supply
Price	High	Low	Variable
Dedicated circuit required?	No	Yes	Yes
Availability	24 hours/day	>6 hours/day (see supplier)	Variable
Solar system pumps	Required	No	No
Electric boost	Yes	Yes	Yes
Gas boost	Required	No	No
Heat pumps	Recommended	Yes	Yes
Natural gas systems	Yes*	No	No
LPG bottled systems	Yes*	No	No

*Gas water heaters need electricity supply to provide the ignition for the gas flame. This means that 'off-peak' is not suitable for continuous gas water heaters because it is not available 'on demand'.



Chapter 4

Solar Science & Technology

Solar Science & Technology

4.1 Solar radiation

4.1.1 Solar collectors

'Collectors' are the part of the solar water heater (SWH) system on the roof. The sunlight that falls on the collectors during the day heats the water that cycles through the collector. This water is then stored in the tank ready to be used.

SWH systems only work effectively if they have good access to solar radiation (sunlight) throughout the day to maximise the amount of energy collected. In most SWH systems, any additional energy (known as boost energy) required to keep the water temperature sufficiently high is provided by either gas or electricity.

4.1.2 Tracking the sun

The efficiency of an SWH system is affected by the positioning of the solar collectors. Careful attention needs to be paid to the location of collectors to ensure that they receive sufficient solar radiation to heat the water effectively.

Two important considerations in the correct positioning of collectors are **altitude** and **azimuth**. Azimuth and altitude are important for describing the position of the sun in the sky, and to ensure that the SWH collector is installed so that it can produce as much hot water as possible.

Altitude

Altitude is the angle between the sun and the horizon or ground (expressed in degrees).

The sun is always in the northern part of the sky in Australia, except in the tropics where the sun can be in the southern part of the sky during summer. This happens because of the natural tilt of the Earth.

The sun is higher in the sky in summer and lower in the sky in winter because the natural tilt of the Earth changes throughout the year.

Azimuth

For the installation of SWH collectors, the term 'azimuth' has two possible meanings:

1. How far away the sun is from north (like a compass direction);
2. How far from an optimal north facing direction are the SWH collectors installed.

The azimuth of the sun changes continually as the sun moves from east to west during the day.

Figure 4.1 shows altitude and azimuth, together with the points of the compass.

Figure 4.1 Azimuth and altitude angles

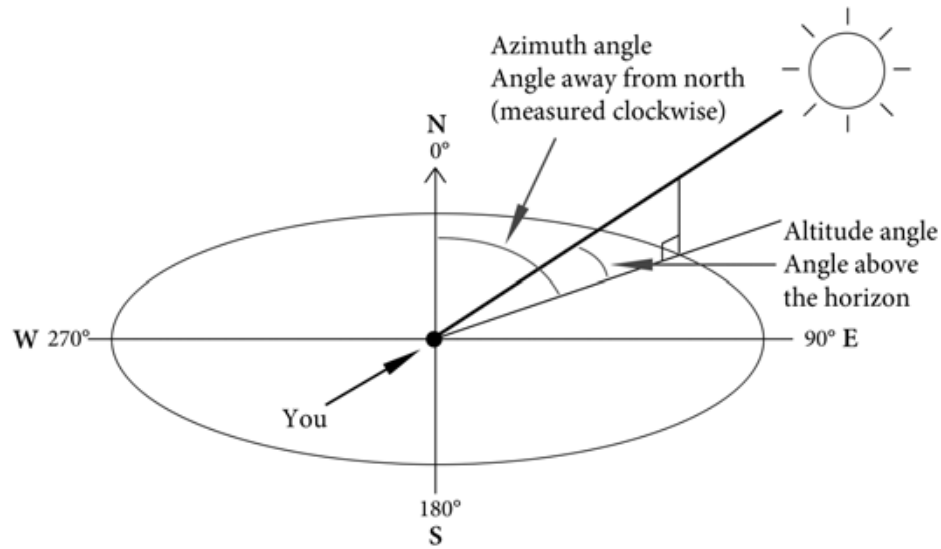
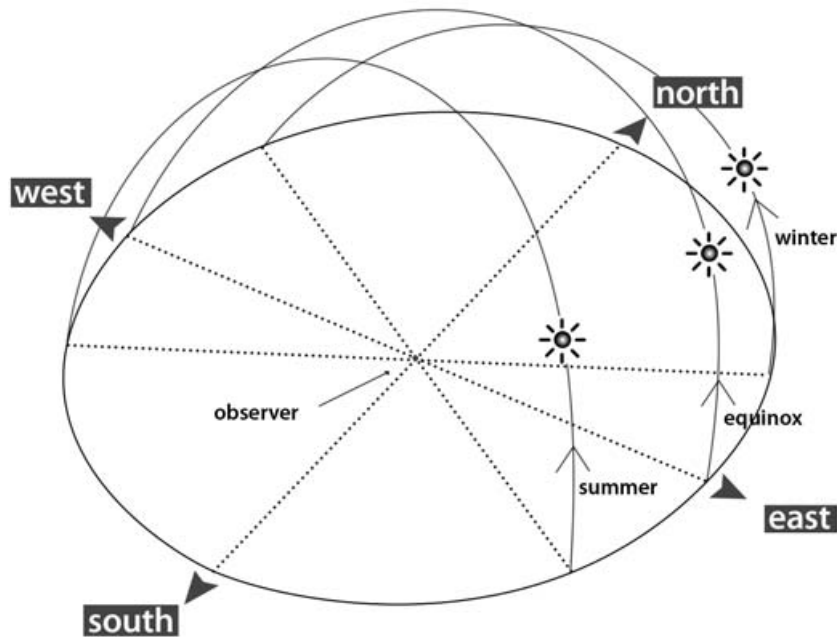


Figure 4.2 shows the variation in the sun's path through the year; the sun's path in summer, winter and at the equinoxes (middle of spring and autumn) is shown. The sun is much higher in the sky during summer, when it passes over the observer, whereas in winter the sun remains low in the northern part of the sky.

Figure 4.2 Variation in the sun's path during the year



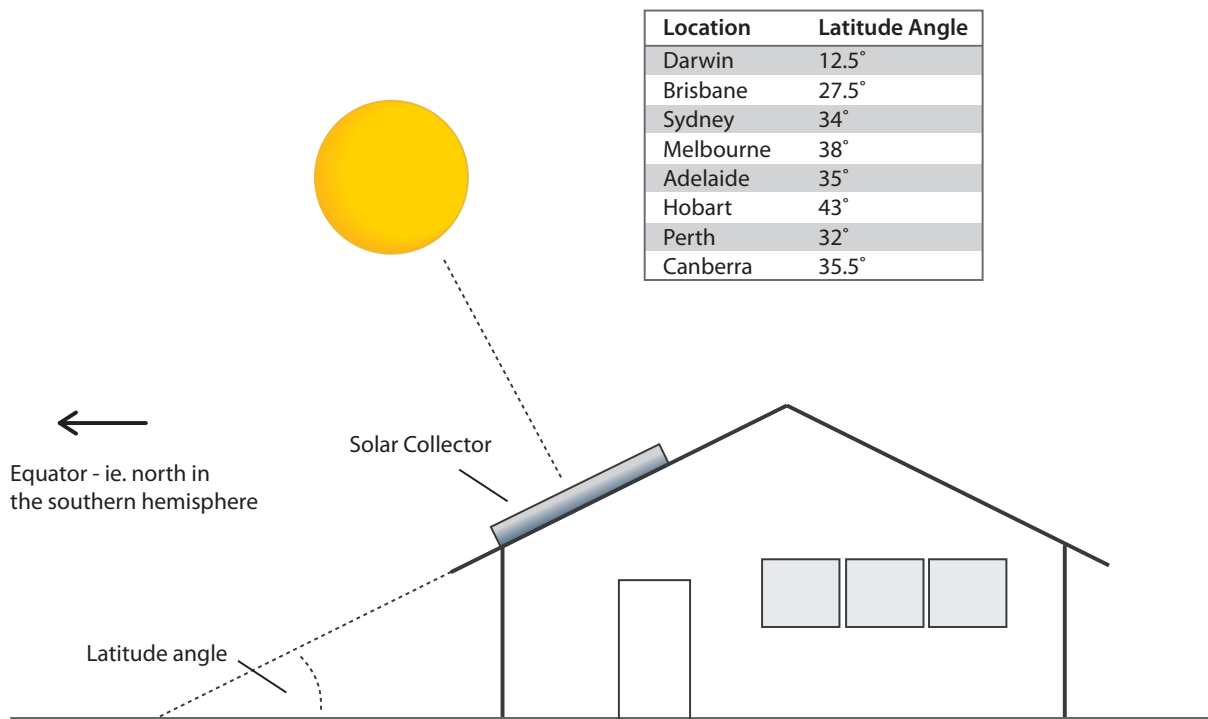
By understanding altitude (elevation) and azimuth (direction from north) of the sun, it is possible to predict the location of the sun at any time of year. Using this information, the shading on the collectors and the overall performance of the system can be calculated.

4.2 How to position solar collectors

4.2.1 Ideal location

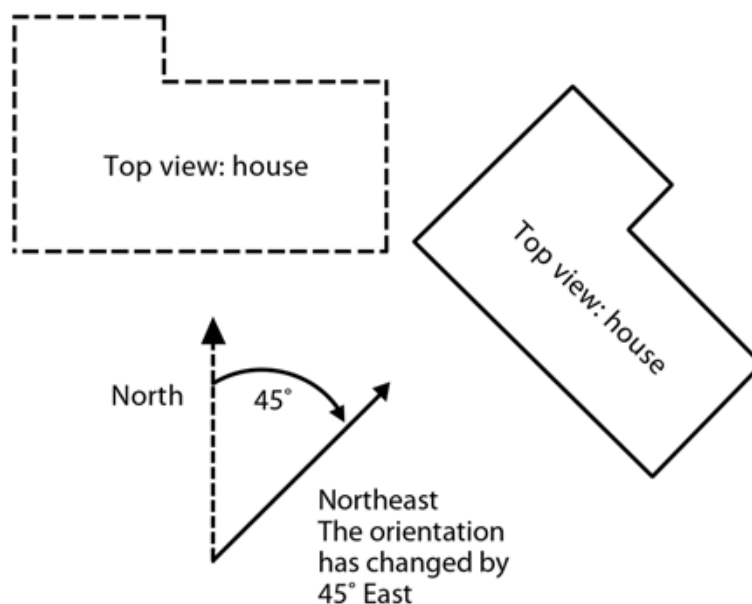
Ideally, the SWH collectors should directly face the sun at all times. A north-facing roof is ideal for Australian locations. The best tilt angle of the collectors for all-round performance depends on the latitude at the site of installation of the system (Figure 4.3). For non capital cities use a GPS to find the actual latitude, this is the angle the panel should be installed, or go to the following www.mapsofworld.com/lat_long/australia/australia-lat-long-b.html

Figure 4.3 Ideal location for solar collectors



In Figure 4.4, the azimuth of the house roof has changed from 0 degrees (facing due north) by 45 degrees (now facing northeast).

Figure 4.4 Showing house roof at 45° azimuth from north



For SWH collectors, the Australian/New Zealand Standard AS/NZS 3500.4:2003 (Plumbing and drainage) recommends that the azimuth of the collectors be:

- between 50° east and 70° west for Victoria (Figure 4.5)
- between northeast (45°) and northwest (315° , or 45° west) for all other states (Figure 4.6).

Figure 4.5 Recommended maximum azimuth variation for solar collectors in Victoria

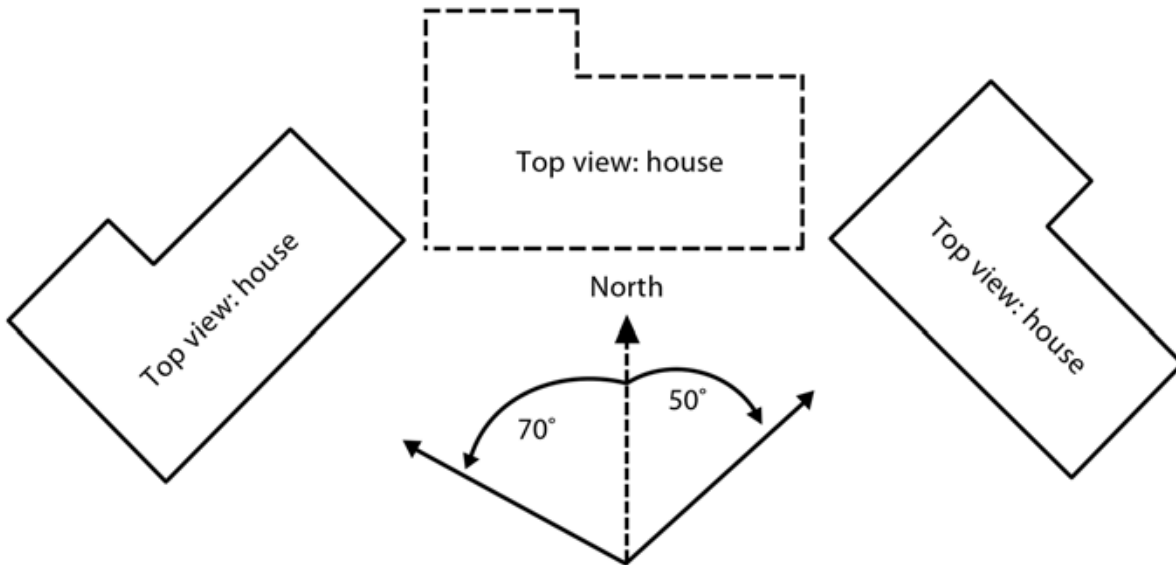
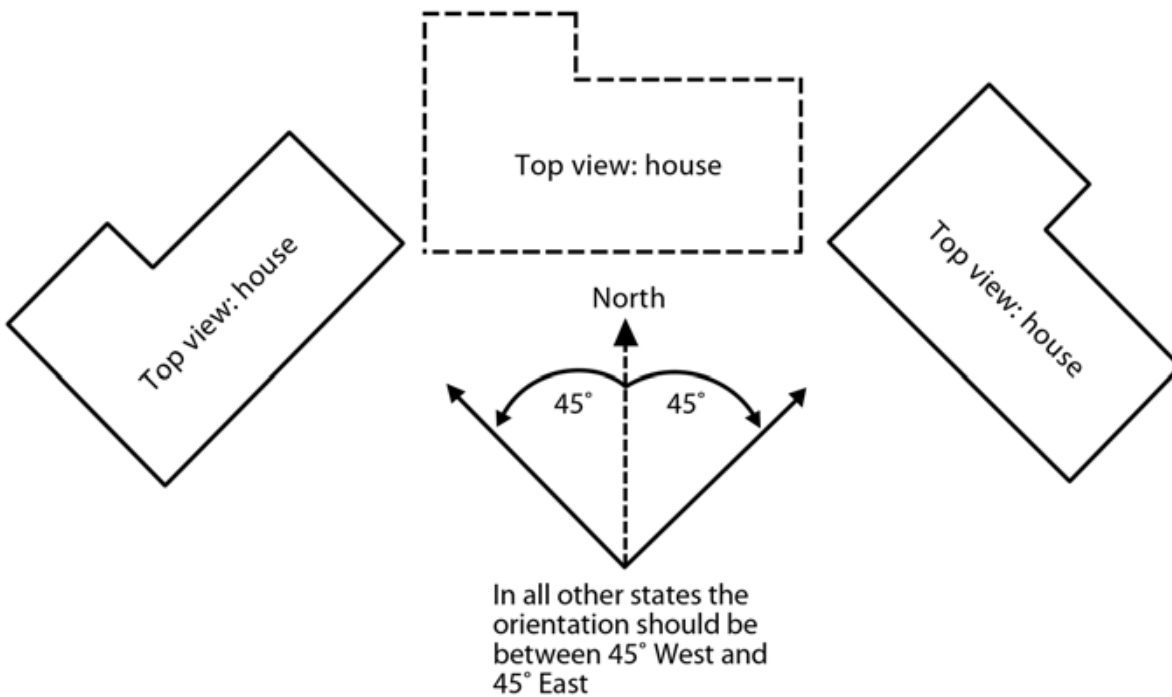
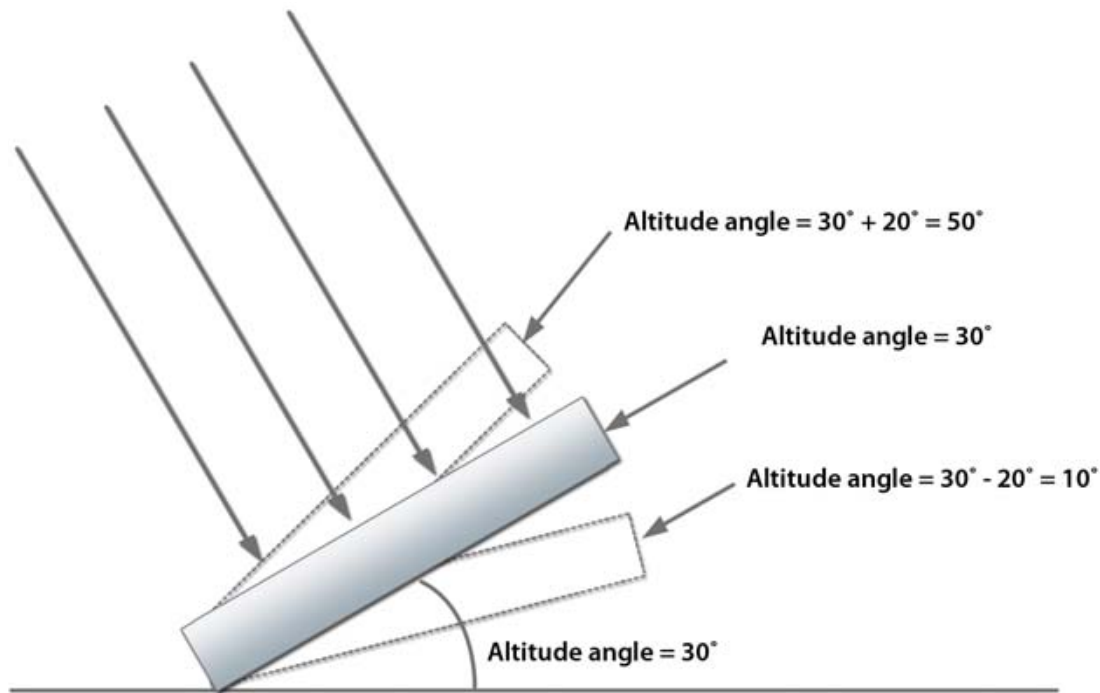


Figure 4.6 Recommended maximum azimuth variation for solar collectors in states other than Victoria



According to AS/NZS 3500:2005, the altitude angle of the collectors should be $30^\circ \pm 20^\circ$ to the horizontal, as shown in Figure 4.7.

Figure 4.7 Variation in altitude angle



4.2.2 Variations from ideal

Due to the practicalities of fixed mounting systems and the slope and orientation of typical roofs, it is not always possible to mount collectors facing directly north. Collectors can be installed on roofs that do not face north, but the system will have reduced performance.

The altitude angle of an SWH collector will affect the seasonal performance of the system. The system's annual performance will be optimised if the system is installed with altitude angle equal to the location's latitude (e.g. 34° for Sydney, which is 34° south). In most cases, the difference in output between a standard pitched roof of 20° and the latitude is not significant.

When there is a seasonal variation in the amount of hot water required—for instance, a swimming pool that only needs additional heating over cooler months—raising the altitude angle of the collector will allow additional water heating in winter, when the sun's arc is lower in the sky.

Any expectation that the output performance will be decreased for some reason (e.g. by non-optimal orientation or shading) should be included in the system performance estimate for that system. If necessary, extra collectors can be installed.

Even when mounted at the ideal orientation and slope, SWH and heat pump systems will experience variations in efficiency and delivery throughout the year. This is inevitable as the solar contribution and ambient temperatures rise and fall with the seasons.

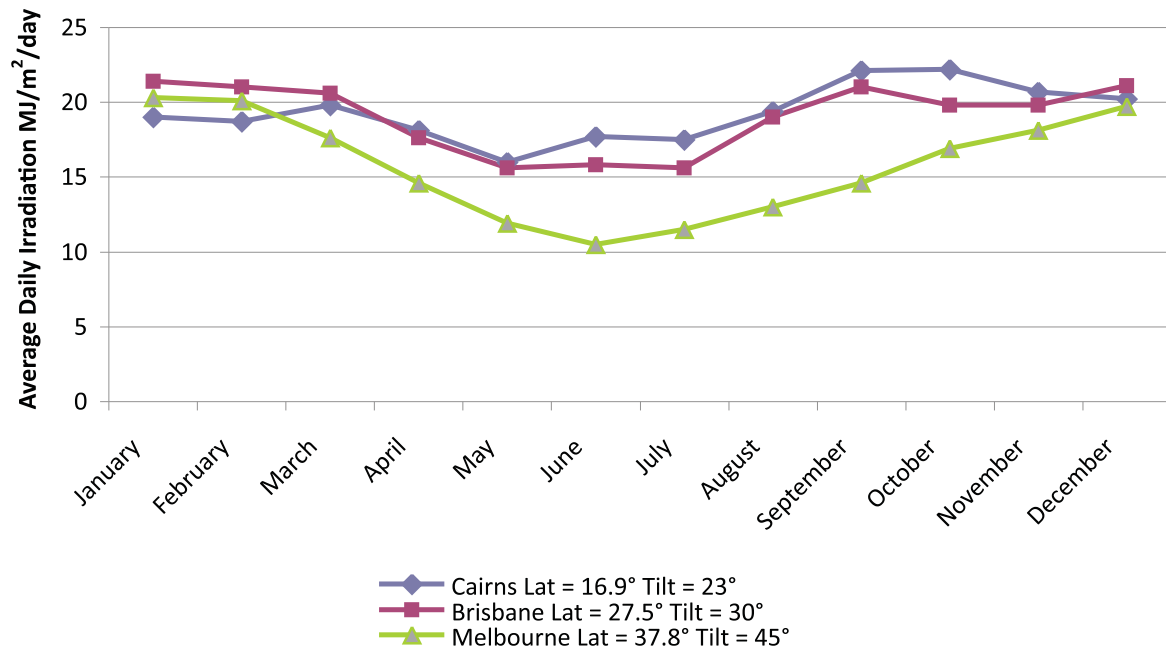
Table 4.1 shows the average daily irradiation for three Australian east-coast cities. The table also supplies irradiation figures for two different angles of elevation (tilt) for each city. This is a perfect example of the seasonal variations in solar access, as well as the difference that sun access provides for potential heating or power output.

Table 4.1 Average daily irradiation during the year for Cairns, Brisbane and Melbourne

Average daily irradiation (MJ/m ²)						
Month	Cairns (Lat = 16.9°)		Brisbane (Lat = 27.5°)		Melbourne (Lat = 37.8°)	
	Tilt = 10°	Tilt = 23°	Tilt = 23°	Tilt = 30°	Tilt = 30°	Tilt = 45°
January	20.4	19.0	22.4	21.4	22.5	20.3
February	19.4	18.7	21.7	21.0	21.6	20.1
March	19.7	19.8	20.8	20.6	17.8	17.6
April	17.2	18.1	17.3	17.6	14.1	14.6
May	14.7	16.0	15.0	15.6	10.9	11.9
June	15.8	17.7	15.0	15.8	9.5	10.5
July	15.8	17.5	14.9	15.6	10.4	11.5
August	18.1	19.4	18.4	19.0	12.3	13.0
September	21.5	22.1	20.9	21.0	14.6	14.6
October	22.4	22.2	20.3	19.8	17.9	16.9
November	22.0	20.7	20.6	19.8	19.9	18.1
December	22.1	20.2	22.1	21.1	21.9	19.7
Average	19.1	19.3	19.1	19.0	16.1	15.7

Figure 4.8 shows the variations in average daily irradiation throughout the year for Cairns (for a surface with a tilt angle of 23°), Brisbane (with a tilt angle of 30°) and Melbourne (with a tilt angle of 45°).

Figure 4.8 Irradiation for north-facing roofs in Cairns, Brisbane and Melbourne throughout the year

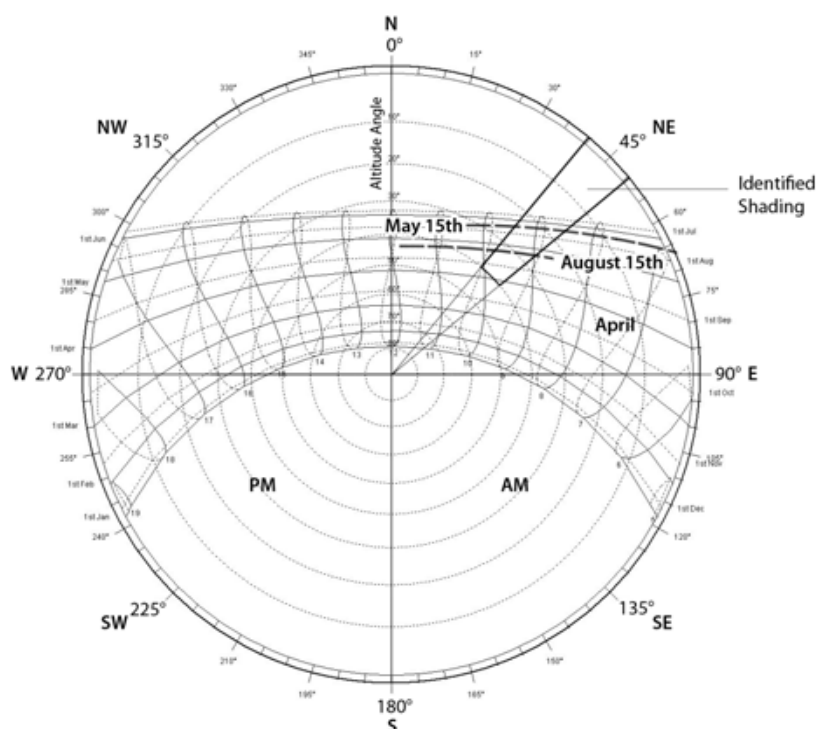


4.2.3 Shading

It is important to prevent shading of the collectors at all times, as this will decrease their performance. Since the sun changes position throughout the year, shading from all possible positions must be considered, taking into account that trees may grow up to shade the collectors in the future. Several technologies can be used to estimate shading effects throughout the year, including Solar Pathfinder (www.solarpathfinder.com) and SunEye (www.solmetric.com).

Figure 4.9 shows a sunpath diagram that has been used in conjunction with a Solar Pathfinder to determine when shading from a tree will occur.

Figure 4.9 Example of a sunpath diagram



4.2.4 Collector placement for thermosiphon effect

For thermosiphon SWH systems (see Section 4.4.1) to work effectively, the collectors must be tilted at a minimum of 10° above the horizontal, and the tank must be situated above the collectors. A maximum tilt angle of 'latitude + 10° ' is also recommended due to support requirements of the collectors and possible shading of the collector by the tank.

4.3 Heat

4.3.1 Heat transfer

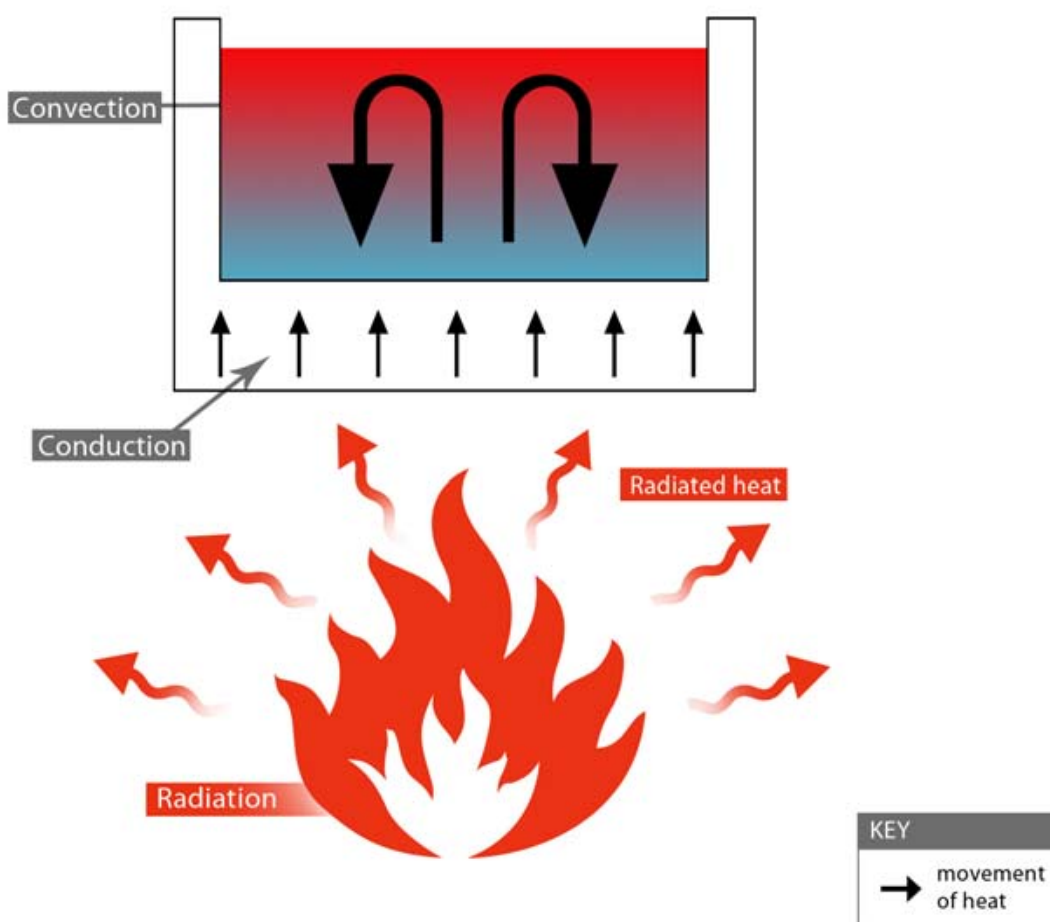
Heat can be transferred from one material to another by conduction, convection or radiation (Figure 4.10).

Conduction is the transfer of heat through a conducting material, such as copper. An example is heat moving from a warmer substance to a colder substance on contact.

Convection is the transmission of heat within a liquid or gas (air) by movement of particles. An example is rising of air when it is heated, resulting in a decrease in its density ('hot air rises'). The same effect occurs with water stratification in a tank. Alternatively, the heated liquid or gas can be forced to move—for example, air is moved using a fan (as in a convection oven).

Radiation is the transfer of heat via direct rays of energy. An example is an object giving off electromagnetic radiation because of its heat (e.g. an electric heater or a fire).

Figure 4.10 Examples of convection, conduction and radiation



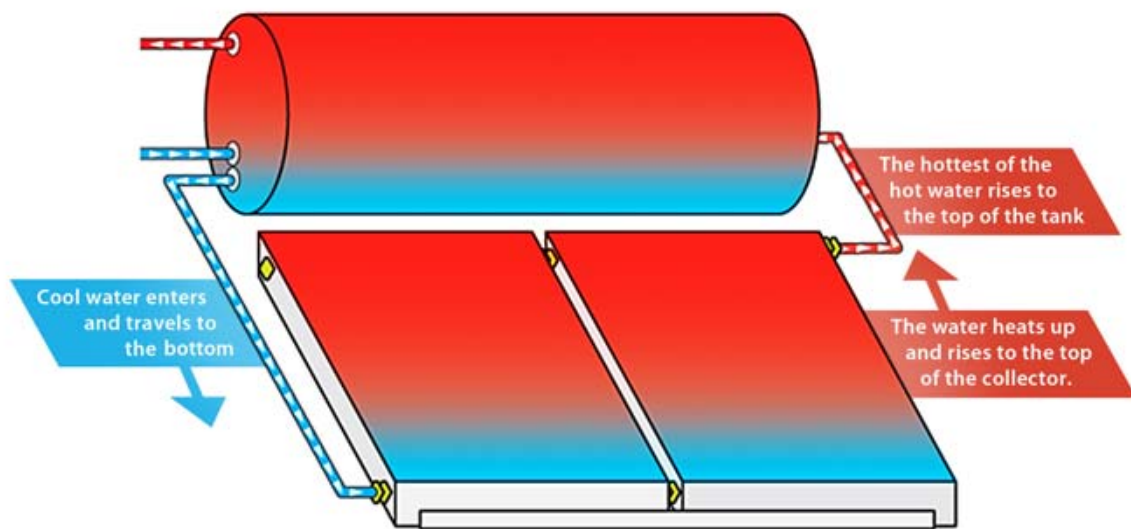
4.3.2 Thermosiphon effect

The thermosiphon effect occurs when water naturally circulates through a system as convection induces a flow of warm water around the system. A thermosiphon SWH consists of two major components—the solar collectors and the hot water tank.

In a hot water tank, hot and cold water are both present. The hot water moves to the top of the tank by the thermosiphon effect. The cold water sinks to the bottom of the tank and is sent from there to the collector, either by convective force if the tank is above the collectors (cold water sinks) or by a pump (if the tank is below the collectors).

Cold water flows into the bottom of the collectors. As the water heats up due to the sun's radiation, it becomes less dense and rises up through the collectors (due to convection). If the hot water tank is directly above the collectors, the hot water will flow straight into the storage tank (Figure 4.11). Facilitating this flow of hot water is the reason for the minimum recommended tilt angle for a thermosiphon SWH.

Figure 4.11 Close-coupled thermosiphon system, showing stratification: temperature-induced water circulation.



4.3.3 Stratification

Stratification is the layering of water of different temperatures within the water tank, with hot water at the top and cold water at the bottom. Stratification occurs when hot water (which is less dense) rises to the top of the tank.

Storage tanks are designed to minimise the mixing of hot and cold water. Excessive mixing can reduce the efficiency of the solar system because the collectors are more efficient when heating cold water.

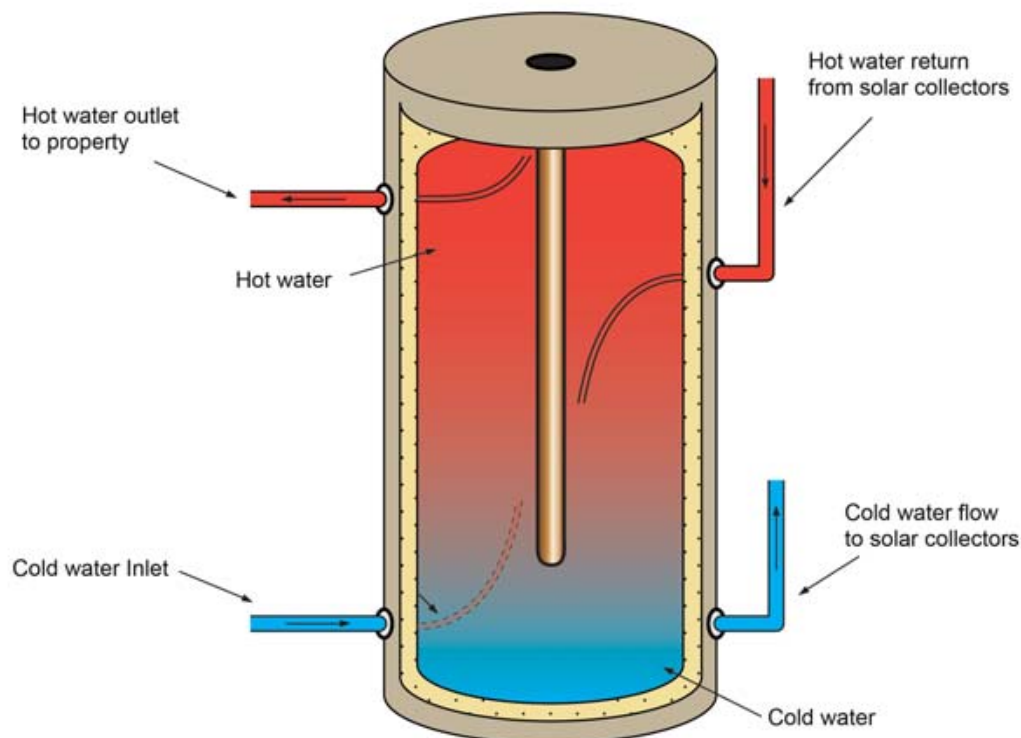
Hot water from the solar collector should be fed back into the tank at a higher position than the cold-water outlet.

The hot-water outlet is located at the top of the tank to ensure that:

- the water at the highest temperature is drawn
- the likelihood of mixing water is reduced.

Figure 4.12 shows the location of water inlets and outlets in a vertical storage tank.

Figure 4.12 Vertical hot water storage tank, showing temperature stratification



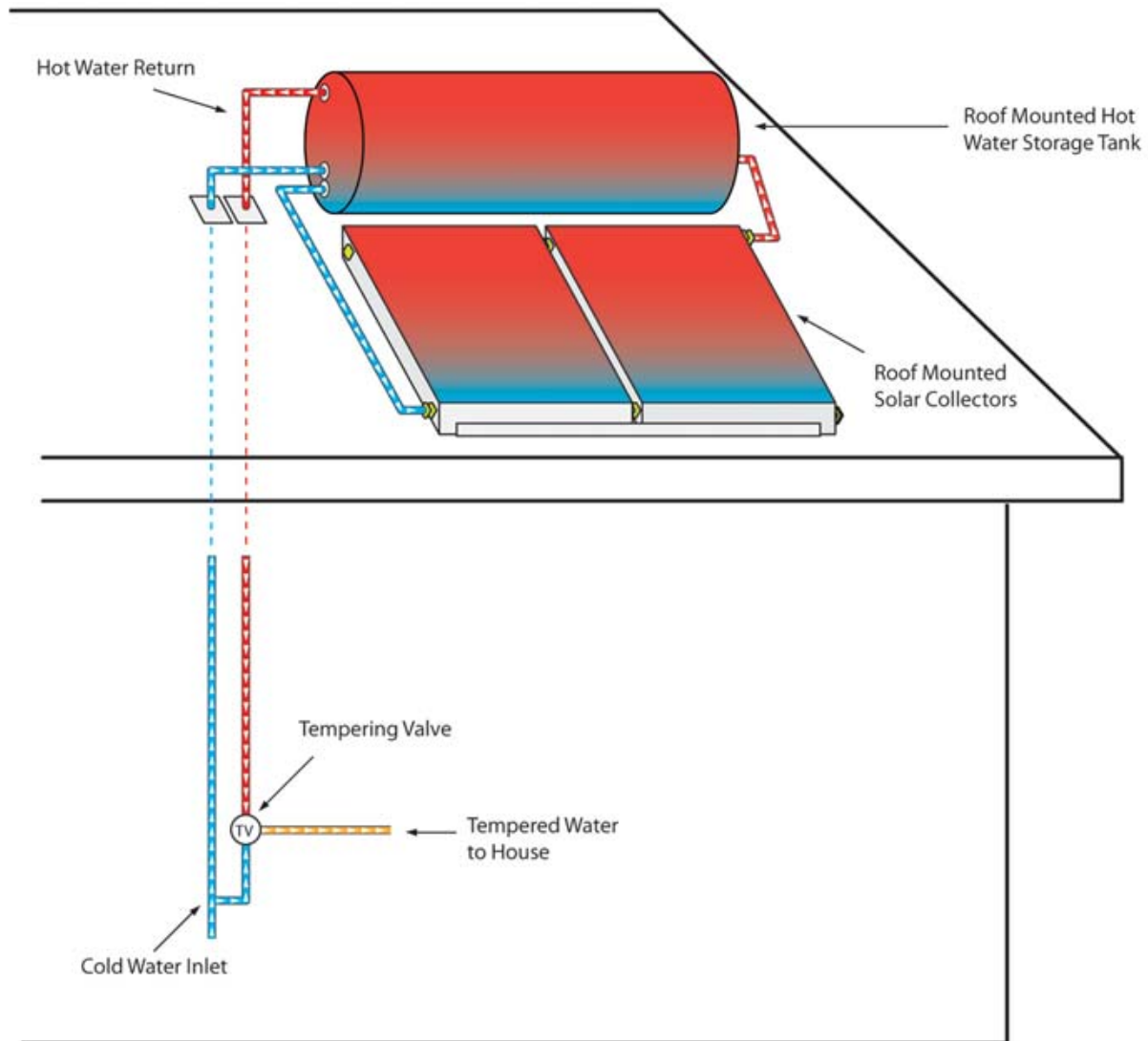
4.4 Types of solar water heaters

4.4.1 Thermosiphon-based technologies

Close-coupled thermosiphon

Close-coupled thermosiphon systems have the collectors and tank close together. Both are located on the roof, with the tank above the collectors to facilitate the thermosiphon effect (Figure 4.13).

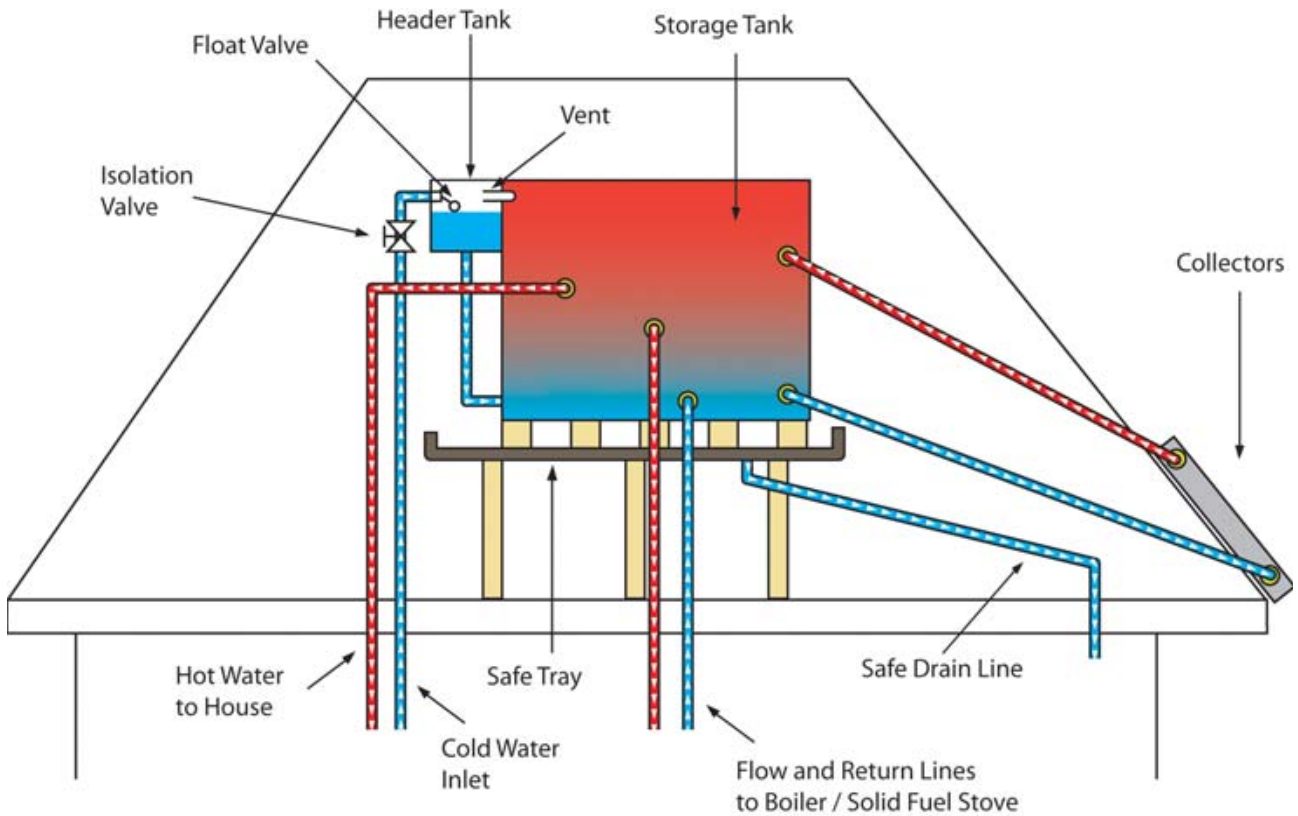
Figure 4.13 Close-coupled thermosiphon SWH system



Remote thermosiphon

A remote thermosiphon system shares many features with a close-coupled thermosiphon system, except that the tank is located in the roof space (Figure 4.14). The tank may be placed here for aesthetic reasons, or if the weight on the roof is a problem, or if mains pressure is not available. The tank still needs to be located above the collectors in order to facilitate the thermosiphon effect.

Figure 4.14 Thermosiphon remote storage SWH system

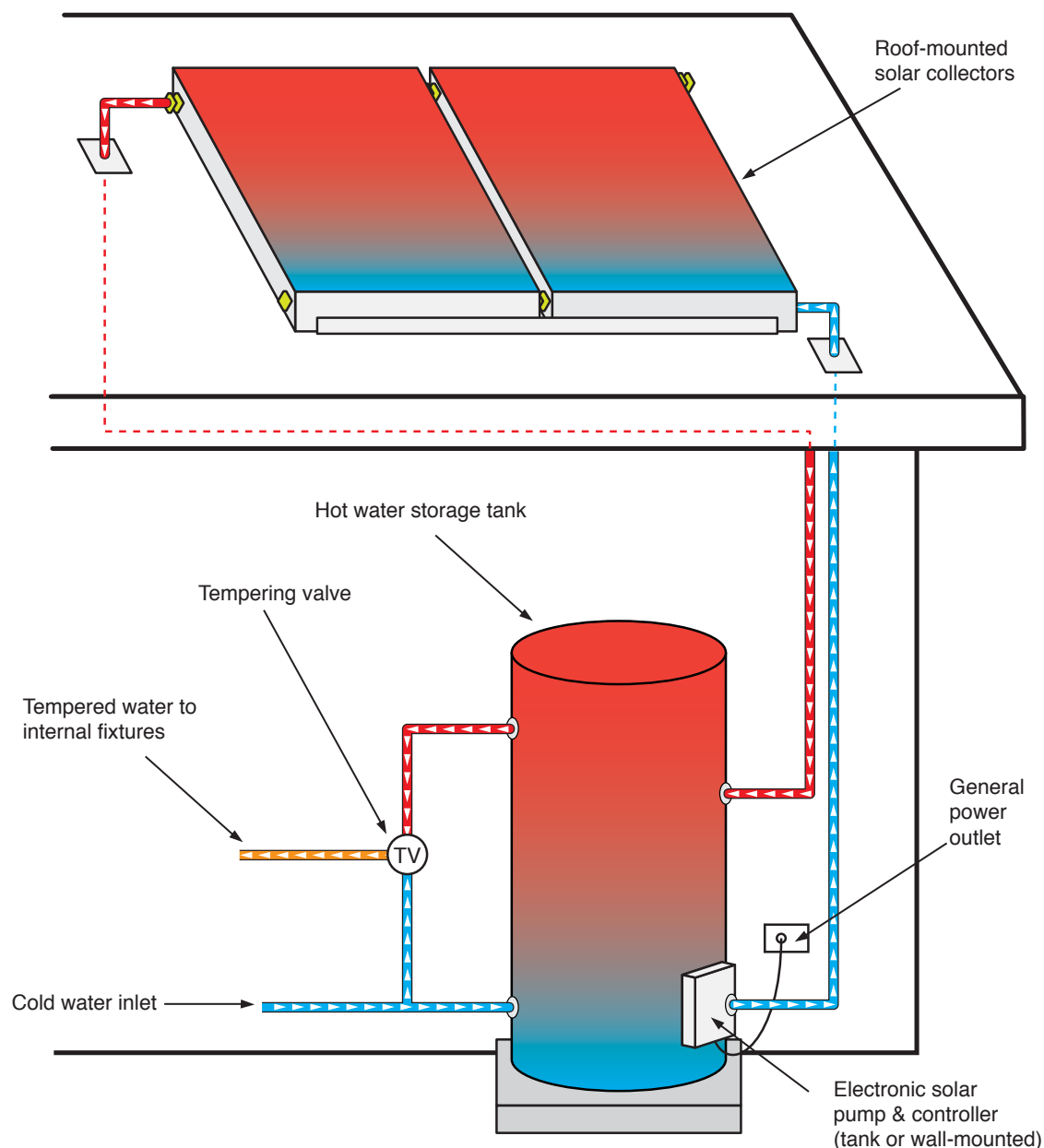


4.4.2 Split Systems: non-Thermosiphon-based technologies

Split system (forced circulation)

In a split system, the water tank is installed on the ground. A pump is required to circulate the water around the system (Figure 4.15).

Figure 4.15 Example of an SWH split system

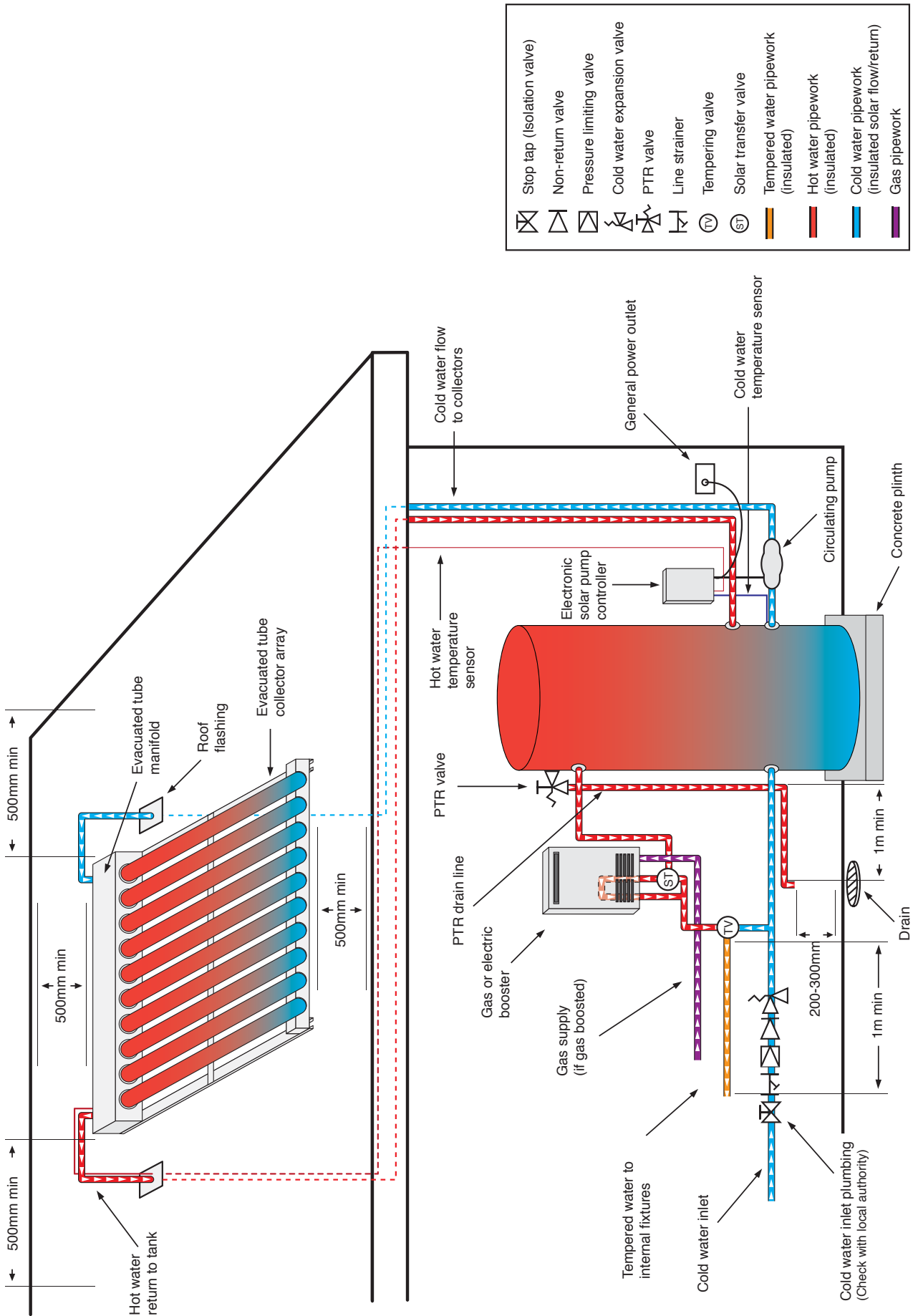


Evacuated tube

The evacuated tube system consists of a series of tubes. Each tube has an outer glass tube and an inner glass tube. The outer tube allows light to pass through it, while the inner tube is coated with a special coating to maximise heat gain within the collector. The space between the two tubes is 'evacuated' to form a vacuum. A vacuum is an extremely good insulator (since there is no air in the gap for convection to occur, and two layers of glass stop conduction), resulting in less heat loss.

Inside the inner glass tube is a copper tube filled with a liquid (water or glycol). As the fluid heats up, it moves to the top of the tube. A heat exchanger at the top within the manifold enables the heat to pass through to the water. Figure 4.16 shows the design of an evacuated tube split system.

Figure 4.16 Example of an evacuated tube split system

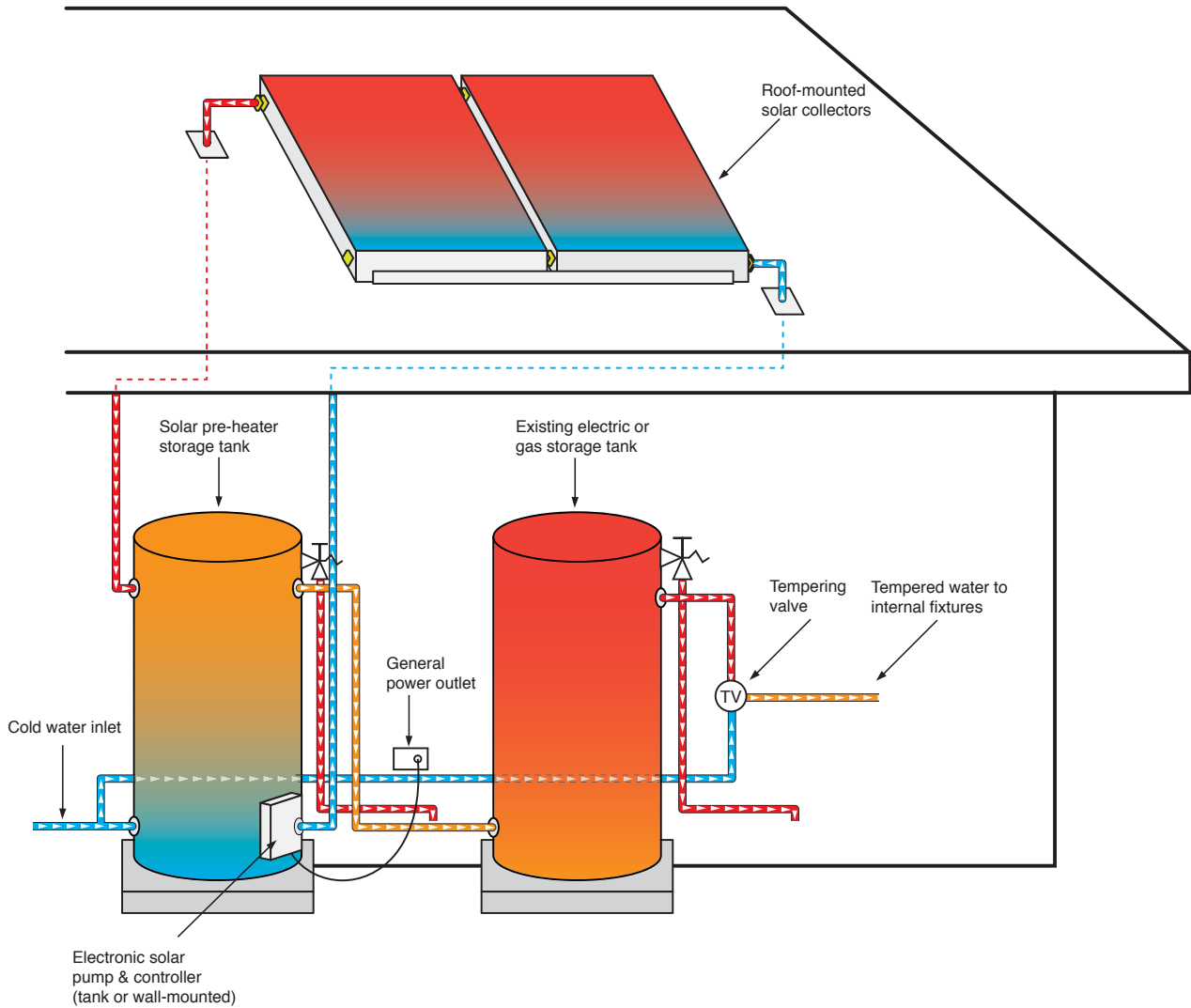


Pre-heater

A pre-heater acts as a preliminary heating source for the water in an existing hot water system. A separate SWH and tank (with no booster) is installed ahead of a conventional water heater.

These systems result in a reduced need for heating in the main tank, and are useful when large amounts of hot water are required. They are typically not covered by rebates or renewable energy certificates.

Figure 4.17 Example of an SWH pre-heater system



4.4.3 Heat pump/refrigeration cycle

A heat pump water heater consists of:

- (a) an evaporator—in the evaporator, the liquid refrigerant absorbs heat from the outside environment, which changes the refrigerant liquid into a gas
- (b) a compressor—compresses the refrigerant gas, which increases its temperature further
- (c) a condenser—transfers heat from the refrigerant gas to the water in the tank, resulting in the gas cooling down and turning back into a liquid
- (d) a storage tank.

This process, shown in Figures 4.18 and 4.19, is the same as that used by refrigerators and air conditioners, except in reverse: refrigerators and air conditioners are seeking to remove heat, whereas heat pumps harness the heat. Figure 4.20 shows an installed integrated heat pump.

Figure 4.18 Heat pump cycle

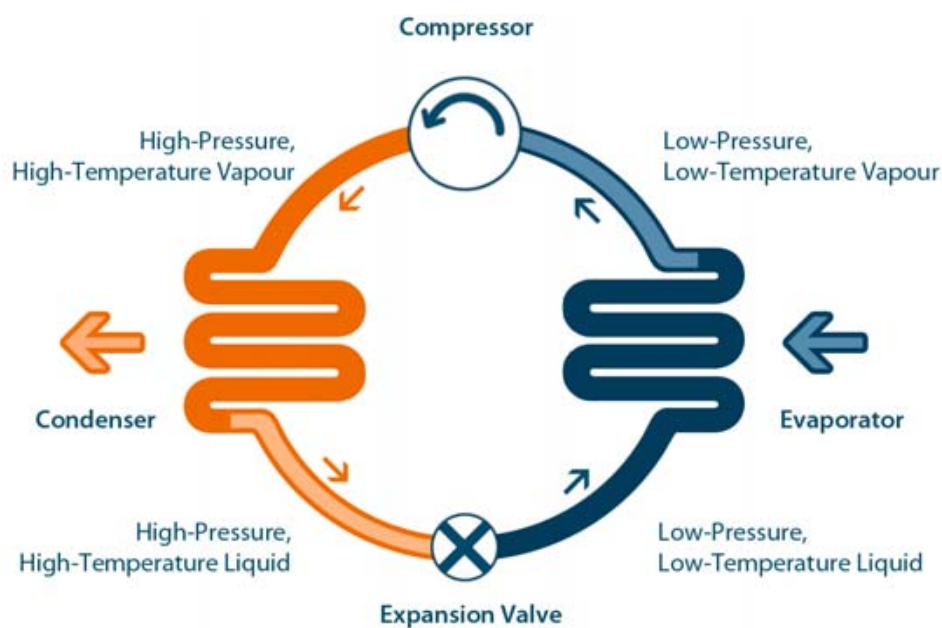


Table 4.2 summarises the suitability of different types of SWH and heat pump systems for different conditions.

Figure 4.19 Example of a heat pump compressor/condensing system

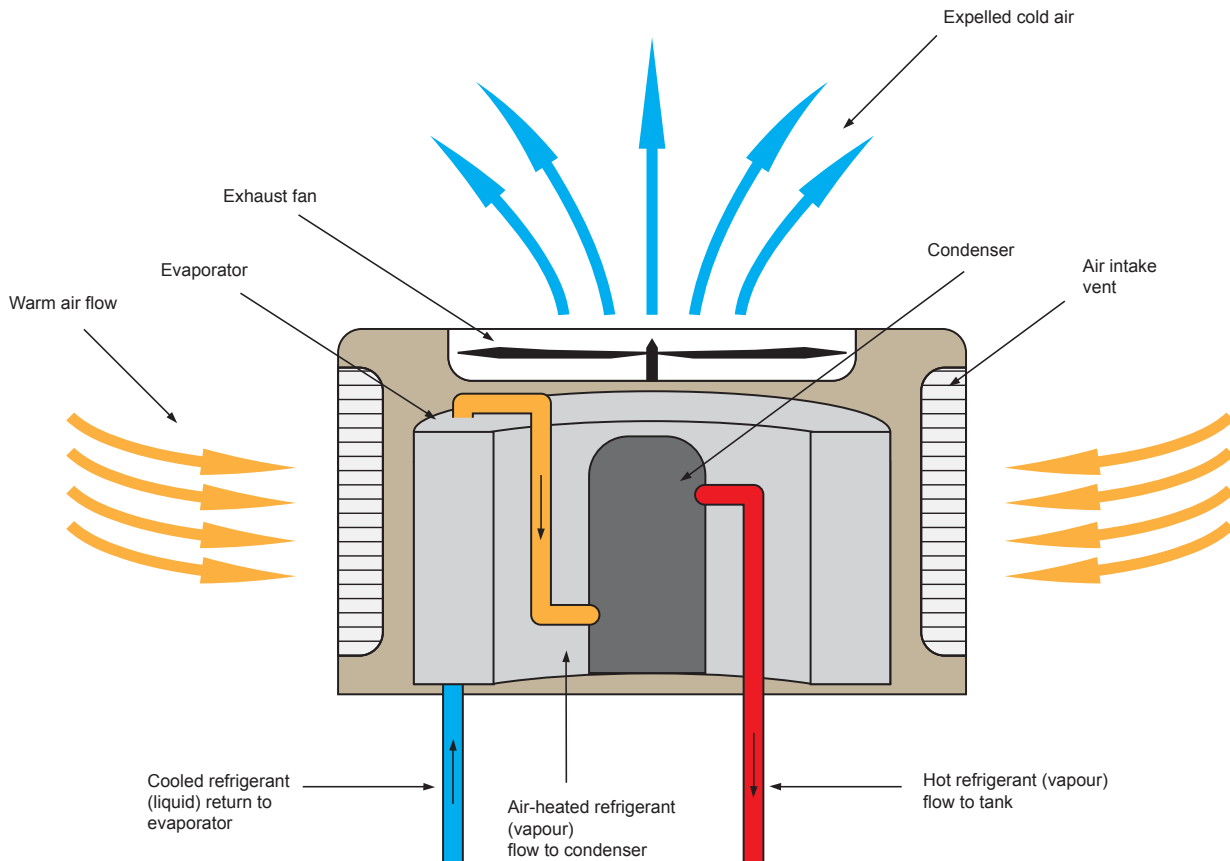


Figure 4.20 Integrated heat pump installation

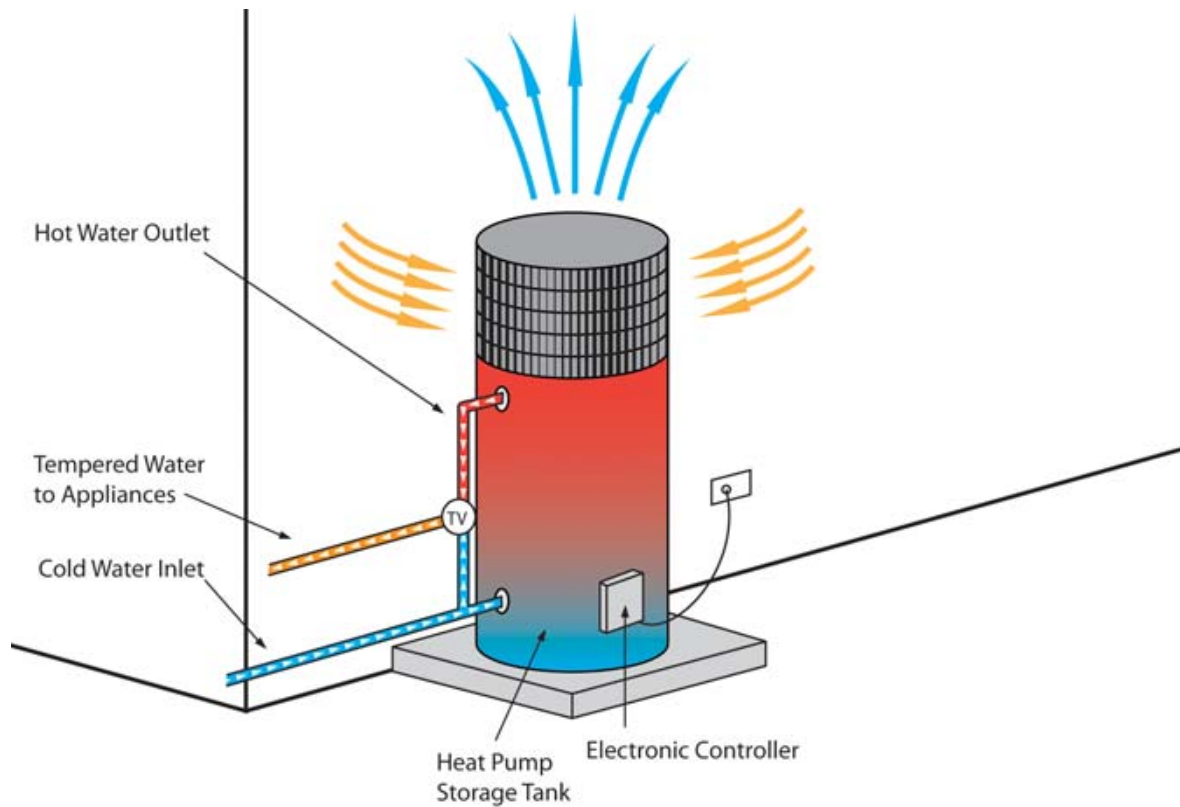


Table 4.2 Suitability of different types of SWH and heat pump systems for different conditions

Conditions or Technology	Close coupled thermosiphon	Remote thermosiphon	Flat panel split system/ forced circulation	Evacuated tube	Heat pump	Natural Gas & LPG Systems
Hot and/or humid climate	Not recommended Collectors are not designed for high temperatures	Not recommended Collectors are not designed for high temperatures	Yes	Yes	Yes	Yes
Temperate climate	Yes	Yes	Yes	Yes	Yes	Yes
Cold climate (e.g. susceptible to frost)	Yes—if glycol or high efficiency collectors used	Yes—if glycol or high efficiency collectors used	Yes—if glycol or high efficiency collectors used	Yes—provide optimal performance in cold climates	Consider system specifically designed for colder climates	Yes
Non-ideal solar conditions (e.g. shading, bad orientation, not enough roof space)	No	No	No	No	Yes—depending on climate and situation of water heater	Yes
Issues with aesthetics or weight on roof	Yes*	Maybe†	No‡	No‡	No	No
Able to retrofit to existing roof	No	No	Yes	Yes	Not applicable	Not Applicable
Licensing	Plumbing/electrical	Plumbing/electrical	Plumbing/electrical	Plumbing/electrical	Plumbing/restricted split system air con	Plumbing/electrical/gas fitting

* There are issues with the weight and the aesthetics of this technology type for on-roof installations.

† There may be aesthetics issues and weight issues in the ceiling.

‡ There are no weight issues, but possible aesthetic issues.

In all cases, be sure to consult manufacturer's installation instructions to confirm the required minimum physical area for the model chosen.

4.5 General installation

Depending on the system the customer has chosen, installation can take up to two full days. Most installations, however, are completed within one working day. Installers may need access to the roof and ceiling space as well as inside and outside the property. They may remove tiles from a tiled roof and will need to turn off water and gas and/or electricity during the installation.

If any professional advice is to be sought regarding the installation work, more than two days may be required.

For all systems involving electrical supply (e.g. heat pumps) or any system with an electric or gas booster, the services of a fully licensed electrician will be required unless the installation is a 'like for like' replacement hot water system, in which case a restricted electrical licence (e.g. as held by a licensed plumber) could be used. Installations involving working with gas, including gas connection, may require a suitable qualification. For heat pump installations that do not use integrated systems, a Restricted Split System Air Conditioning Installation and Decommissioning Licence may be necessary. Licensing requirements must be identified so that suitably qualified tradespeople are available and the installation cost can be accurately determined.

The licensing requirements for installation of different types of SWH and heat pump systems could vary between Australian jurisdictions.

Some jurisdictions require that a compliance document is provided to the customer confirming that the installation meets the prevailing plumbing regulations. For example, in Western Australia, a certificate of compliance endorsed by the licensed plumbing contractor must be given to the customer (under Plumbers Licensing Board of Western Australia regulations).

A jurisdiction might also require training of installers before they can undertake this type of work—for example, training for working at heights or in existing roof spaces.

The customer will require the information and paperwork necessary to lodge for any applicable rebates, incentives and renewable energy certificates.



Chapter 5

Solar Water Heater Components

Solar Water Heater Components

This section provides details on the main components of a solar water heater (SWH) system that are common to most SWH systems and should be understood if designing a larger system. The components are:

- (a) collectors
- (b) tanks
- (c) boosters
- (d) frost protection.

The following sections describe the different types of each component that are available.

5.1 Collectors

A large number of different collectors are available on the market. It is recommended that collectors selected for installation meet the Australian standards for design and construction of solar and heat pump water heaters (AS/NZS 2712:2007, Solar and heat pump water heaters—design and construction). Collectors that meet these standards will bear a WaterMark. (See Section 8.2 for details of compliance with this standard.)

The type of glass used in a collector or set of evacuated tubes may or may not be rated for hail resistance. This is indicated by a WaterMark defining the level of compliance of the glass with AS 2712:2007. Collectors that do not comply will also carry a permanent WaterMark notation.

5.1.1 Flat plate collectors

Although different collectors may consist of different materials or technologies, the basic design is quite standard (Figure 5.1) and includes:

- (a) a **collector box**, usually made of steel or aluminium sheet
- (b) the **absorber plate**, with tubes attached for a heat transfer fluid to pass through, located in the middle of the box
- (c) **insulation** below the absorber plate to prevent loss of heat through the bottom of the box
- (d) a **transparent cover**, usually glass, above the absorber plate; this is designed to trap solar radiation and convert it to heat in the absorber plate, and to prevent cold air from blowing over the plate and taking heat away.

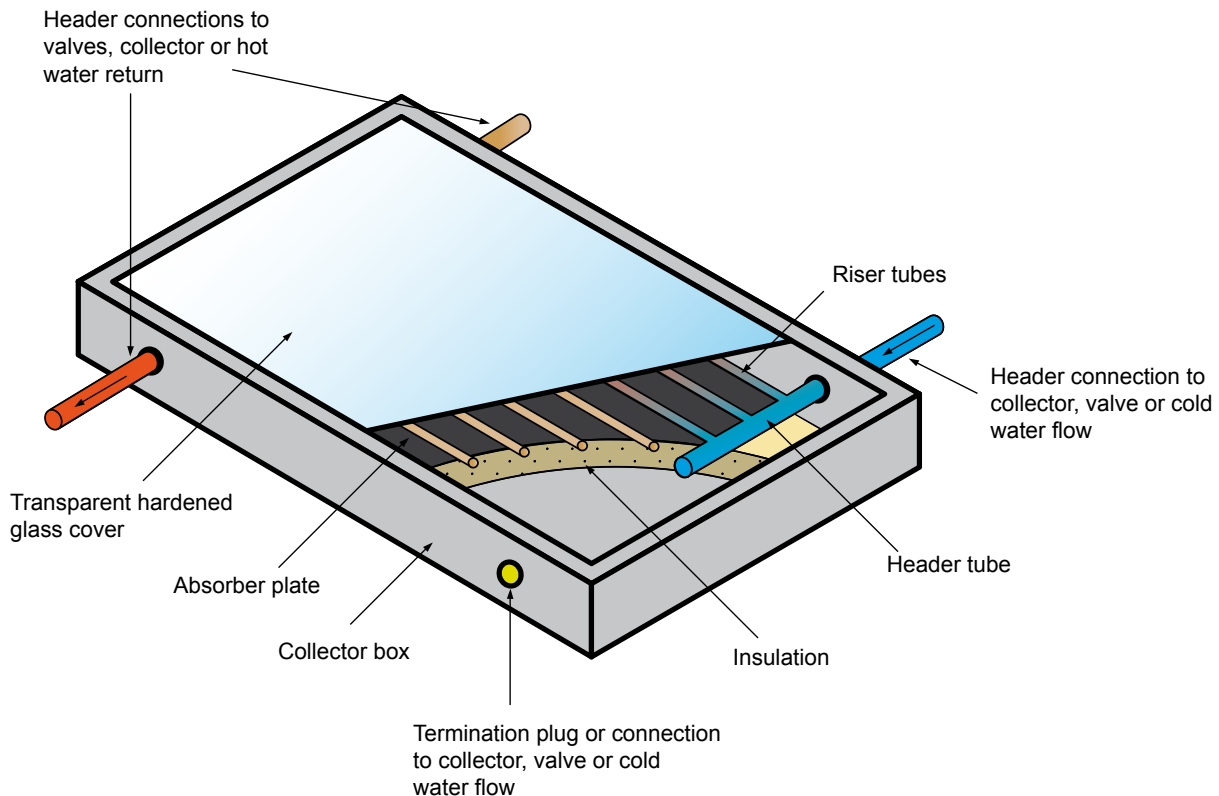
In a flat plate collector, heat is gained in the form of solar radiation, both direct and diffuse, which enters the collector and heats the absorber plate. The plate then conducts the heat to the water or the heat transfer fluid, depending on the type of SWH, in the riser tubes.

Heat is lost from the absorber plate and the rest of the collector by conduction, convection and radiation of long-wave infrared energy.

Heat losses can be minimised by:

- (a) bulk insulation, such as rock wool or fibreglass, along the sides and base of the collector to minimise conductive losses
- (b) a transparent cover for the absorber plate to create a still air layer and reduce convective losses; the cover also reduces the energy lost by re-radiation
- (c) using selective surfaces on the absorber plate to reduce the amount of re-radiated energy.

Figure 5.1 Typical flat plate collector



Absorber plate

The absorber plate can be designed in a number of ways, each resulting in a different degree of contact between the absorber and the working fluid. There are three common designs of collector plate:

- (a) **Fin and tube.** A conductive absorber plate (the fin) is in thermal contact with riser pipes (tubes) that are in parallel along the collector and joined by header pipes at the top and bottom. The most common form of this design has a single ultrasonic welded seam securing the approximately 8–10mm copper pipe to the selectively coated fin material, which can be aluminium or copper.
- (b) **Flooded plate.** Two sheets are welded together so that water channels are able to form between the welds. When the fluid is passed through the collector, it is heated directly by the sun.
- (c) **Plastic, rotationally moulded systems** that have a storage tank integrated with the collector. These require less protection from overheating and ‘hard’ water quality (see Section 5 for details of water hardness).

Absorber surface

The surface of the absorber should be designed to maximise the amount of solar radiation absorbed and to minimise the heat re-radiated into the collector box. To this end, selective surfaces such as copper, nickel, chromium or titanium oxides have been developed that can be chemically (or electrochemically) bonded to the absorber.

Collector cover

It is important that the material used for the collector cover meets AS/NZS 2712:2007 (Solar and heat pump water heaters—design and construction)—in particular, sections 4.4 and 4.6.

The most common material used for the transparent cover is toughened, low-iron glass. Compared with normal window glass and many plastics, low-iron glass has the following improved qualities:

- (a) Very high transmittance means it reflects and absorbs less incoming solar energy, so more energy gets to the absorber plate.
- (b) Low absorptance means the cover remains cooler, and less energy is lost by re-radiation.
- (c) The surface can be etched to further reduce reflection.
- (d) It is long lasting and strong, and will resist damage from hail or other projectiles.

Collector box

The collector box holds the collector and absorber together. It must have sufficient strength to protect against thermal stresses, wind forces and hail, and to support the contents. The box must also protect against water, snow, dust, corrosion and degradation by ultraviolet light. Finally, the box needs to be manageable during installation and have minimal maintenance requirements.

5.1.2 Evacuated tube systems

Operating principle

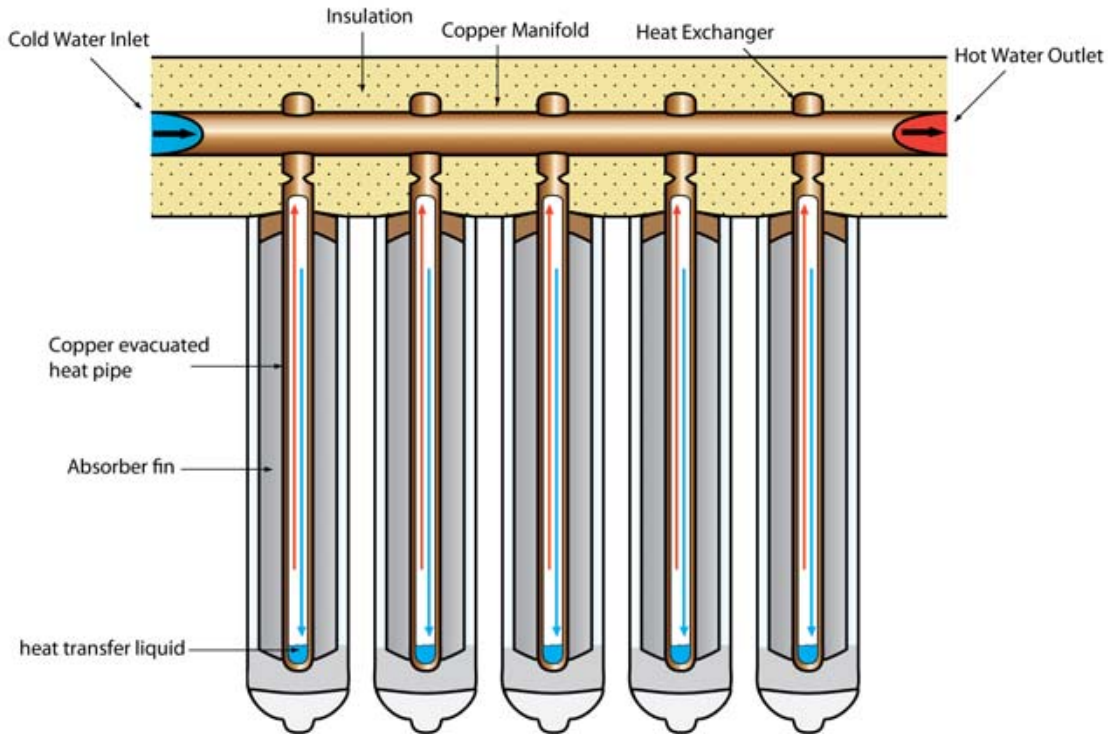
The common principle in both types of evacuated tube system (described below) is that the tubes have a vacuum that protects against heat loss.

Evacuated heat pipe collector

An evacuated heat pipe collector is made up of a copper heat pipe that contains a very small amount of heat transfer liquid (usually water or glycol) in a partial vacuum. The heat pipe is encased in a hardened dark glass tube with an evacuated layer that absorbs the sun's energy, traps it inside (like a thermos flask) and uses it to heat the copper heat pipe inside.

As the copper heat pipe warms up, the small amount of liquid inside vaporises and rises to the top of the heat pipe into the heat exchanger in the manifold. The cold water is heated as it flows through the manifold and at the same time the vapour inside the copper heat pipe cools. As it cools, it condenses and falls to the bottom of the heat pipe. The process is repeated, thus creating a highly efficient thermal engine for transferring the sun's energy from the tubes into the water supply.

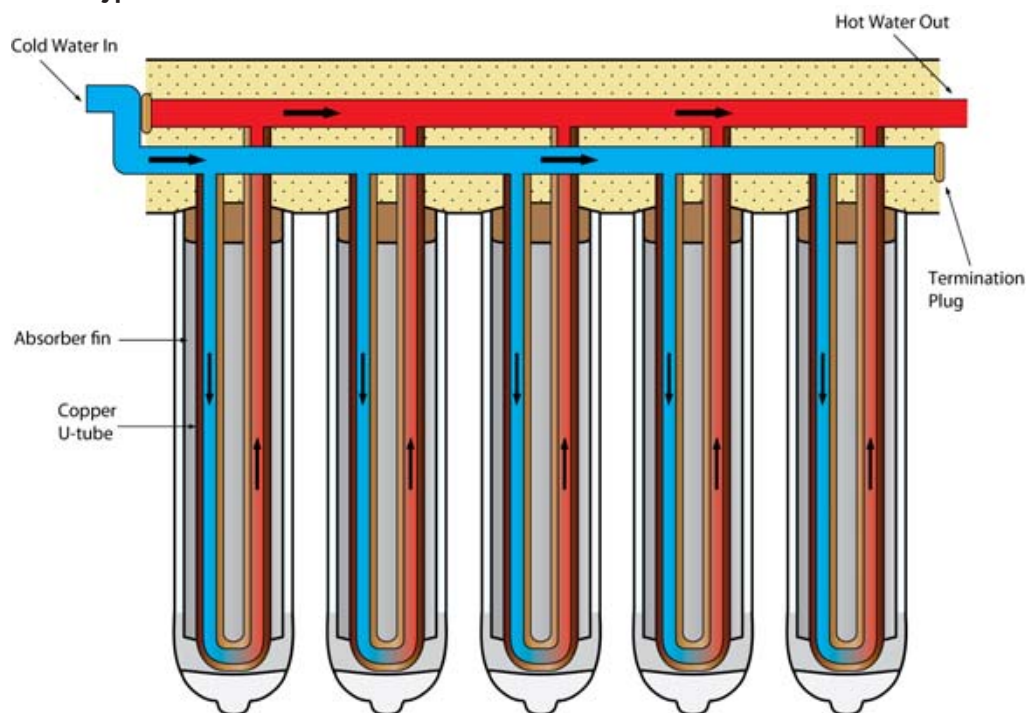
Figure 5.2 Typical evacuated heat pipe collector



Evacuated U-tube collectors

Evacuated U-tube collectors use a similar principle to the evacuated heat pipe collector. However, instead of having a heat transfer liquid in copper pipes, the collector has cold water flowing through the evacuated glass tubes inside 'U'-shaped copper pipes. The energy from the sun is absorbed and heats the water in the copper pipes (Figure 5.3).

Figure 5.3 Typical evacuated U-tube collector



Parts and features of evacuated tube systems

The evacuated tubes join together to form an evacuated tube collector, which can be one of two kinds:

- (a) An evacuated tube collector with a single glass tube. In this design, a fin-shaped or plate-shaped absorber sits inside a single glass tube. Solar radiation enters through the outer glass tube and is absorbed by the internal plate.
- (b) An evacuated tube collector with concentric glass tubes. In this design, the absorber is also shaped like a cylinder, so a cross-section of the collector will show the absorption tube sitting inside the outer glass tube.

Each evacuated tube collector has a mechanism that transfers the heat from the absorber fins into a fluid inside the collector tube (either the heat transfer fluid or the water supply itself). It does so by passing the fluid through the evacuated tube and over the absorber fin. This can happen in one of three ways:

- (a) Single pass collector. Water passes in one direction only, from the top manifold to the bottom manifold. This type is not commonly seen in the domestic market.
- (b) Concentric tube collectors. Water flows as a liquid through concentric tubes or U-tubes. Fluid passes down through the evacuated tube collector, then back up through the collector to the manifold. This can happen through two concentric tubes, or in a U-shaped tube (Figure 5.4).
- (c) Heat pipe collectors (Figure 5.5). Heat transfer fluid passes down into the collector as a liquid, and back up through the collector as a vapour in a single sealed tube, known as a heat pipe.

Figure 5.4 Construction details for a U-tube evacuated tube collector



Source: Clean Energy Council

Figure 5.5 Example of a heat pipe collector



Source: Apricus Australia

The heated fluid is then transferred to the manifold by one of two mechanisms:

- (a) In concentric tube and U-tube collectors, the water flows directly into the manifold and into the connected supply and return pipes.
- (b) In heat pipe collectors, the heat transfer fluid releases its energy into a heat exchanger in the manifold at the top of each collector (Figure 5.6).

The manifold is generally an insulated box, containing the header pipe through which the water flows. The header pipe picks up heat from the heat pipes. In the case of the U-tube or concentric pipe, there are two header pipes for the flow and return.

Figure 5.6 The heat transfer mechanism in the manifold of a heat pipe collector



5.1.3 Comparison of flat plate and evacuated tube collectors

Evacuated tube collectors are able to retain more heat than flat plate collectors and are better suited to higher latitude regions, such as the southern parts of Australia and New Zealand.

The shape of evacuated tube collectors means that the surface of the glass outer tube that absorbs solar radiation is always perpendicular to the sun's rays, maximising efficiency. This feature of evacuated tube collectors is referred to as 'passive tracking'. The efficiency of flat plate collectors varies with the angle of the sunlight, so that peak output occurs at midday when the sun is perpendicular to the collector.

Evacuated tube collectors rely on vacuum seals to retain the vacuum surrounding the absorption plate. Over time, erosion and decay of the vacuum seal can reduce effectiveness and efficiency.

Evacuated tube collectors are often manufactured with a lighter weight glass surround, which can be more vulnerable to severe weather and projectiles. This can make these collectors more delicate and more difficult to install. The thicker glass of flat plate collectors may result in a more durable unit.

The major disadvantage of evacuated tube collectors is the possible increased cost, which can be prohibitive despite the increased efficiency of these systems. Flat plate collectors can offer a lower cost solution in most cases.

5.2 Storage tanks

Water storage tanks used in solar hot water installations must be designed and constructed in accordance with AS/NZS 2712:2007 (Solar and heat pump water heaters—design and construction) and AS/NZS 4692.1 (Electric water heaters) and must be installed to the manufacturer's instructions, provided that these instructions are not in conflict with AS/NZS 3500.4:2003.

Storage tanks are designed to minimise the mixing of hot water and cold water. Solar collectors are more efficient when heating cold water, and excessive mixing of hot and cold water can reduce the efficiency of the system.

5.2.1 Types of tanks

Storage tanks are typically made of the following materials:

- (a) stainless steel
- (b) copper (minimal use)
- (c) vitreous enamel lined steel
- (d) plastic or rubber (for atmospheric pressure formats).

Stainless steel and copper storage tanks tend to have a longer life where the water quality is good, but suffer from corrosion with a poor-quality water supply. Vitreous enamel storage tanks can withstand poor-quality water due to the enamel coating inside the tank. A manganese or aluminium anode is installed to protect the lining of the tank (see below).

Figures 5.7 and 5.8 show typical non-boosted vertical and horizontal storage tanks.

Figure 5.7 Typical vertical storage tank

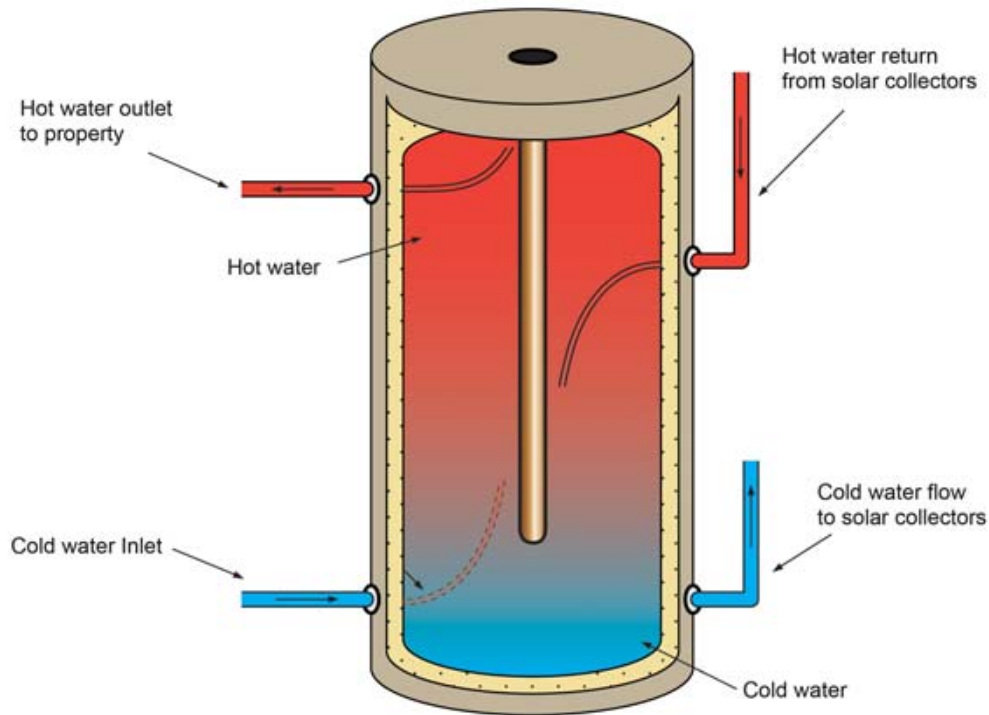
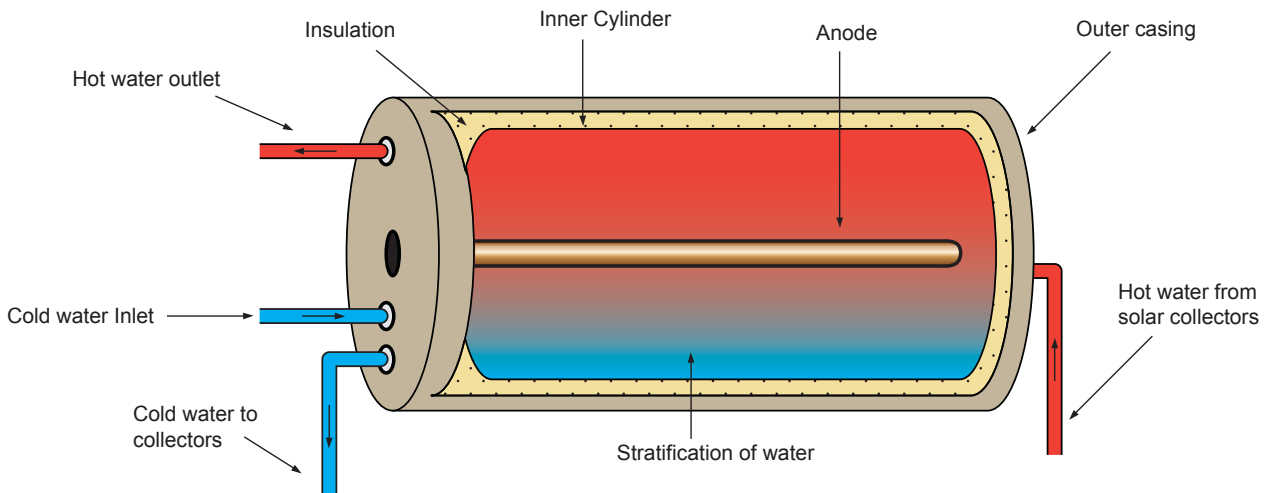


Figure 5.8 Typical horizontal storage tank



Sacrificial anodes

Sacrificial anodes are commonly used with vitreous enamel tanks and are typically constructed of magnesium with small percentages of manganese, aluminium or zinc.

The purpose of the sacrificial anode, as the name suggests, is to increase the life of the storage tank by attracting the total dissolved solids in the water and corroding or sacrificing the anode (rod) instead of the storage tank.

Tank life can be increased if the sacrificial anode is replaced regularly, especially in areas with hard water.

5.2.2 Heat exchange tanks

In frost-prone areas or where the water quality is very poor, a heat exchanger can be used to separate potable water from the water circulating through the collectors.

In this type of tank, a corrosion-inhibiting antifreeze liquid, such as propylene glycol or glycerine, is circulated through the solar collectors and returned through the heat exchanger. The heat is then transferred to the water in the storage tank by contact with the copper pipe.

Heat exchangers are commonly designed by integrating:

- (a) an outer tank or 'jacket' around the cylinder (Figure 5.9)
- (b) a coil arrangement of copper pipework inside or around the cylinder (Figure 5.10).

Figure 5.9 Horizontal storage tank with jacket heat exchanger
(this type of storage tank can also be manufactured vertically)

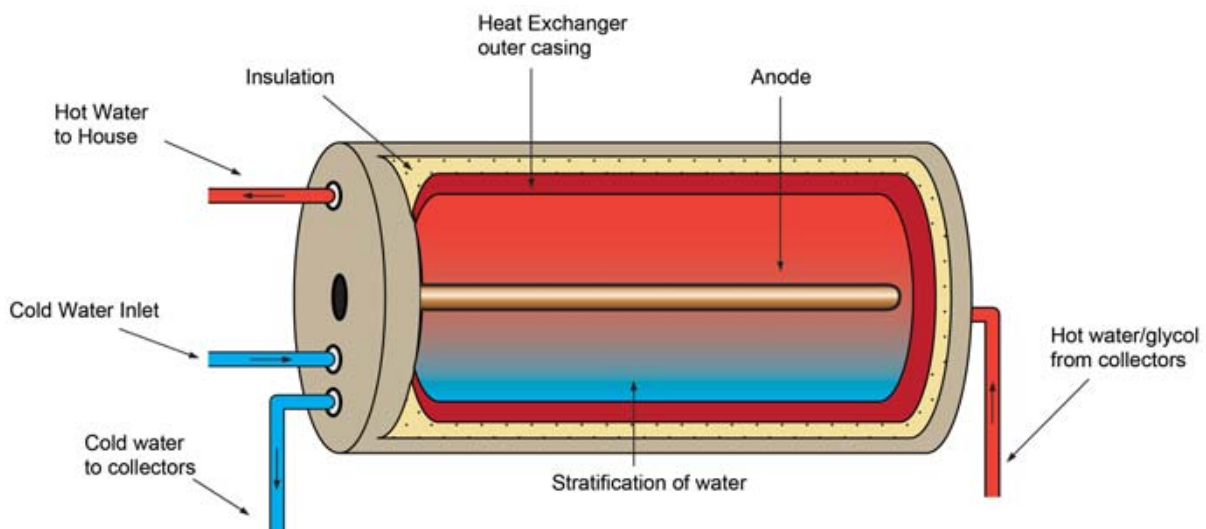
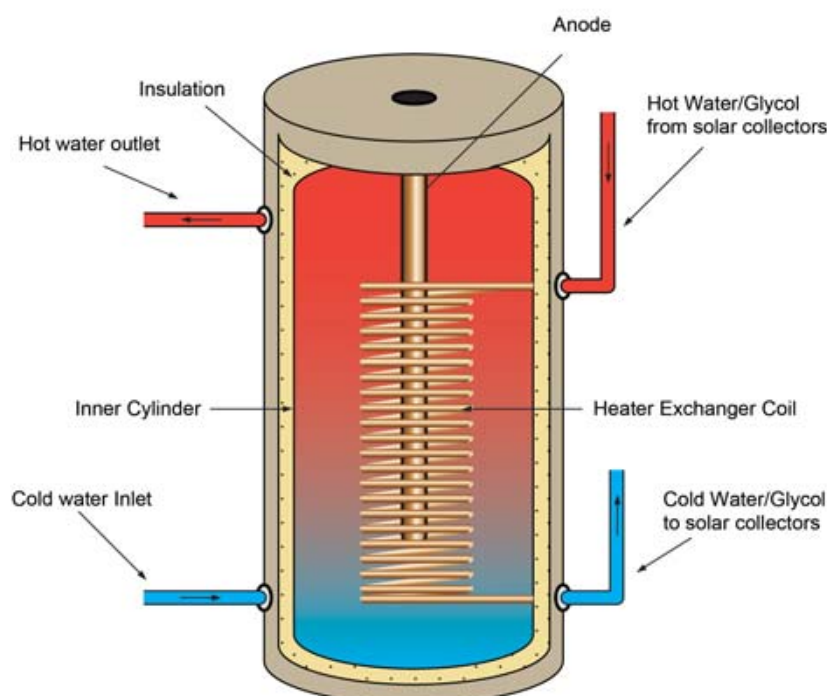


Figure 5.10 Vertical tank with submersed coil heat exchanger



5.2.3 Water quality

Water quality can affect the design and the longevity of the system. Water quality is measured using a number of factors, including:

- (a) pH—measure of acidity or alkalinity of water, from 0 to 14; pH less than 6.5 or more than 8.5 can cause corrosion and pipe blockage
- (b) hardness—measure of the concentration of magnesium and calcium in water; hardness above 200 mg/L can cause scaling and blockages of pressure/temperature relief valves
- (c) total dissolved solids—measure of minerals and organic matter dissolved in water; total dissolved solids above 500 mg/L can cause scaling.

If using a glycol/water mix, the water must meet the above requirements, and the glycol content of the liquid must not exceed 50%, unless the manufacturer specifies that a different ratio is recommended for use with that SWH. Glycol may need to be changed periodically (every 3–5 years) to prevent it from becoming acidic; guidelines provided by the glycol manufacturer will specify replacement times.

Glycerine-based heat transfer fluids are now available and used widely for closed-loop systems. In order to meet health and safety regulations, only food-grade heat transfer fluids should be used.

5.3 Boosting for solar water heaters

For many solar water heater systems, some additional energy will be required to heat the water during colder months, during extended periods of dense cloud cover, or when demand for hot water is greater than the storage capacity. This additional energy is referred to as ‘boost energy’, and the source of the boost energy as a ‘booster’.

Available sources of boosting are internal gas, in-line gas and electric element.

Another reason for boosting is to ensure the water is safe. When water is stored, it needs to be heated to at least 60°C as a precaution against the development of legionnaire’s disease in stagnant parts of the water tank. Although this is rare in water heating applications, it can occur if the water is kept at less than 50°C for extended periods. The booster raises the water temperature to above 60°C regularly.

Under AS/NZS 3500.4:2003, clause 1.9.2, it is a requirement that only tempered water be delivered to ‘sanitary fixtures used primarily for personal hygiene purposes’. Heated water must be less than 45°C for preschools, schools and nursing homes, and less than 50°C for all other buildings. A hot-water tempering valve is fitted to the tank’s hot-water outlet to comply with this standard. AS 3500.4:2003 differentiates between residential and commercial buildings and the requirements for tempering valves can vary across building type and state plumbing jurisdiction.

The table below shows the required boosting in solar water heater storage tanks for capital and major Australian cities.

Figure 5.11 Solar input and water temperature rise in storage tank

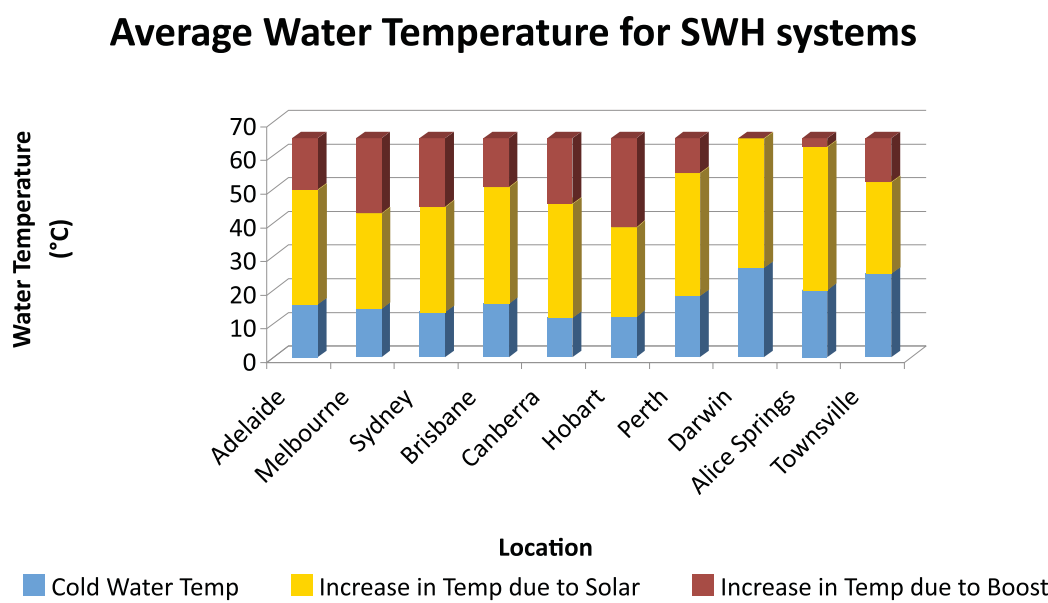
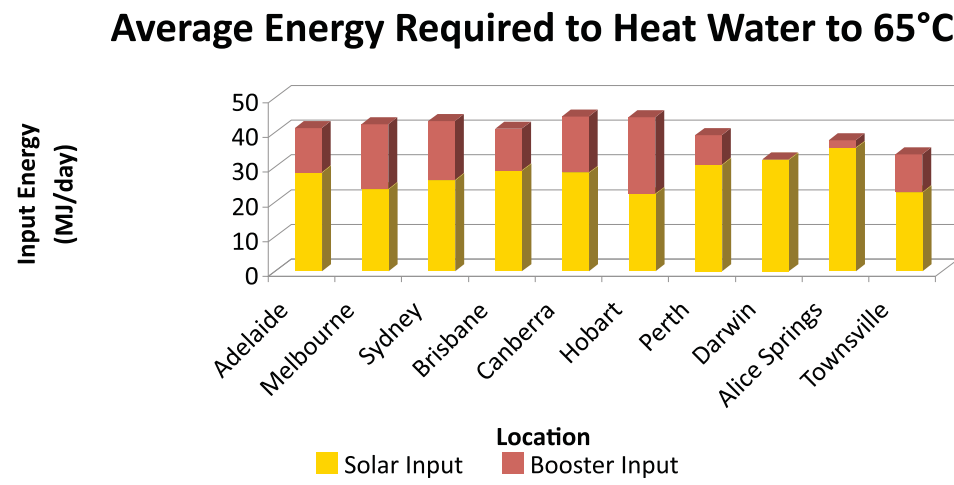


Figure 5.12 Energy contributions per day from boosting and solar to heat 200 litres of water to 65°C for Australian capital and major cities.



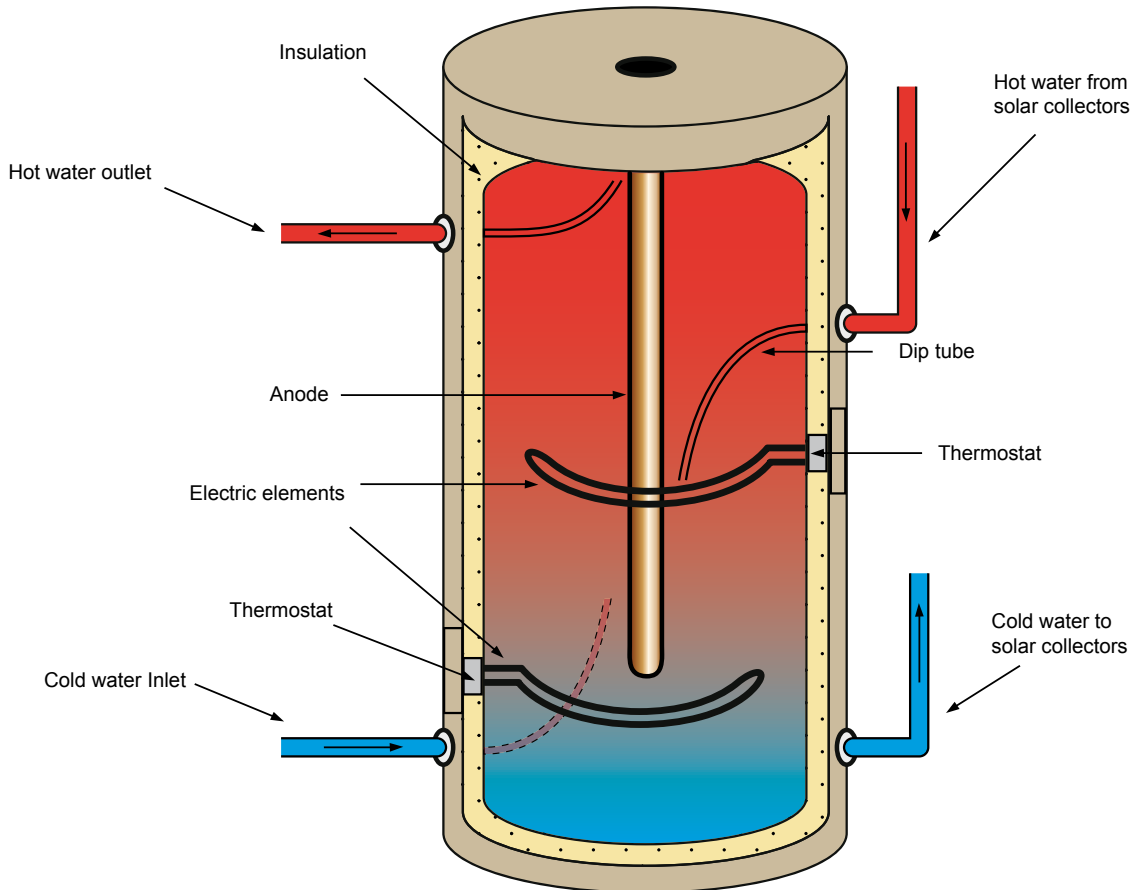
5.3.1 Electric boosting

Electric storage

In electric-boosted storage systems (Figure 5.13), one or two electric elements are immersed in the storage tank. An electric element is curved in shape and can be positioned so the curve points up or down to provide varying amounts of boosted hot water.

A thermostat controls the boosting element by switching it on when the water temperature drops to a predetermined temperature and off when the temperature reaches between 60°C and 70°C, depending on thermostat settings.

Figure 5.13 Electric-boosted storage tank



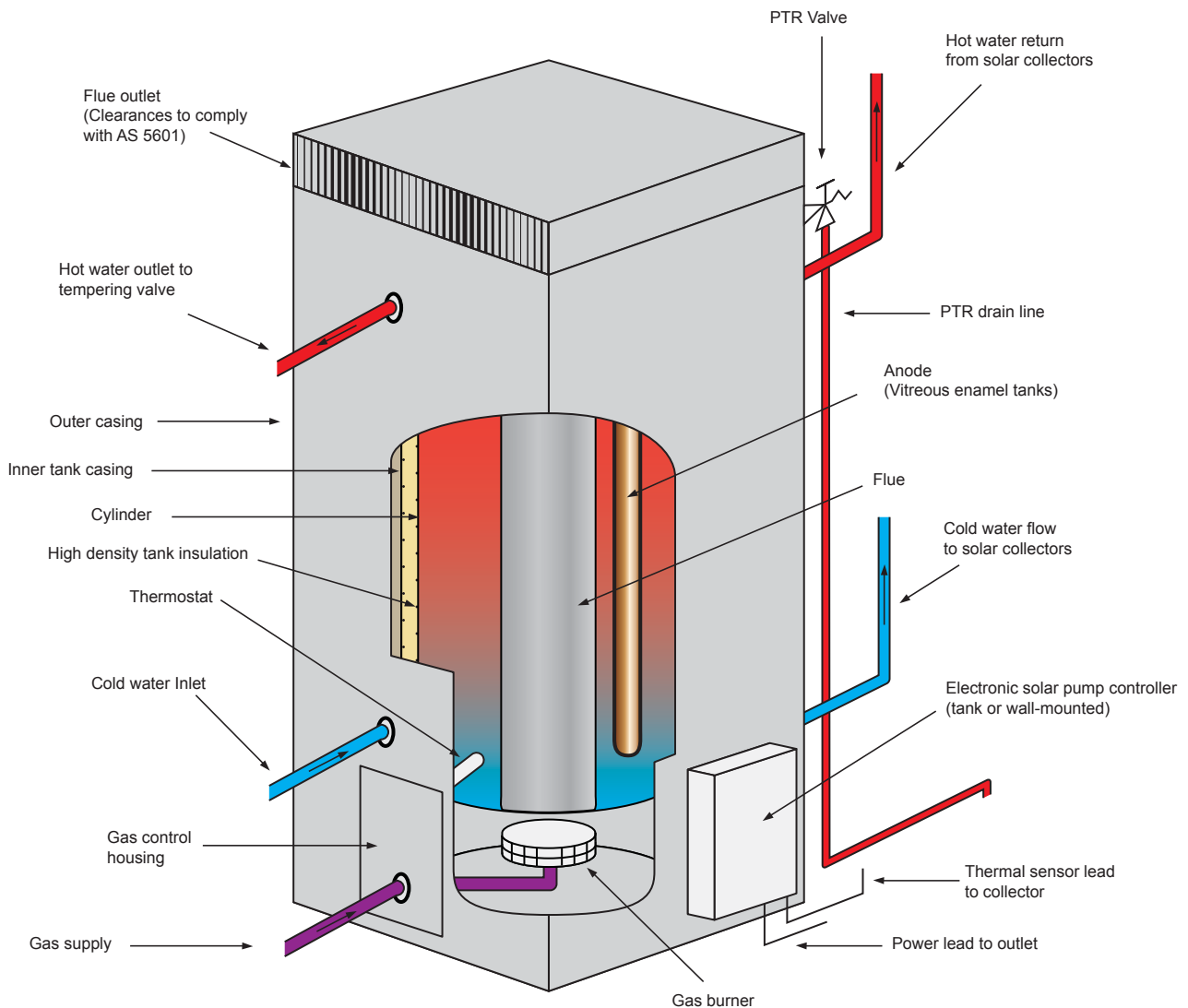
5.3.2 Gas boosting

If the household is located in a natural gas reticulated area, gas can be supplied to the booster by mains gas supply. Alternatively, if natural gas is unavailable, an LP gas cylinder can be installed by a gas supplier or plumber. The customer would have to be made aware of the increased cost associated with bottled gas.

Gas storage

Gas boosting in the storage tank occurs by means of a burner that is thermostatically controlled. The burner ignites when the water temperature drops to a predetermined temperature and the gas source heats the water to 60°C.

Figure 5.14 Gas Storage Tank

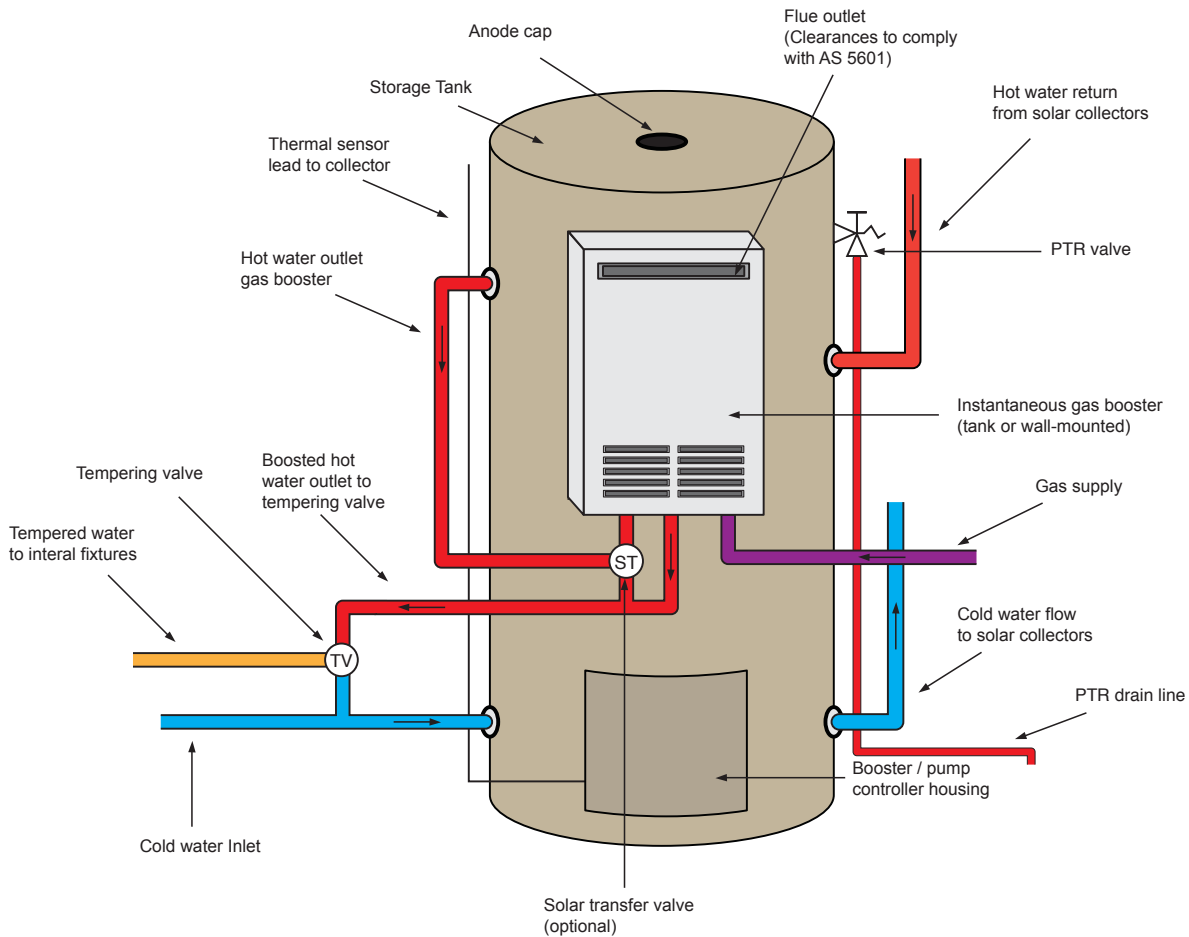


Gas instantaneous

Gas instantaneous boosting does not occur inside the tank; instead an in-line gas instantaneous unit is fitted between the tank and the hot water pipes into the building. This unit is usually mounted directly onto the storage tank but may also be remote to the tank, mounted to a wall.

The solar hot water system is used to preheat the water before it flows through the instantaneous gas unit. The gas burner will typically ignite every time water flows through the unit. However, it will only operate at full capacity if the water is not at the required temperature (60°C); if the water is already at the required temperature, it will bypass without additional boosting.

Figure 5.15 Gas instantaneous boosted storage tank



5.4 Frost protection

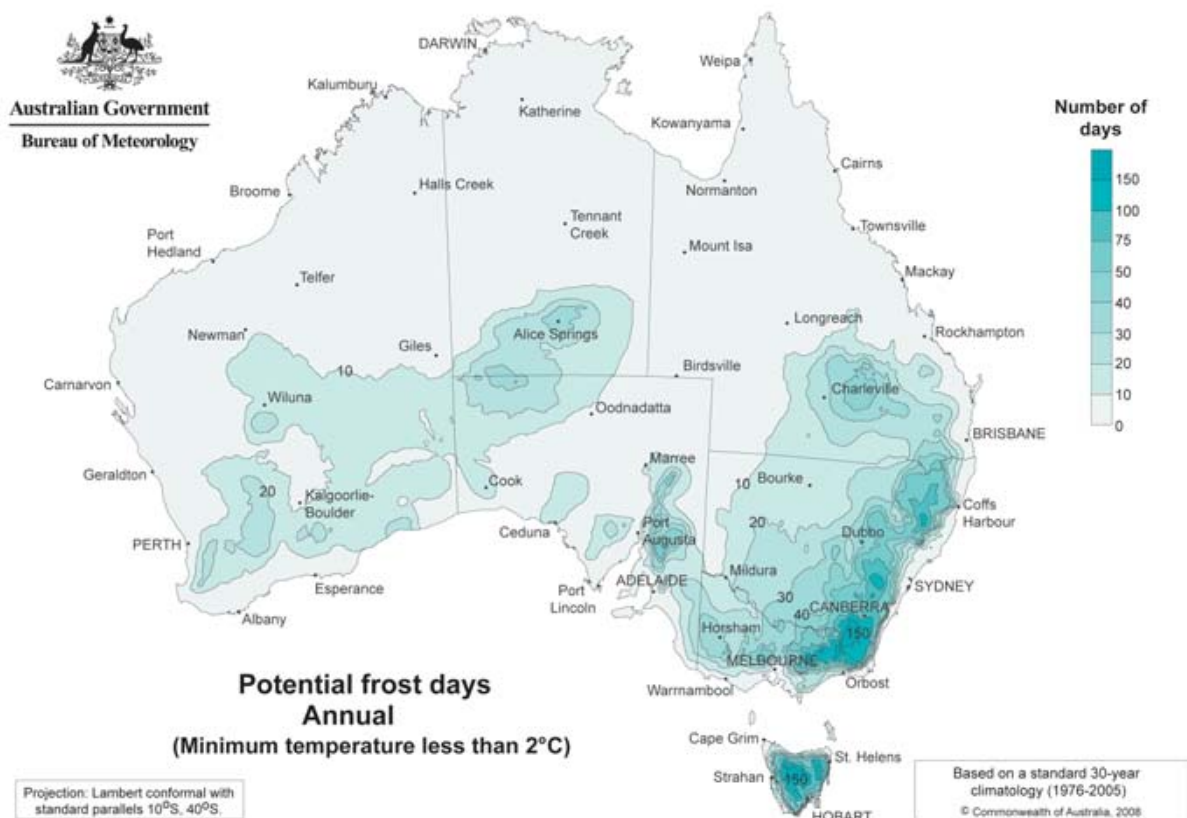
In many parts of Australia, low temperatures and frosts have the potential to cause serious damage to SWH systems when the water stored within the collector begins to freeze and expand.

Frost occurs when the temperature drops sufficiently for water to turn to ice, which can occur once the air temperature is below 2°C. Water starts to expand as it reaches the temperature required for it to turn to ice. Expansion becomes significant at about 4°C. Most manufacturers say that frost protection is required for an SWH system if the air temperature is expected to drop to 4°C or below.

The map of Australia in Figure 5.16 shows potential frost days. Coastal areas (close to sea level) north of Sydney do not generally require frost protection.

The system manufacturer or the Bureau of Meteorology should be consulted about whether a particular location is prone to frost. In many situations, local knowledge can be valuable as frosts tend to be noticed, particularly in regional areas.

Figure 5.16 Potential annual frost days



5.4.1 Types of frost protection

Several techniques have been developed to protect SWH systems from frost damage in a range of different conditions, with some systems designed to operate well into negative temperatures. This section outlines the most common techniques used.

Frost dump valves and frost-protection valves

The most common form of frost protection across all system types is a frost-protection valve, which uses a heat-sensitive metal element to mechanically release a valve once the temperature falls below 4°C.

Frost dump valves help to protect the collectors in two ways:

- (a) by relieving pressure building up due to water expansion, reducing the chance of the collectors bursting
- (b) by encouraging water circulation around the collector system—water circulated from the storage tank will be at a higher temperature than the water in the collector, warming up the collector and reducing the risk of refreezing.

The most common type of frost-protection valve used is the brass frost-protection valve shown in Figure 5.17.

Figure 5.17 Brass frost-protection valve



Source: Clean Energy Council (previously BCSE Australia) SWH Heater Manual

In locations where frosts are light and rare, it is likely that one frost valve will be sufficient to protect the system. Where frosts are common and temperatures fall to below 4°C regularly, two frost valves can be installed. The advantage of two frost valves is that if freezing occurs in the middle of the collector, pressure can be released from both the top and bottom of the collector.

When installing frost valves, it is important to install them so that the water released will be directed down the roof line.

Pump circulation protection

A second solution used commonly for split (pumped circulation) systems is to circulate warm water from the tank whenever the water stored in the collectors falls below a minimum temperature threshold, often 5°C. When this warmer water is circulated, it heats up the collector and prevents freezing. This system is normally a function of the pump controller and will repeat a set pumping cycle until the temperature of the collector is above either the minimum temperature threshold or some other preset temperature.

The advantage of such a system is that no additional components are required, reducing the overall system cost slightly. The disadvantages are:

- (a) if the electricity supply fails, the frost protection will not operate; for this reason, it is good practice to use both this system and a frost-protection valve
- (b) in some circumstances, the amount of heat lost from the tank overnight can mean that a significant amount of additional boost heating will be required.

Antifreeze or closed-loop systems

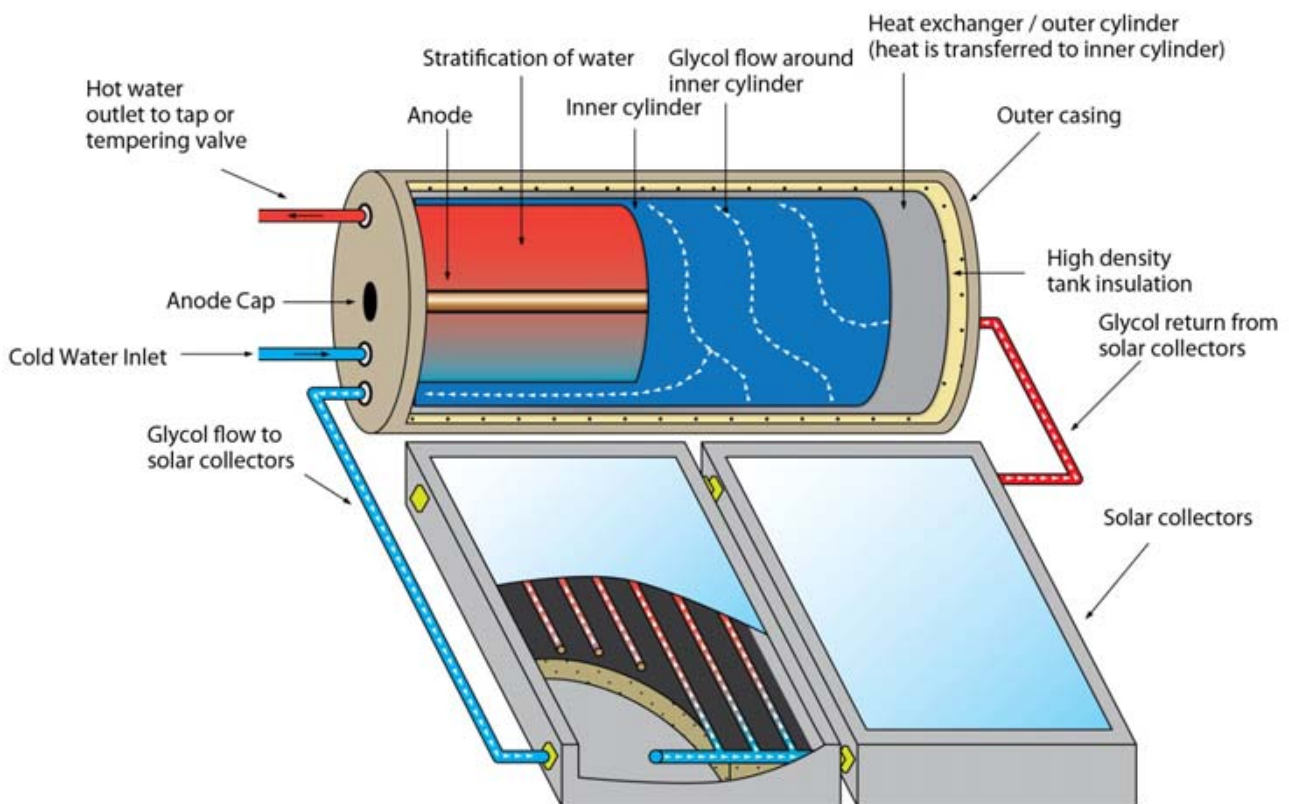
In some situations, where sub-zero temperatures are common, antifreeze heat exchanger systems are used. These systems use compounds such as ethylene glycol or propylene glycol (as used in car radiators). Glycerine is also used as an antifreeze compound in some 'closed' systems.

The antifreeze is kept separate from the potable water supply through the use of a heat exchanger system. For details of the way these tanks operate, see Section 5.2.2.

Antifreeze systems differ depending on the design of the system, the concentration of glycol used and the type of tank. Some suppliers offer antifreeze systems rated to temperatures as cold as -23°C , while others suggest a maximum tolerance of -8°C . This wide range of temperatures can make system design difficult. For this reason, it is best to consult suppliers or manufacturers before selecting a system to install.

Figure 5.18 shows a close-coupled thermosiphon system using antifreeze.

Figure 5.18 Close-coupled thermosiphon system using antifreeze



Frost protection using an antifreeze and heat is widely used in cold parts of the world; however, the following issues need to be considered.

- (a) Any heat exchange system is more expensive than a system that directly heats the water from the tank in the collectors.
- (b) A system using a heat exchanger is an indirect system, which is less efficient than a direct system.
- (c) The water in the tank can never be as hot as the heat transfer liquid in the collectors.
- (d) The system may not be appropriate for warm climate zones.

System draining

In some systems, a very different approach is taken to frost protection. Once the temperature drops below a prescribed level, a valve system is released and the collector is drained of water (or transfer fluid). This approach simply acknowledges that air is highly unlikely to freeze. The valves can be operated in a number of ways, including mechanically, electronically or automatically.



Chapter 6

Solar Hot Water & Heat Pump Systems

Solar Hot Water & Heat Pump Systems

6.1 Thermosiphon systems

6.1.1 Operating principles

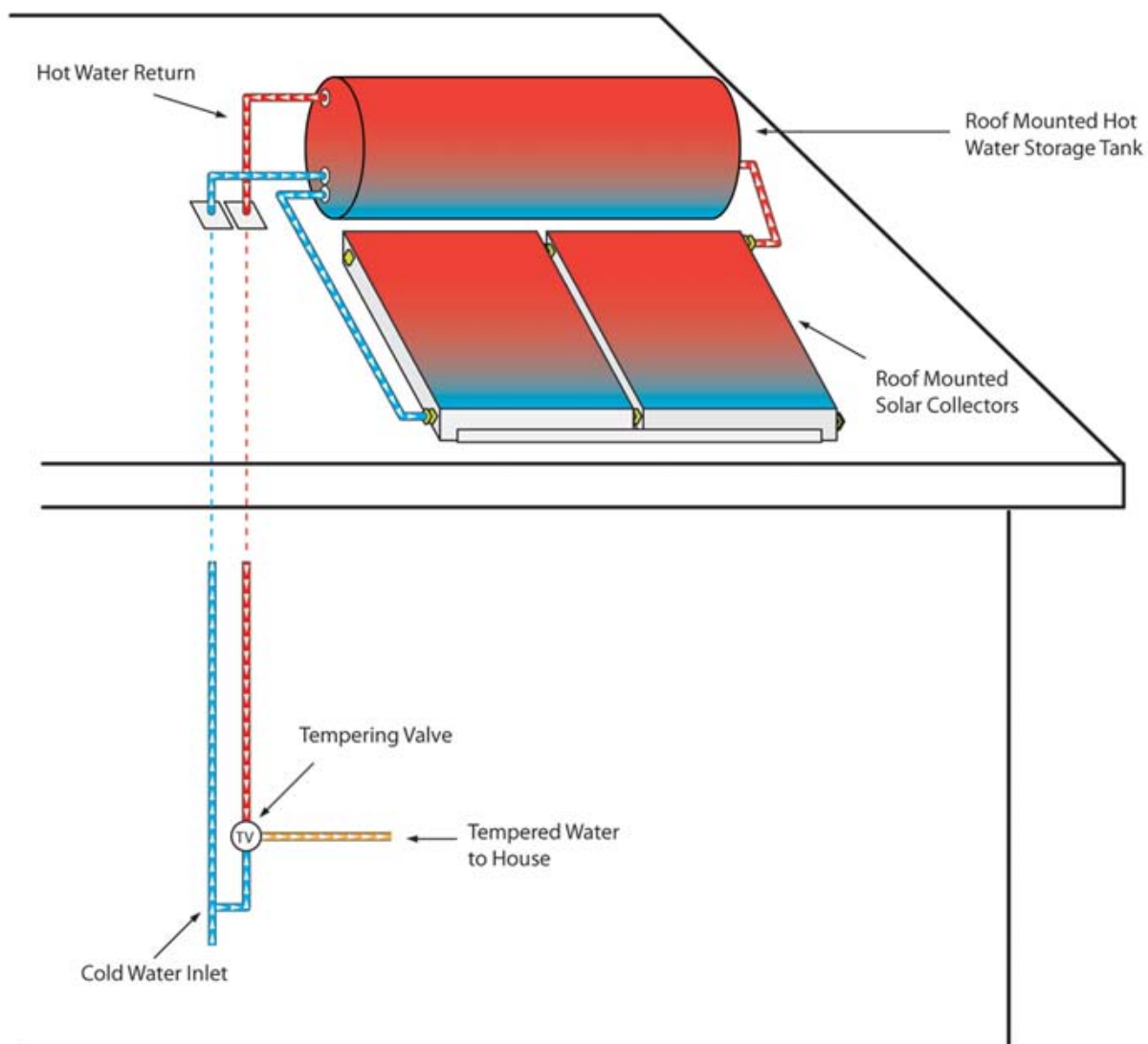
In a 'close-coupled' or thermosiphon solar water heater (SWH), the collectors and the storage tank are close together. The storage tank is mounted directly above the collectors. The most common installation has both the tank and collectors on the roof.

Water is supplied to the storage tank from the main cold water inlet and flows to the bottom of the solar collectors. The water is heated by the collectors and moved to the storage tank by thermosiphon flow. The hot water rises to the top of the collectors and back to the storage tank via a short return pipe on the opposite side of the storage tank.

Hot water from the top section of the tank is supplied to a tempering valve, where it is mixed with cold water from the main cold-water inlet and then distributed to the household fixtures.

A thermostat controls the water storage temperature and activates the 'booster' (if fitted) as required.

Figure 6.1 Thermosiphon system with a tempering valve fitted



6.1.2 Remote thermosiphon systems

A remote thermosiphon system has the tank in the roof cavity, rather than on the rooftop (Figure 6.2). These low-pressure systems are often used in areas without reticulated water. Note that the minimum gradient for the thermosiphon effect to occur is 1:20, unless special piping arrangements, tanks or valves are used to prevent reverse thermosiphon flow.

Figure 6.2 Remote thermosiphon system with storage tank in the roof cavity

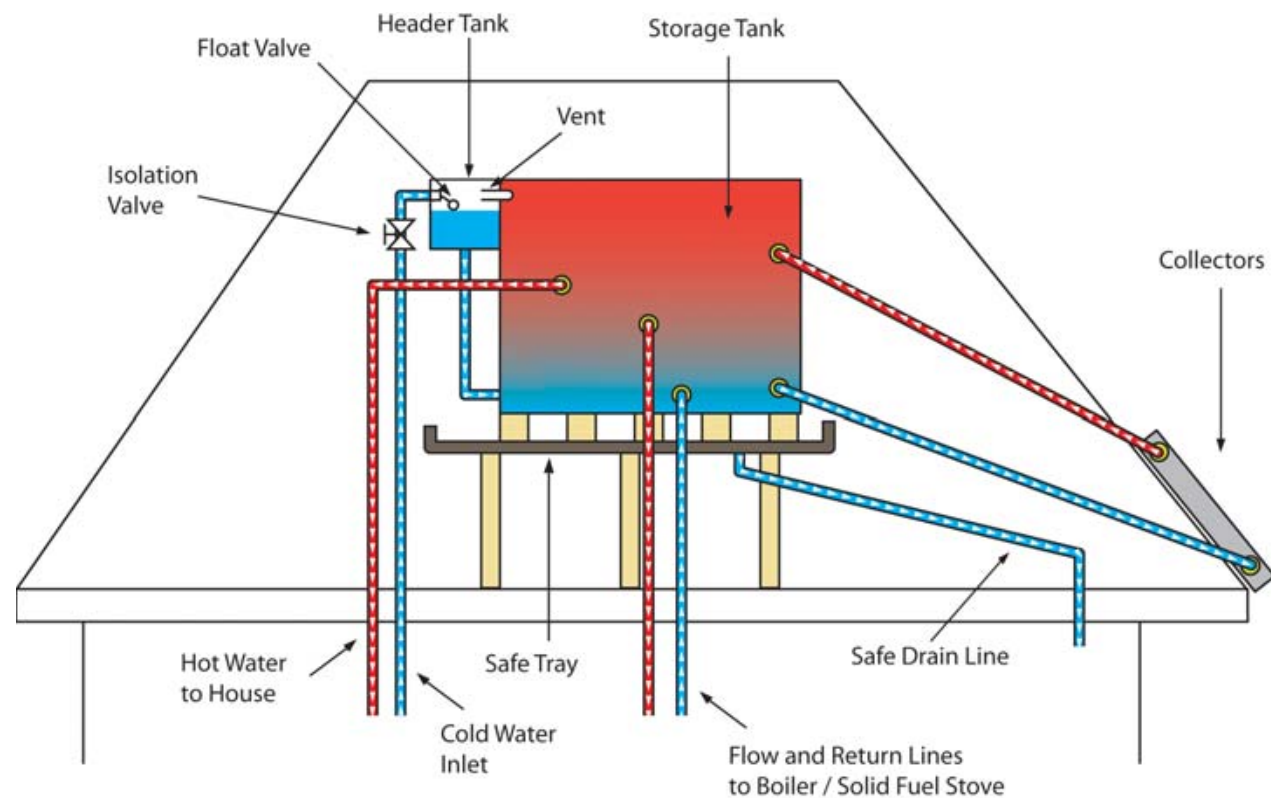


Table 6.1 summarises the differences between close-coupled and remote thermosiphon systems.

Table 6.1 Comparison of close-coupled and remote thermosiphon systems

	Close-coupled system	Remote system
Easy to install and quote	Yes	No
Installation components typically supplied	Yes	No
Mains pressure	Yes	No
Water storage in roof	No	Yes
Safe tray required	No	Yes

6.1.3 Features and parts

Storage tank

Typical storage volume is about 300L. Tank sizes vary from 150L to 440L.

Tanks may use:

- (a) direct heating of potable water
- (b) indirect heating of potable water via an integral heat exchanger shell tank that surrounds the inner potable water tank (used when frost protection is required and antifreeze is used in collectors instead of water)
- (c) indirect heating of potable water via a heat exchanger external to the tank and collectors (used when frost protection is required and antifreeze is used in collectors instead of water).

The tank may be supplied with cold water at:

- (a) full mains pressure
- (b) reduced pressure, via a pressure limiting valve as specified in AS/NZS 3500:2003.

Depending on the operating pressure, the tank may be made from:

- (a) vitreous enamel-lined mild steel
- (b) stainless steel
- (c) copper.

Tanks are reasonably well insulated with high-density polyurethane foam insulation with a thickness of about 50mm.

Collectors

For domestic applications, one, two or three collectors of approximately 2m² each are used, depending on storage tank size. A rule of thumb is 2m² of collector per 150L of storage.

Absorber

The absorber is enclosed in a glass-covered metal box made from zinc-alume or aluminium sheeting, insulated at the back and sides. The absorber surface may be painted matte black or finished with a selective surface (e.g. AMCRO or Black Chrome). The glass cover may be constructed of toughened, low-iron, antireflective glass (higher transmittance) or plain window glass (cheaper models).

Absorbers may be made from:

- (a) copper pipe attached to copper or aluminium sheeting (fin and tube design)
- (b) mild steel (flooded plate design—heat exchange systems only).

Cold water entry

Cold water from the mains supply enters the bottom of the tank via a series of valves, as specified in AS/NZS 3500.4:2003, Figure 5.5. These are often in a cluster called a combination set. Their purpose is as follows:

- (a) isolating valve—allows isolation and maintenance of the system
- (b) line strainer—filters larger particles from the water
- (c) non-return valve—prevents back-flow of water into the mains (not required for a low-pressure system with float valve)
- (d) pressure-limiting valve—reduces mains pressure to below the maximum rated pressure of the tank and collector (not required in all situations or on low-pressure, vented systems)
- (e) cold-water expansion valve—releases cold water rather than hot water due to pressure build-up as the water in the storage tank is heated and expands, thereby preventing wastage of hot water and protecting the tank from excessive pressure; the pressure setting should be about 200 kPa less than for the pressure/temperature relief valve (see below) (typical cold-water expansion valve pressure setting is 500 kPa—see AS/NZS 3500.4:2003, Table 5.2).

The cold-water inlet pipe connects to a diffuser or spreader pipe running part of the length or the full length of the tank at the bottom. The diffuser pipe reduces the water velocity and limits mixing of hot and cold layers in the tank. This helps maintain stratification of water temperature, thereby keeping the hottest water at the top of the tank.

Hot water exit

After water is heated in the collectors, it passes into the tank through the hot-water inlet at the opposite side of the tank from the cold-water inlet. The hot-water inlet is usually located about halfway up the tank.

The hot water entering the tank rises to the top of the tank, causing some mixing of the water in the top half of the tank as it enters, although the hottest water will always rise to the top of the tank. Hot water is drawn off from the very top of the tank through either a top diffuser pipe or a scoop.

The water exits via a **pressure/temperature relief (PTR) valve**. This valve protects against excessive temperature ($>99^{\circ}\text{C}$) and pressure ($>1\text{ MPa}$); its typical pressure setting is 500 kPa (under AS/NZS 3500.4:2003). If either of these conditions is exceeded, the valve opens and dumps a large quantity of hot water through a drain or soakage trench.

AS/NZS 3500.4:2003, clauses 1.9.2 (Sanitary fixtures delivery temperature) and 1.9.3 (Acceptable solutions for control of delivery temperatures) should be referred to for selection and requirements of temperature-control devices in general.

6.1.4 Other system types

Most SWHs use collectors with metal absorber plates that maximise conduction of heat to the water. However, in regions of high solar radiation all year, such as northern Australia and Southeast Asia, these systems can overheat in summer. Also, in many regions, hard water can shorten the life of metal tanks and collectors. One solution to these problems is a plastic, rotationally moulded, integrated collector and tank system. This aims to be a low-cost, low-maintenance system in regions of high annual radiation and hard water. Because the absorber plate is less conductive, the collector is less efficient than conventional metal absorbers, so overheating is less of a problem and performance is satisfactory. These systems have electric boosting.

All plastic systems are low-pressure systems. They can be used as pre-heaters in cooler regions.

6.1.5 Advantages and disadvantages of close-coupled systems

Close-coupled systems have the following advantages and disadvantages compared with other types of SWH and heat pump systems.

Advantages

- (a) Less heat loss in pipework between collectors and the storage tank as they are close together
- (b) Suit houses with no ceiling space (e.g. cathedral ceilings)
- (c) Provided the roof has sufficient slope ($>10^\circ$), there is no problem with reverse thermosiphon flow at night
- (d) May be easier to sell because the public has been more aware of close-coupled systems in the past
- (e) Can still operate when mains power is down.

Disadvantages

- (a) Some property owners do not like the look of the tank on the roof
- (b) Wide, low storage tank has poor stratification, and heat from the hot water is conducted down to the cold water below it
- (c) Roof must be checked to ensure that it is strong enough to support the weight of the storage tank when full of water. If not, reinforcing must be undertaken and might not be possible (see AS/NZS 1170/AS 1781). Any opinion given regarding structural integrity of a roof must be given by a suitably qualified person
- (d) Storage tank and double jacket heat exchange unit are very heavy; lifting equipment is usually required to lift the product onto the roof, especially if roof is steep (see Chapter 8)
- (e) Safety equipment is now required under law (state based)
- (f) Not recommended for use with combustion cooker or heater as a boost source—but commonly installed this way in rural areas.

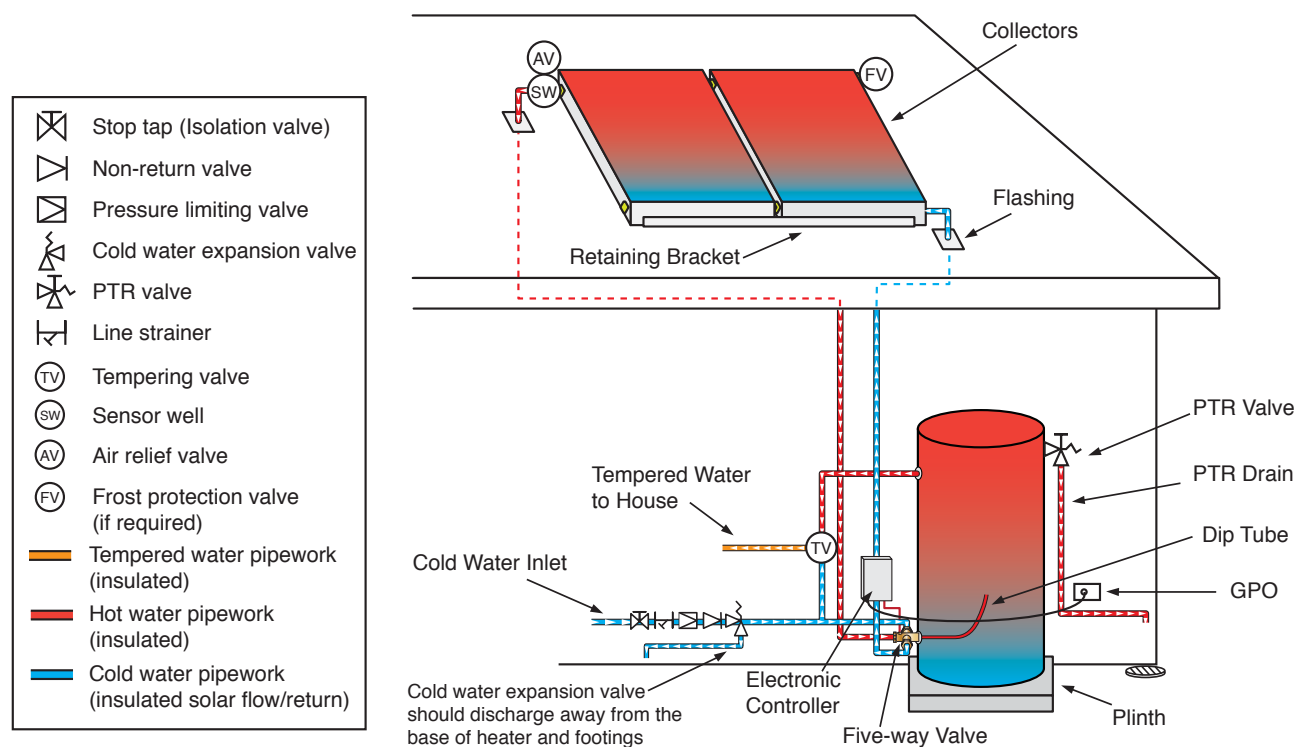
6.2 Split (pump-circulated) systems

6.2.1 Operating principle

In a split system, there is generally a significant distance between the collectors and the storage tanks. The storage tank is usually mounted below the collector panels. These arrangements mean that a pump is required to circulate the water from the storage tank up through the collector. The water is then heated in the collector and goes back to the storage heater, either by the effect of gravity or as a result of the pressure applied by the pump. As only the collector panels are mounted on the roof, split systems are often referred to as lo-line systems.

Figure 6.3 shows a simplified layout of a typical split SWH system.

Figure 6.3 Typical split SWH system



This style of system is most often used when:

- (a) the tank cannot be mounted above the collectors due to lack of space
- (b) the existing roof structure is not sufficient to support a tank
- (c) the collector is to be retrofitted to an existing water tank
- (d) aesthetic considerations require the tank to be hidden from view.

6.2.2 Different system types

Retrofitting

In a retrofit system, a solar collector is connected to supplement the operation of the heating element in an existing storage hot water system. Such a system will operate in the same way as a new SWH system: the water enters the storage tank from the mains water line, and is drawn through the solar collector from the tank.

The typical layout of a retrofit SWH system is shown on Figure 6.3 above.

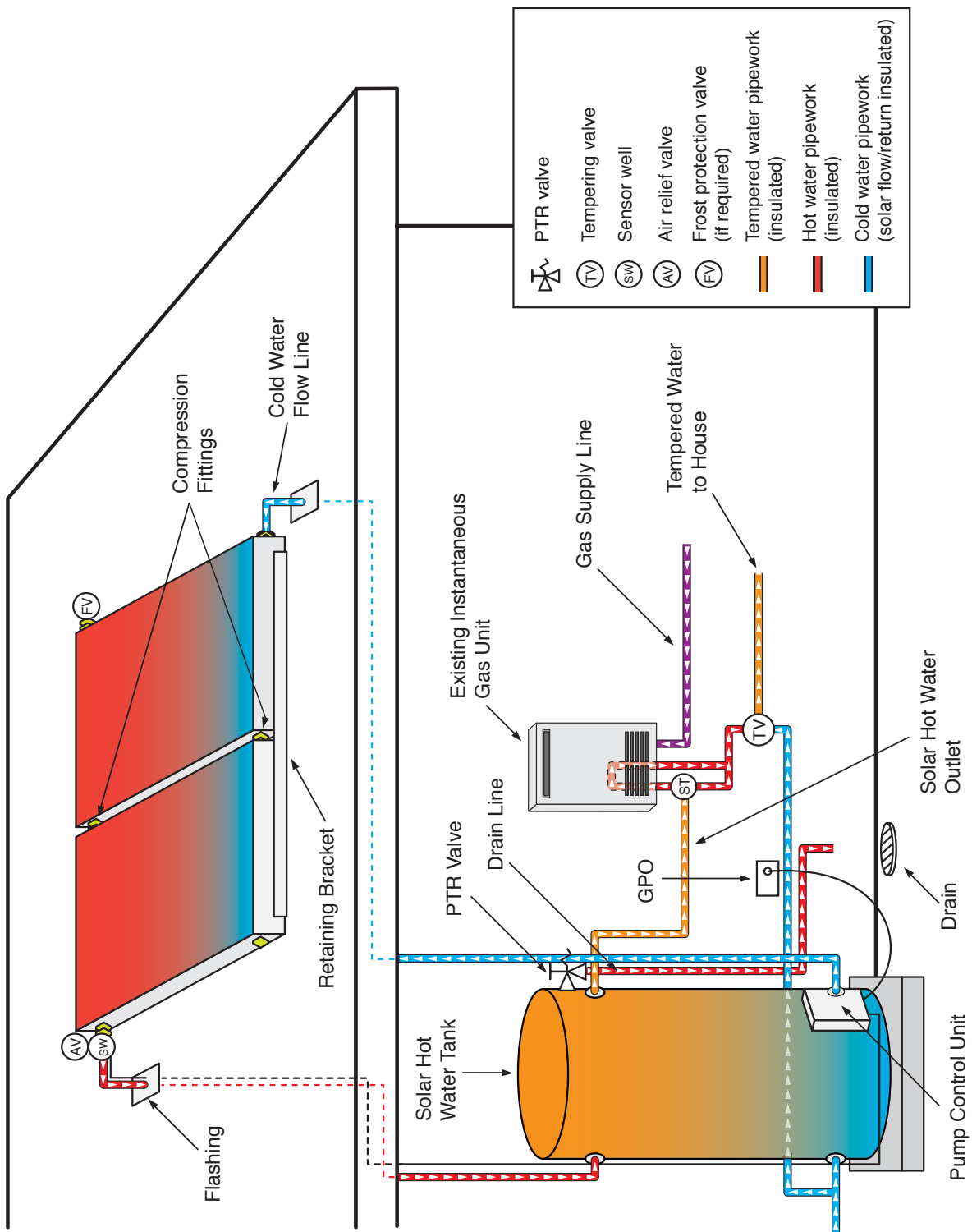
In most instances, retrofitted solar systems will receive less in the way of rebates if any and are ineligible for renewable energy certificates. This is because heating elements in conventional electric water heaters are installed towards the bottom of the tank, and the *Renewable Energy (Electricity) Act 2000* states that only approved SWHs are eligible for renewable energy certificates.

Preheating

In a preheat system, the solar collector is used to raise the temperature of water in a non-heated tank before a conventional water heater heats the water to the required temperature. Introducing warm water into the main water heater can significantly reduce the heating load and the energy required to heat the water.

Figure 6.4 shows a typical system layout for a retrofitted preheat system with an instantaneous gas primary heater.

Figure 6.4 Example of a preheated instantaneous gas system



6.2.3 Components

The standard components in a split system SWH are:

- (a) storage tank (direct heating or heat exchanger type)
- (b) collectors
- (c) auxiliary heating or booster element
- (d) sacrificial anode (vitreous enamel tanks only)
- (e) hot-water PTR valve
- (f) cold-water valves
- (g) circulation pump
- (h) pump controller.

Collector panels

The collector panels can be of either flat plate design or evacuated tube design. The rule of thumb for split systems is 2m² for each 150L of storage.

Cold water entry

Cold water from the mains supply enters the bottom of the tank via a series of valves, as specified in AS/NZS 3500.4:2003, Figure 5.5. These are often in a cluster called a **combination set**. Their purpose is as follows:

- (a) isolating valve—allows isolation and maintenance of the system
- (b) line strainer—filters larger particles from the water
- (c) non-return valve—prevents back-flow of water into the mains (not required for a low-pressure system with float valve)
- (d) pressure-limiting valve—reduces mains pressure to below the maximum rated pressure of tank and collector (not required in all situations or on low-pressure, vented systems)
- (e) cold-water expansion valve—releases cold water rather than hot water due to pressure build-up as the water in the storage tank is heated and expands, thereby preventing wastage of hot water and protecting the tank from excessive pressure; the pressure setting should be about 200 kPa less than for the PTR valve (typical cold-water expansion valve pressure setting is 500 kPa—AS/NZS 3500.4:2003, Table 5.2).

The cold-water inlet pipe connects to a diffuser or spreader pipe running part of the length or the full length of the tank at the bottom. The diffuser pipe reduces the water velocity and limits mixing of hot and cold layers in the tank. This helps maintain stratification of water temperature, thereby keeping the hottest water at the top of the tank.

Hot water exit

After water is heated in the collectors, it passes into the tank through the hot-water inlet at the opposite side of the tank from the cold-water inlet. The hot-water inlet is usually located about halfway up the tank.

The hot water entering the tank rises to the top of the tank, causing some mixing of the water in the top half of the tank as it enters, although the hottest water will always rise to the top of the tank. Hot water is drawn off from the very top of the tank through either a top diffuser pipe or a scoop.

The water exits via a **PTR valve**. This valve protects against excessive temperature (>99°C) and pressure (>1 MPa); its typical pressure setting is 500 kPa (under AS/NZS 3500.4:2003, Table 5.2). If either of these conditions is exceeded, the valve opens and dumps a large quantity of hot water through a drain or soakage trench.

According to AS/NZS 3500.4:2003, clause 2.4.3 (Plastic pipes and fittings), no plastic pipes or fittings can be used as drain lines from the PTR valve.

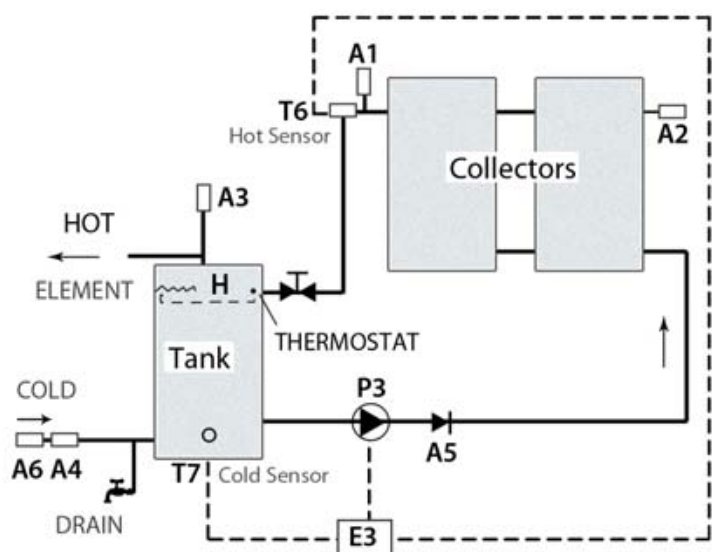
Additional safety components

A split system SWH has additional valves to ensure efficient and safe operation:

- A non-return valve after the pump eliminates reverse flow back to the tank when the pump is not operating. This reverse flow is sometimes referred to as reverse thermosiphon.
- An air eliminator valve at the highest point in the system purges any air trapped in the system when the system is commissioned or after the water supply has been disconnected.
- Pressure and temperature release valves on the collectors and tanks ensure that the pressure does not increase beyond the rated pressure (typically set at 500kPa) or above the rated temperature (99°C).

These elements and their locations, which are included in AS/NZS 2712:2007, are shown in Figure 6.5.

Figure 6.5 Example of the placement of additional valves for safe and efficient operation



Legend

A1	Automatic air vent
A2	Pressure/temperature relief valve
A3	Pressure/temperature relief valve
A4	Combination strainer, stopcock non-return valve
A5	Non-return valve
A6	Pressure-limiting valve
H	Auxiliary heater
P3	Collector circuit pump
E3	Electronic pump controller

Pumps

Pumps used for SWH systems must be able to operate for long periods, with temperatures of the pumped fluid reaching 100°C. They must also withstand the effects of water quality at these temperatures.

The amount of energy used to run one of these pumps is estimated to be less than 5% of the total 'solar gain' (energy equivalent for heating that volume of water) for the year. The cost for power to run the pump is around \$15 per year, based on an electricity price of 20 cents/kWh.

AS/NZS 3500:2003 requires a non-return valve to be fitted between the pump and the solar collectors.

Pump controllers

Two types of pumps are available:

- (a) simple controllers that only switch the pump on and off
- (b) smart controllers that control both the pump and booster switching.

Simple controllers for pump only

The pump must be controlled so that it does not run continuously and therefore cause the water to be cooled down at night. Several methods can be used to ensure that the pump runs only when solar energy is available. The most common type is a differential temperature controller.

Differential temperature controllers rely on temperature information received from thermistors (small temperature-sensitive resistors) placed at various points on the hot-water circuit. Some controllers use two sensors, whereas others use three or more. With two sensors, one is placed at the outlet from the collectors and the other at the bottom of the tank. They measure the temperatures at each location and send that information back to the temperature controller. When the controller sees a difference of 7°C to 10°C between the sensors (this varies a little from controller to controller), it will turn the pump on. As the water is pumped through the collectors, the difference in temperature will be gradually lost until the controller turns the pump off at a difference of about 2°C. With this system, the pump turns on and off all day. Similar units are used by solar pool heating manufacturers.

Other, less common, pump control systems are also available:

- (a) A 24-hour timer to turn the pump on and off. The timer can be set to operate the pump between, say, 9am and 4pm. It does not have an automatic sensing system to tell it to turn on when a frost is imminent. Also, if the flow rate through the collector is too high or the flow persists for too long under poor solar conditions, the water may be cooled rather than heated
- (b) A switch operated by a photoelectric cell, with a light sensor that turns the pump on during daylight hours. This switch has similar problems to the timer switch
- (c) An appropriately sized photovoltaic module to provide power to a DC pump. In this case, no differential controller is required, as the photovoltaic output and hence the pump flow rate will increase and decrease in proportion to the solar energy available. However, a maximum powerpoint electronic controller will be required between the photovoltaic module and the DC pump.

Other controller functions

The controller will also turn the pump on if the water temperature drops to between 3°C and 5°C, as an antifreeze function. In some cases, there is a third sensor, mounted at the bottom of the collectors, which is used to switch the pump on when freezing conditions occur. Water starts to expand at 4°C and continues expanding until freezing is completed at 0°C. This expansion will burst the tubes in the collectors or pipework. The pump switches off when the water in the bottom of the collector reaches about 7°C. This method does waste heat energy stored in the tank by passing hot water through the

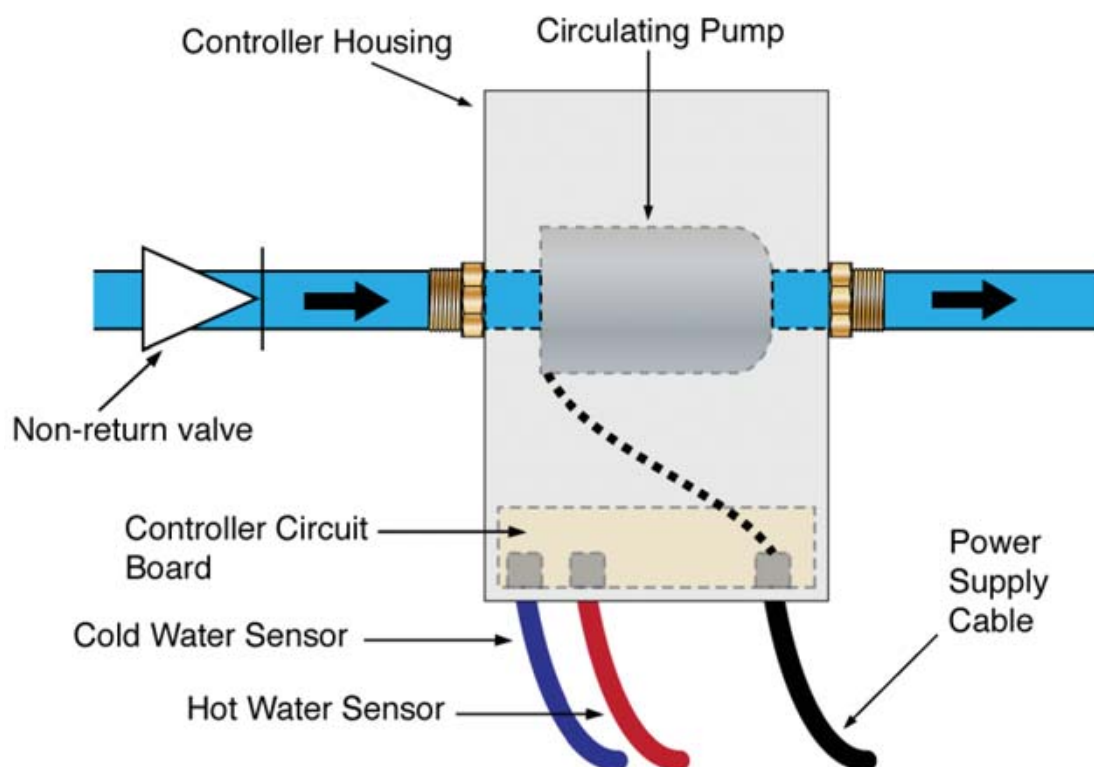
collectors and heating them a little, but protects the system from damage caused by freezing. Some manufacturers advise that the use of antifreeze dump valves should be combined with the pump circulation freeze protection, as a power failure will prevent the pumps and controller from working.

The controller can also turn the pump off to prevent overheating of the water in summer, for safety reasons or to prevent damage to vitreous enamel linings in mild steel tanks. Overheating can occur if the system is unused for a period. Some controllers will switch the pump off when the bottom tank sensor reaches 65°C. The thermistors are best fitted in a sealed tube that protrudes into the water flow. Sealing is important as water can greatly affect the accuracy and operation of the thermistor. For this reason, it is inadvisable to simply tape the sensors to the side of the pipe. If that is the only option, the thermistors should be set in heat-conducting paste and then covered with sealing tape.

Smarter controllers for pump and booster

More intelligent controllers are now available that aim to optimise the solar contribution while minimising booster use and meeting user hot water demands in all weather conditions. For example, one controller model uses three sensors, the third one being at the centre of the tank, see figure below. The sensors at the collector outlet and tank bottom perform the usual pump control for solar heating, freeze and over-temperature control. The third sensor allows monitoring of the amount of hot water in the tank and control of the boosting. By following an adjustable two-hourly temperature profile throughout the day, the third sensor will limit boosting to a preset (but user-adjustable) temperature for each two-hour period. This allows the user to boost sufficiently to meet their patterns of hot water demand, but avoid excessive boosting during daylight hours when the collectors will do most of the work (see Section 5.3 for more details).

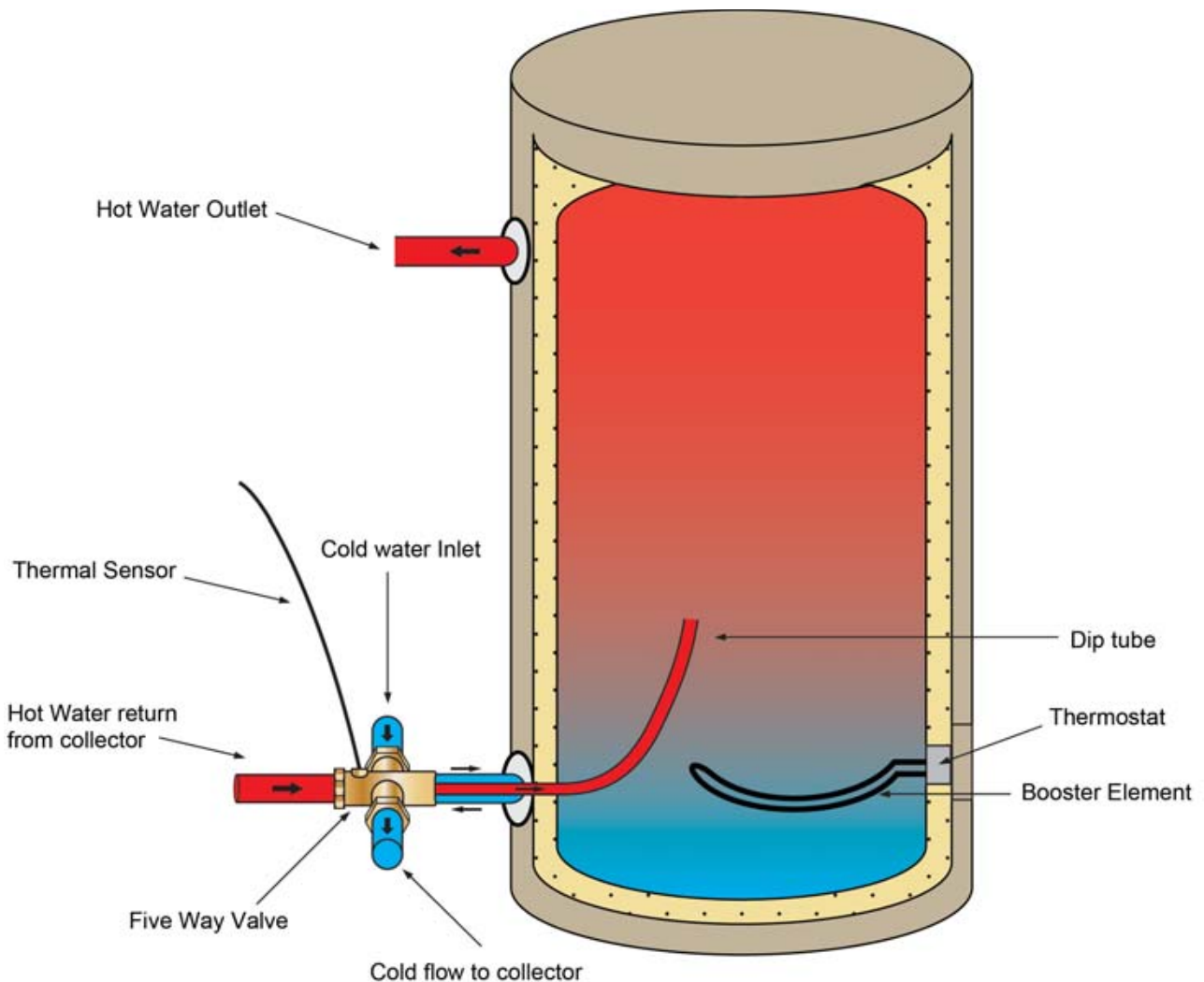
Figure 6.6 Integrated pump and pump control unit



Five-way connectors

If the system is being retrofitted to an existing storage tank, it can be connected using either pre-existing additional fittings or a five-way connector fitted to the cold inlet of the tank. In the five-way connector (Figure 6.7), cold water flows through one connection supplying the storage tank. The circulation pump then draws water from the storage tank—through another outlet on the connector—and circulates it to the solar collectors where the water is heated. The heated water returns to the storage tank through the hot-water inlet in the five-way connector and is then distributed to the middle of the tank via an upward-turned dip tube.

Figure 6.7 Five-way connector fitted to existing electric storage tank



6.2.4 Advantages and disadvantages of split systems

Split systems have the following advantages and disadvantages.

Advantages

- (a) More visually appealing to a wider customer base because there is no tank on the roof
- (b) Can sometimes be retrofitted to use existing storage tanks, which can help to reduce the cost to the user (although this may result in slightly lower system efficiencies)
- (c) Less roof work—no need to lift the storage tank or potentially reinforce the existing roof structure
- (d) Improved system performance because the tank or collectors can be located in more accessible or appropriate locations; the tank can be located close to point of use
- (e) Temperature stratification within the tank can be more easily maintained in a vertical storage tank.

Disadvantages

- (a) Often more expensive than thermosiphon systems due to the pump and controller costs
- (b) Power is required to run the pump and temperature controller; however, if a DC pump is run directly using photovoltaics, the power and control requirements can be negated
- (c) Require extra valves to ensure safe operation of the system
- (d) Higher system heat losses caused by longer pipe runs. In these situations, thicker insulation should be used.

6.3 Heat pumps

6.3.1 Operating principle

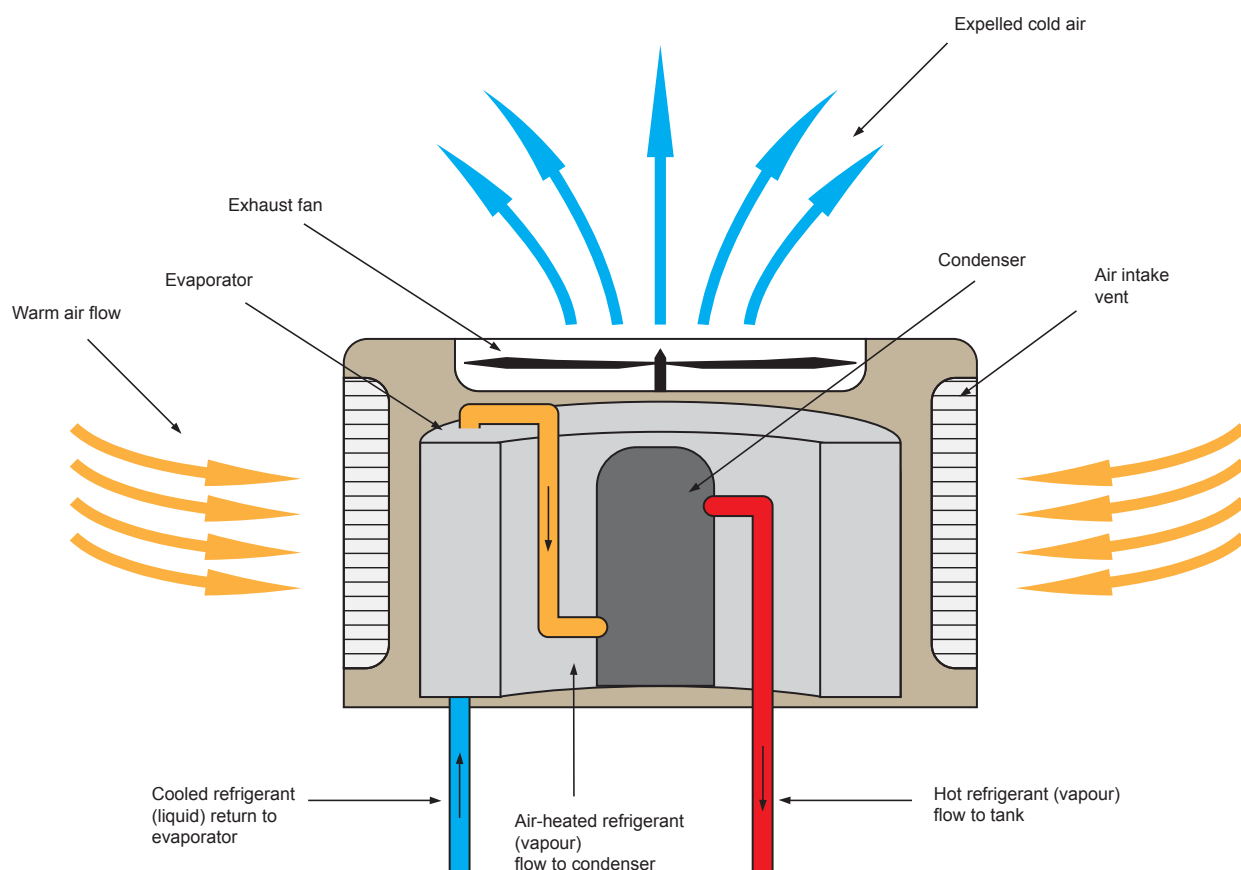
Heat pumps use the refrigeration cycle (as discussed in **Section 4.4.3**). Heat from the ambient air is absorbed by a refrigerant via a heat exchanger. The refrigerant then travels to the hot water tank, and the heat is transferred to the water via another heat exchanger. The cooled refrigerant then returns to be heated again.

6.3.2 Features and parts

Figure 6.8 demonstrates the components of a heat pump compressor:

- (a) air intake vent—warm air is drawn into the heat pump by a fan
- (b) evaporator—a heat exchanger that absorbs heat from the ambient air and transfers it to the refrigerant
- (c) exhaust fan—expels cool air that has already passed through the evaporator (see below)
- (d) condenser—a second heat exchanger that transfers heat from the pressurised refrigerant to the water in the storage tank
- (e) refrigerant (vapour)—stores heat absorbed from the ambient air, after the air passes through the evaporator, and is then passed through the compressor
- (f) compressed refrigerant (vapour/gas)—when the refrigerant is passed through the compressor, its temperature increases; the compressed refrigerant is then fed to the condenser, where it releases its heat
- (g) refrigerant (liquid)—returns from the water tank ready to absorb heat from the evaporator.

Figure 6.8 Example of a heat pump system



Cold water entry

Cold water from the mains supply enters the bottom of the tank via a series of valves, as specified in AS/NZS 3500.4:2003, Figure 5.5. This is often in a cluster called a **combination set**. Their purpose is as follows:

- isolating valve—allows isolation and maintenance of the system
- line strainer—filters larger particles from the water
- non-return valve—prevents back-flow of water into mains (not required for a low-pressure system with float valve)
- pressure-limiting valve—reduces mains pressure to below the maximum rated pressure of tank and collector (not required in all situations or on low-pressure, vented systems)
- cold-water expansion valve—releases cold water rather than hot water due to pressure build-up as the water in the storage tank is heated and expands, thereby preventing wastage of hot water and protecting the tank from excessive pressure; the pressure setting should be about 200kPa less than the PTR valve (typical cold-water expansion valve pressure setting is 500kPa)
- diffuser or spreader pipes—the cold-water inlet pipe connects to a diffuser or spreader pipe running part of the length or the full length of the tank at the bottom. The diffuser pipe reduces the water velocity and limits mixing of hot and cold layers in the tank. This helps maintain stratification of water temperature, thereby keeping the hottest water at the top of the tank.

Hot water exit

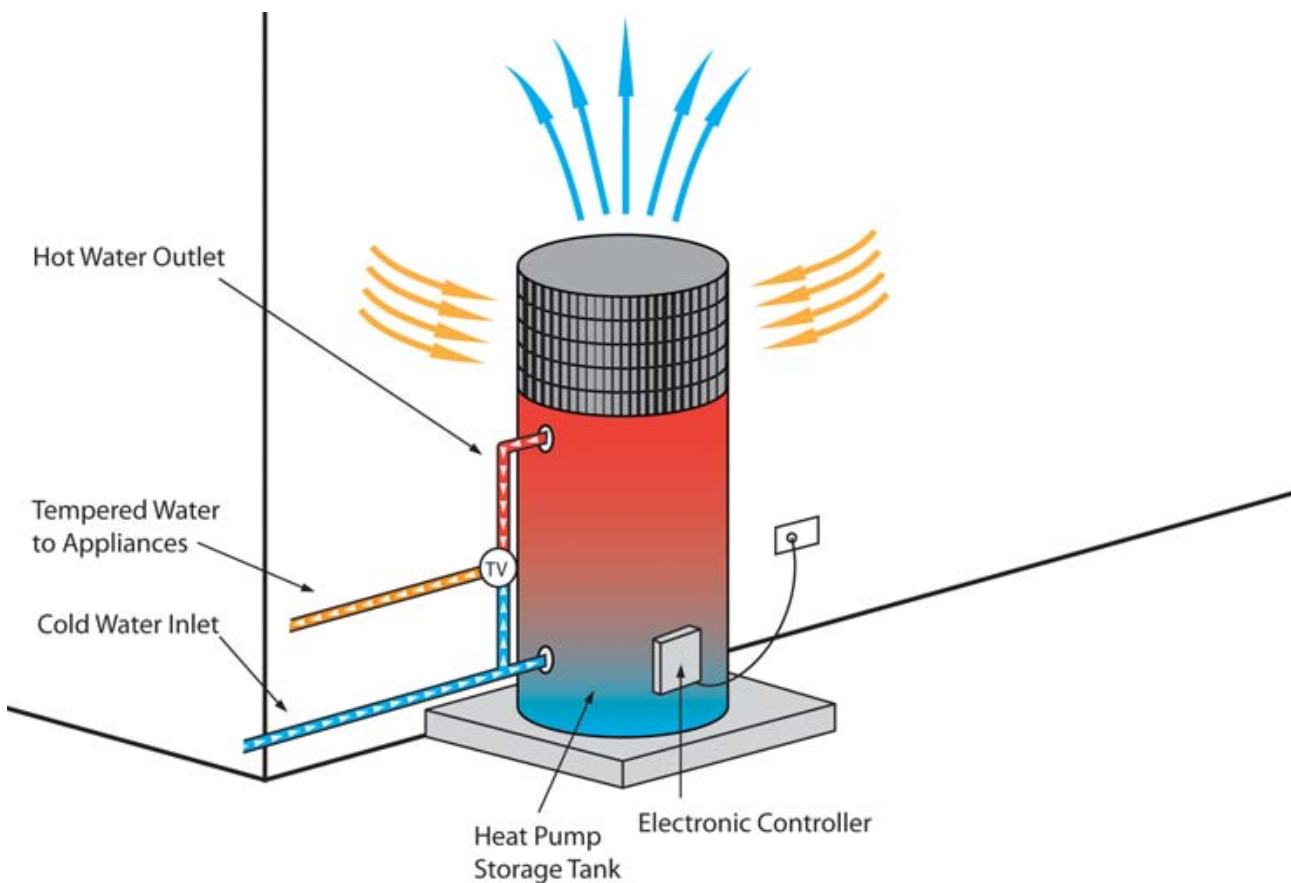
After water is heated in the collectors, it passes into the tank through the hot-water inlet at the opposite side of the tank from the cold-water inlet. The hot-water inlet is usually located about halfway up the tank.

The hot water entering the tank rises to the top of the tank, causing some mixing of the water in the top half of the tank as it enters, although the hottest water will always rise to the top of the tank. Hot water is drawn off from the very top of the tank through either a top diffuser pipe or a scoop.

The water exits via a PTR valve. This valve protects against excessive temperature ($>99^{\circ}\text{C}$) and pressure ($>1\text{ MPa}$); its typical pressure setting is 500 kPa. If either of these conditions is exceeded, the valve opens and dumps a large quantity of hot water through a drain or soakage trench.

Figure 6.9 shows the heat pump system in its entirety. The heat pump, with the warm air intake and cool air exhaust can be seen on top of the tank. Heat pumps can be sold as either an integrated unit including the pump and tank (such as that in the diagram), or a split system with the pump and tank located separately.

Figure 6.9 Integrated heat pump system



Features of this heat pump system are:

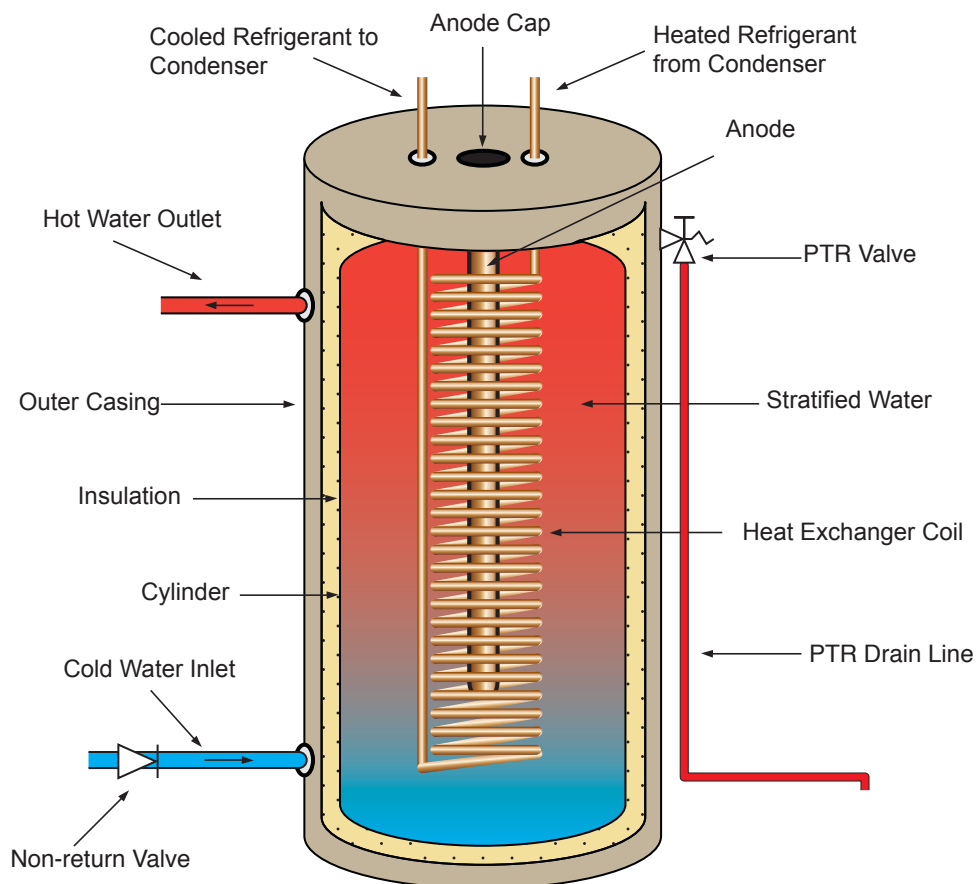
- General power outlet for powering of appliance—The compressor inside a heat pump is used to circulate the refrigerant, and electricity is used to power the compressor.
- Hot-water outlet/cold water inlet—where hot water comes out of the tank and cold water enters the tank. Inside the tank, the cold and hot water have stratified (refer Figure 6.9 and see Chapter 4). This is why the hot water is removed from the top of the tank and the cold water is delivered to the bottom of the tank.

- (c) Tempering valve—This valve mixes hot and cold water to ensure that the hot water that is delivered to the outlets inside the house is at a suitable and safe temperature (also used in conventional water heaters). Hot and cold water will be mixed once the hot water exceeds a set temperature.
- (d) Tempered water to internal features—Tempered water flows to the outlets in the house.
- (e) Electric controller—controls the operation of the fan and compressors, based on the temperature of the water in the tank and the surrounding air temperature. In some cases, this controller will also operate the boosting element.
- (f) Heat pump storage tank—where the hot water is stored.

In the above system, the heat pump system is installed on the top of the tank. Figure 6.10 shows the internal details of the hot water tank for the compact unit in Figure 6.9. A heat pump system can be supplied either as an integrated system or a split system.

In Figure 6.10, the condenser is immersed in the tank, and the pipes that carry the refrigerant to and from the condenser can be seen. If the tank is a vitreous enamel tank, a sacrificial anode (which can be seen in the middle of the tank) is required to prevent corrosion; this is not required for stainless steel tanks. There is also a layer of insulation that surrounds the tank in order to prevent heat escaping. The PTR valve (also installed in conventional water heaters), which operates if pressure becomes too high and/or if the water is too hot, is located at the top of the tank where the water is hottest.

Figure 6.10 Heat pump tank



The heat pump storage tank uses a heat exchange principle. The vapour from the compressor flows through a coil arrangement of copper pipes immersed in the cylinder or wrapped around it. The heat is transferred to the water in the storage tank by contact with the copper.

Figure 6.11 shows a heat pump with the condenser in contact with the inner tank. This tank also has an optional electric booster element, which can be used to heat water quickly if required.

Figure 6.11 Heat pump system with external heat exchanger

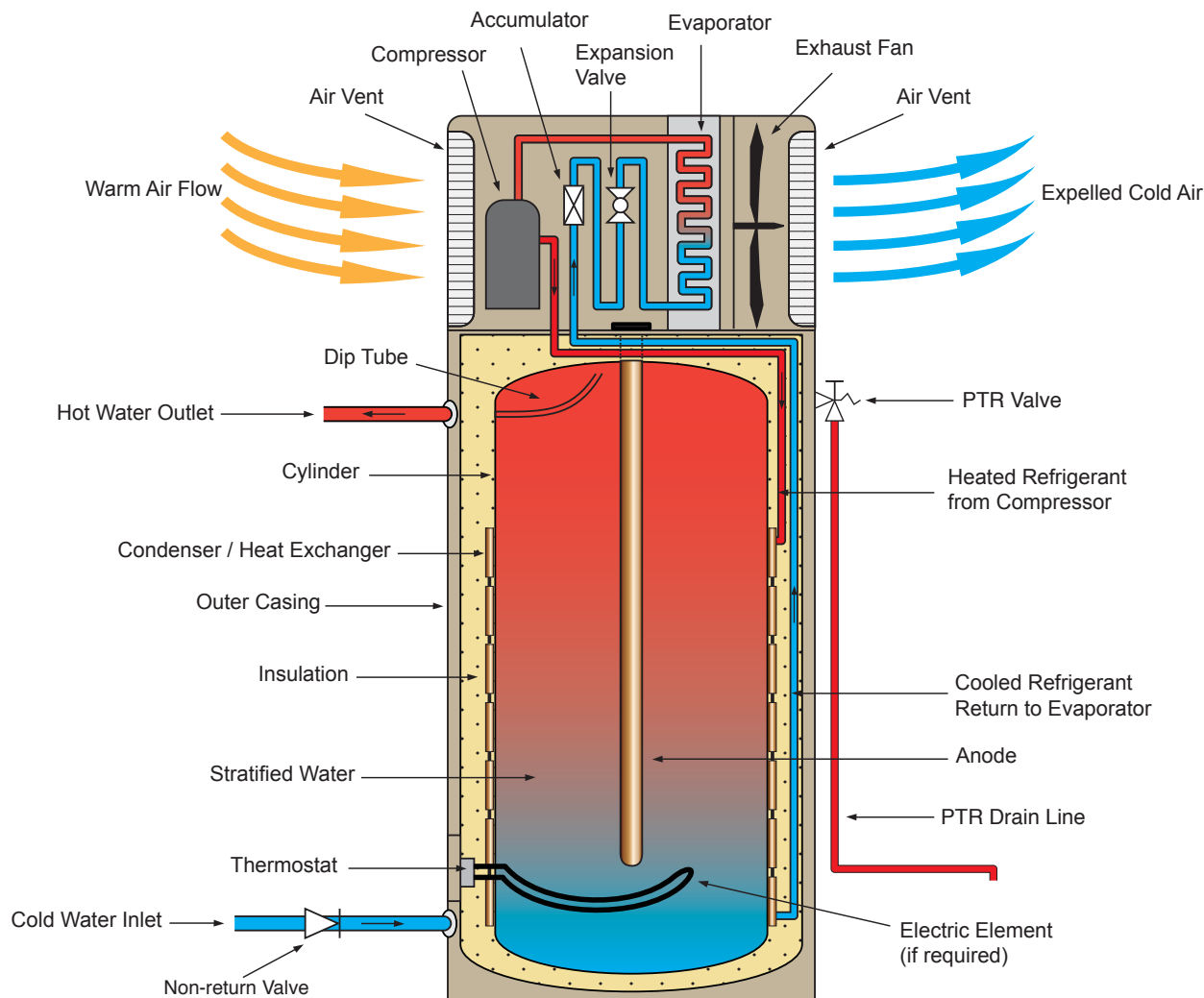
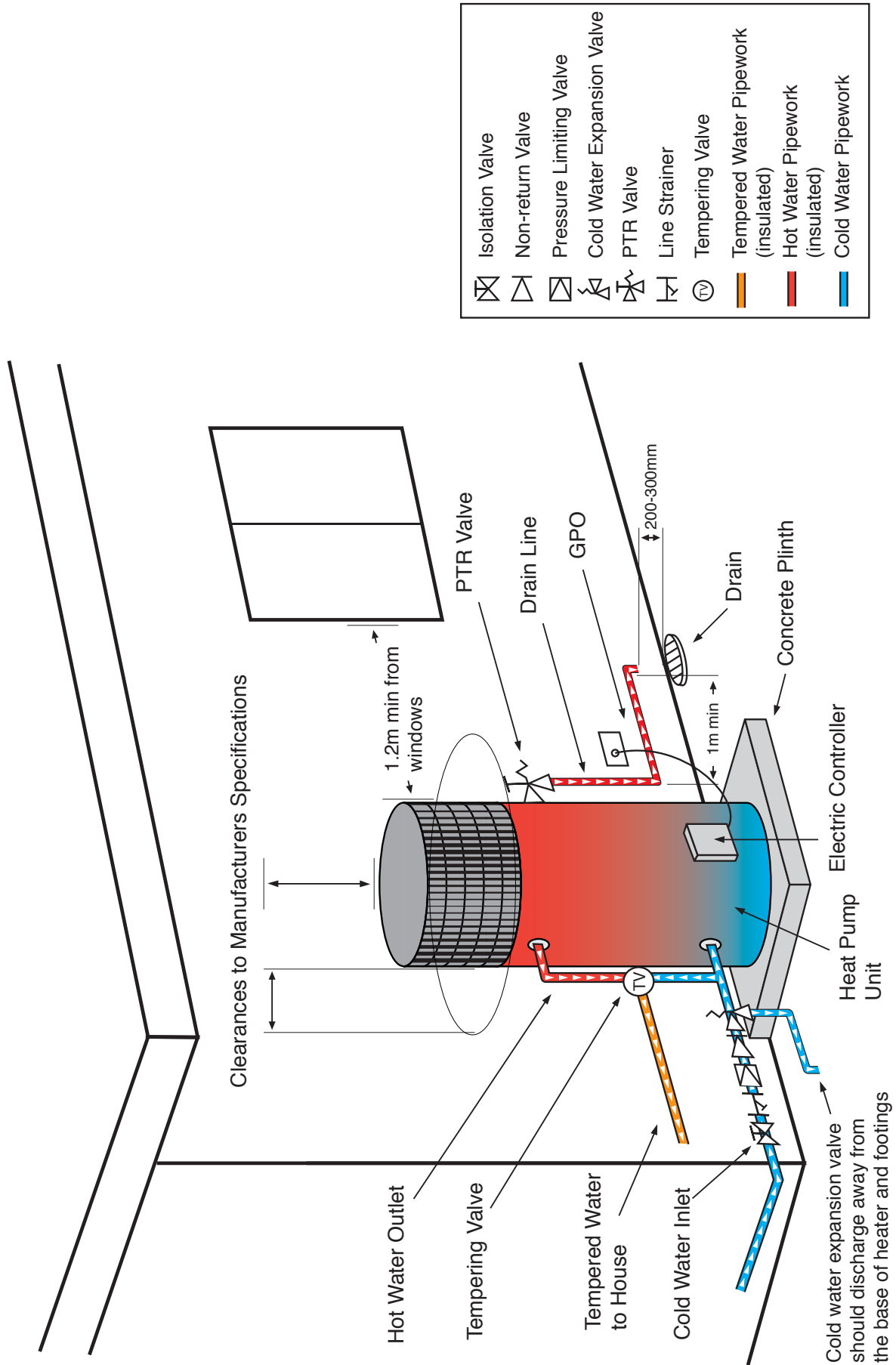


Figure 6.12 shows a heat pump with a PTR and condensate drain. The condensate drain is used to drain condensation, which can occur at low temperatures, away from the evaporator.

Figure 6.12 Heat pump installation with PTR valve and condensate drain



Figures 6.13 and 6.14 demonstrate two methods that are used to deliver hot water to the tank: the once-through or single-pass method and the multipass method. The single-pass method takes cold water from the bottom of the tank at a slow flow rate and delivers hot water to the top of the tank. This will provide hot water quickly, but takes a long time to heat the whole tank. The multipass method uses a pump to rapidly circulate cold water from the bottom of the tank and deliver hot water just above the cold-water outlet. This process continues, gradually raising the temperature of the water. It enables an initially high heat output, which reduces as the water temperature rises.

Figure 6.13 Single-pass method to deliver hot water to the storage tank

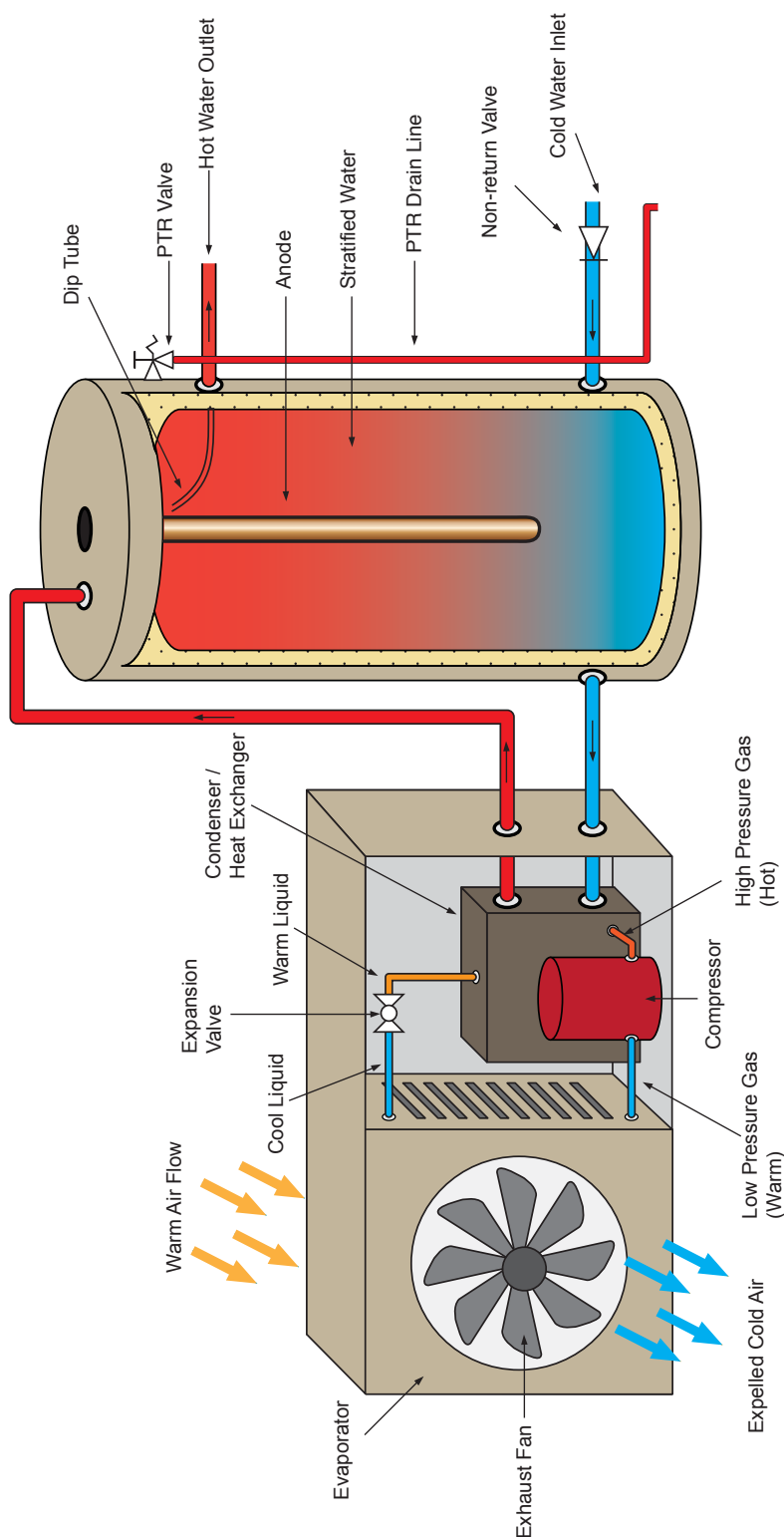
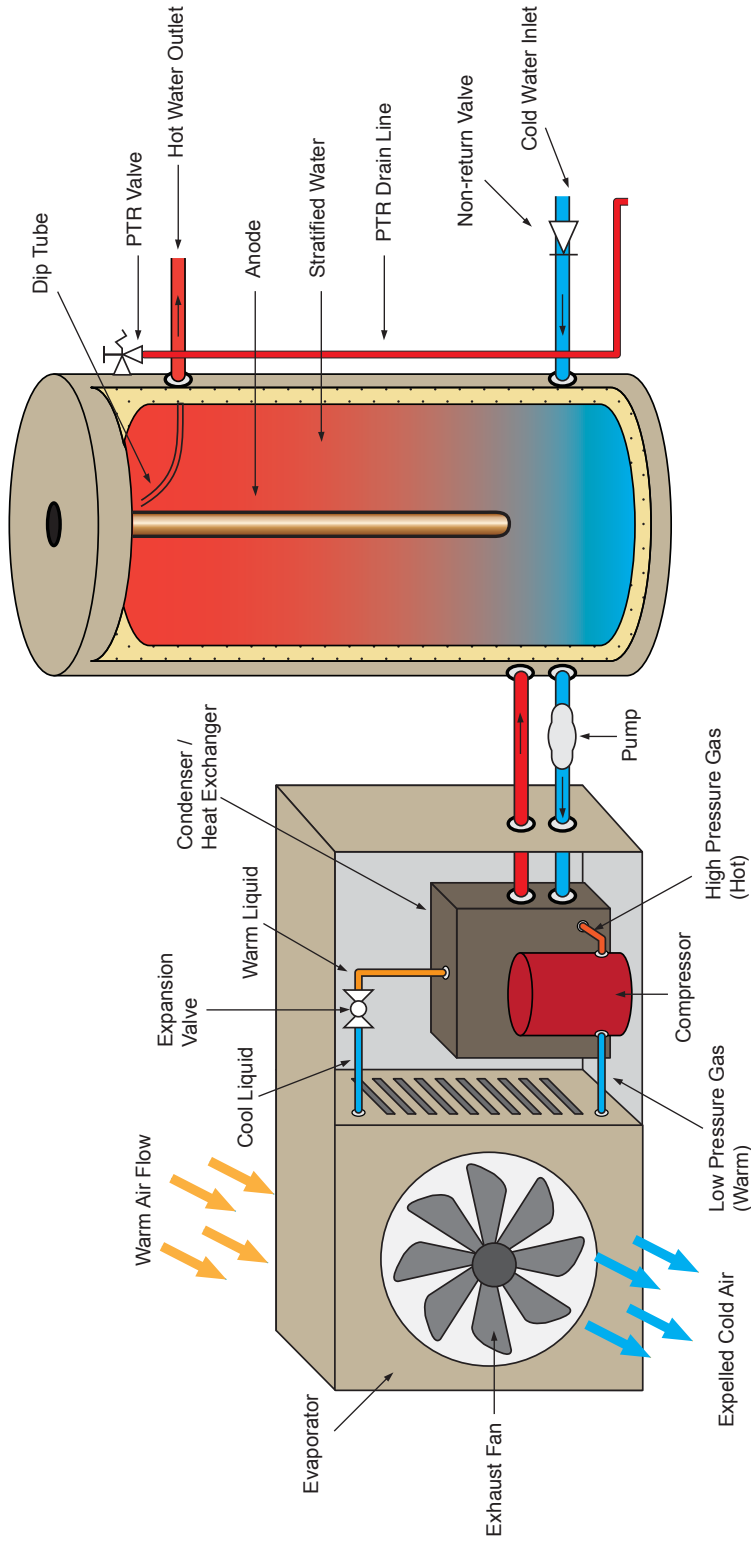
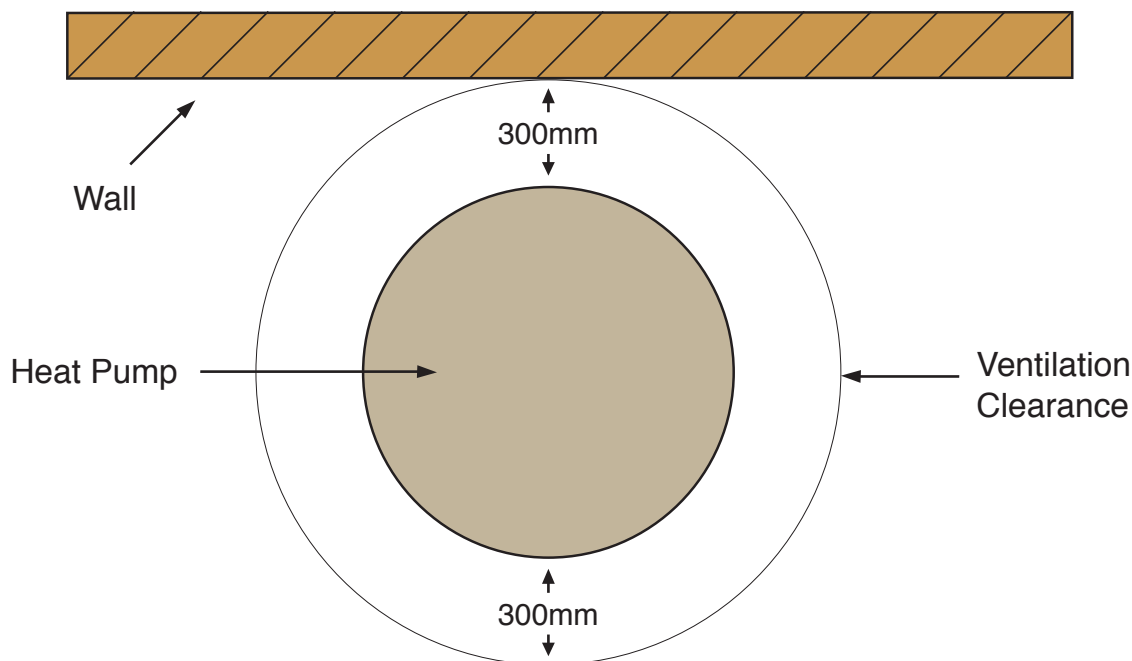


Figure 6.14 Multipass method to deliver hot water to storage tank



Care must be taken to ensure that air can flow in and out of the unit successfully, so that the heat in the air can be used and excessive amounts of expelled cold air do not pool and reduce the operating efficiency of the heat pump. Figure 6.15 shows the typical minimum ventilation clearances required for efficient operation. The manufacturer's installation instructions will confirm clearance requirements for specific heat pump models.

Figure 6.15 Typical clearances required for installation of heat pumps



(The manufacturer's instructions must be checked to determine the clearances required between the tank or heat pump and any solid structure.)

6.3.3 Advantages and disadvantages of heat pumps

Heat pump systems have the following advantages and disadvantages.

Advantages

- Require much less electricity than a conventional electric water heater. An electric water heater will convert 1 kW of electricity into 1 kW of heat energy, whereas a heat pump, which only requires electricity to operate the compressor, under optimal conditions can convert 1 kW into 3–4 kW of heat energy. This is because the refrigeration process has a high *coefficient of performance* (COP), enabling the system to access far more heat energy than electricity supplied to the process.
- Ground mounted, avoiding concerns about aesthetics on roofs or excessive weight on roofs.
- Split system option enables the heat pump to be located in an optimal location for performance and aesthetics.
- Will work in most conditions—for example, in cloudy conditions and at night—although they are more efficient in hot and humid conditions. Therefore, heat pumps can be a good option if solar hot water is not appropriate and the climatic conditions are suitable.
- Commonly have frost-protection measures (like SWHs) to prevent damage due to freezing at low temperatures. These include turning off the compressor when the temperature drops below a certain point but allowing the fan to continue operating (enabling the evaporator to defrost), or switching to an electric boost if one exists. They are also able to prevent overheating by switching off at high temperatures. When frost-protection methods are active, the boosting element will be required to meet all of the hot water demands.

Disadvantages

- Not suitable for cold climates.
- Generally more expensive than conventional water heaters.
- Use electricity. Heat pumps use much less electricity than a conventional electric hot water system, but usually more than the electricity used to boost an SWH system, and they still create greenhouse gas emissions.
- Can be noisy (similar to an air conditioner). Placement of the system needs to be carefully considered, and the noise of the heat pump running at night may breach noise restrictions or cause noise issues for neighbours. A split system heat pump can provide a solution, as the heat pump can be placed in a more suitable location.
- Off-peak tariffs are not advised because the compressor will only run for a limited time and sufficient hot water may not be produced; and off-peak tariffs are typically at night when the air is cooler, which will reduce the efficiency of the heat pump.



Chapter 7

Installation

Installation

7.1 Pre-installation

7.1.1 Standards

Solar water heater (SWH) and heat pump installations should comply with all relevant standards and manufacturers' requirements. The installation requirements include:

- AS/NZS 3500:2003, Part 4 (Heated water services), Section 6 (Installation of solar water heaters)
- AS/NZS 3000 (Wiring rules)
- AS 5601 (Gas installations)
- any other applicable standards, e.g. AS/NZS 1170.2 (Structural design actions—wind actions), AS/NZS 2712 (Solar and heat pump water heaters—design and construction), AS/NZS 4234 (Heated water systems—calculation of energy consumption), AS/NZS 4692.1 (Electric water heaters—energy consumption, performance and general requirements)
- Plumbing Code of Australia
- manufacturers' recommendations
- local government requirements, which will vary according to the state and local council area; it is the responsibility of the installer to confirm compliance
- occupational health and safety (OH&S) requirements (see Chapter 8)
- trade and insurance licensing requirements, which will vary according to the state and local government area; it is the responsibility of the installer to confirm compliance
- any other requirements that affect a particular installation (e.g. heritage-listed buildings, presence of asbestos roofing materials, streetscape planning).

7.1.2 Before installation

Almost every installation will have different requirements, such as access to the site, roof tilt, materials, climate, level of water use or the need for additional tradespeople (such as electricians). All elements of Chapter 8, relating to OH&S obligations, should be considered before pre-installation discussions and inspections.

To ensure that the installer can provide the best recommendation and an accurate quote for the supply and installation of an SWH or heat pump system, the customer's requirements and expectations and the suitability of the site for a given technology need to be determined. Table 7.1 provides a sample list of information needed or questions that the customer should be asked before the installer can provide a quotation or equipment recommendation. The reason for requesting the information is also shown.

In some cases, before visiting the property, site details can be requested from the customer, and it may be possible to view the property on Google maps (although images may be out of date or incorrectly labelled). The details in Table 7.1 can be requested before the visit to reduce the amount of time that the installer spends on site collecting the necessary information to provide a quotation.

An example of a customer contact record is shown in Figure 7.1. It includes many of the relevant details that should be addressed in conjunction with the customer information sheet in Table 7.1.

Table 7.1 Customer information sheet—examples of questions installers should ask potential clients

Issue	Question	Reason
Occupants/ bedrooms/ bathrooms	What is the maximum number of people who will be living there on a continuous basis?	To determine best type and size of SWH or heat pump system
Daily hot water usage	How much hot water is needed per day?	To determine best type and size of SWH or heat pump system
North-facing roof	Where do you want it positioned?	To see if there is enough roof space for collectors if required. To estimate the quantity of hot water able to be supplied from the roof-mounted collectors. Check Panels do not get shaded
North-facing roof	In which direction does the available roof space face?	To see if there is enough roof space for collectors if required. To estimate the quantity of hot water able to be supplied from the roof-mounted collectors
Roof pitch	What is the roof pitch of the proposed installation position?	To ensure proposed system will work properly and meet hot water requirements
Current location of storage tank	Where is your hot water system currently located?	If a direct replacement for an existing unit, distance from collectors on roof or gas/electricity supply could affect the installation difficulty and/or cost
Current location of storage tank	Is the current, or will the new, hot water storage tank be installed close to main hot water usage points?	For efficiency, it is recommended to install tank closest to main hot water usage points
Water pressure	What is the water pressure at the location?	SWH and heat pump systems assume water pressure at location to be 600–750kPA. If not within that range, other measures will be necessary
Roof material	How old is the roof? What material is it? Is the roof strong enough to support the weight of proposed system?	To further define workplace safety issues To allow installation requirements to be assessed and quoted accurately
Type of system proposed	Do you have any reservations about having collectors or evacuated tubes on the roof? If a close-coupled system is to be quoted, do you know that the tank and collector(s) will be on the roof and visible?	To ensure that the customer knows what the intended installation will look like
Local climatic conditions	Does the location experience any frost conditions?	To quote correct product and extras for local conditions as required
Building consent	Are there any local regulations that would impact on the installation of a roof-mounted product?	To inform the customer so that they can contact the local council to determine if there are any necessary approvals

Figure 7.1: Example of a customer contact record

Customer contact record			
Customer name:			
Address:			
Telephone:		Email:	
Installation address:			
(If different to 'Address' above)			
Site information			
Occupants:	Bedrooms:	Bathrooms:	
North-facing roof:	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
No. of storeys:			
Current location of storage tank:			
Daily hot water usage (if known):			
Water pressure (if known):			
Roof material:	<input type="checkbox"/> Tiles	<input type="checkbox"/> Steel	<input type="checkbox"/> Other;
Current HWS power supply:	<input type="checkbox"/> Standard day rate	<input type="checkbox"/> Off-peak rate	<input type="checkbox"/> Gas <input type="checkbox"/> LPG
Will new system require change to power supply rate?	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Will installation require services of licensed electrician?	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Proposed system profile—new systems			
<input type="checkbox"/> Close-coupled thermosiphon			
<input type="checkbox"/> Ground-mounted tank (split system: flat plate or evacuated tubing)			
<input type="checkbox"/> Gravity feed in-ceiling tank			
Tank required:	litres	Distance from collector(s) to tank:	metres
Proposed boost:	<input type="checkbox"/> Natural gas	<input type="checkbox"/> LP gas	<input type="checkbox"/> Electricity <input type="checkbox"/> Solid fuel
PTR (pressure/temperature relief valve) required?	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Safety tray required:	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Tank stand or	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Frost protection	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Mounting block required?	<input type="checkbox"/> Yes	<input type="checkbox"/> No	
Frost protection:	Required?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Proposed frost protection method:			
Roof orientation:	<input type="checkbox"/> North	<input type="checkbox"/> Northeast	<input type="checkbox"/> East <input type="checkbox"/> Southeast
	<input type="checkbox"/> South	<input type="checkbox"/> Southwest	<input type="checkbox"/> West <input type="checkbox"/> Northwest
Roof pitch:			
Party responsible for building consent (if applicable):			

When a site inspection is completed before a formal quote is provided, the appropriateness of the different technologies available should be assessed, so that a recommendation can be made to the householder.

According to AS/NZS 3500:2003, the storage tank must be installed as close as possible to the main hot water usage points. Some jurisdictions may have additional requirements. For example, in Queensland, under the Queensland Plumbing and Wastewater Code (legislated), water heaters are to be installed as close as practicable to the building's common bathroom for any new Class 1 building and for replacement hot water systems for existing Class 1 buildings, after 1 January 2010.

The matrix in Table 7.2 provides an outline of the requirements of different technologies relating to various design considerations. These should be taken into account when selecting the type of system to be used. 'X' indicates that the design consideration can be a factor to consider for that SWH or heat pump system technology.

Table 7.2 Design considerations for different SWH and heat pump technologies

Design consideration	Thermosiphon		Split system		Remote	Heat pump	
	Open	Closed	No boost	With boost		With boost	No boost
pH			X	X	X	X	X
Rainwater			X	X	X	X	X
Ventilation						X	X
Floor space			X	X	X	X	X
Plinth			X	X	X	X	X
Temperature						X	X
Roof structure	X	X					
PTR discharge			X	X	X	X	X
Cold water	X	X	X	X	X	X	X
PTR valve	X	X	X	X	X		
Isolator			X	X	X	X	X
Pressure	X	X	X	X	X	X	X
Solar access	X	X	X	X	X		
Aircon						X	X
Local/State regulation	X	X	X	X	X	X	X

7.2 Collector installation

If the installation is to be carried out in a high-wind or cyclone-rated area, the installer must ensure that any mounting structure to be used has been designed and certified for these conditions.

Before starting the installation, planning for the work should include a job safety analysis. The local state or territory OH&S regulations should be included in any site and/or installation assessment.

7.2.1 Considerations

Solar collectors can be difficult to lift onto a roof. Some manufacturers provide a service to place collectors on the roof, which reduces OH&S risks and the requirement for additional equipment. Where this service is not available, OH&S best practice should be observed. Once the collectors are installed on the roof, they should be covered until the system is commissioned. The temperature in empty collectors can rise to a very high level, potentially damaging the collector or posing a risk to the installer.

7.2.2 Installation principles

The manufacturer's installation instructions should be consulted before the system is unpacked and installation begins.

Collector mounting

Where possible, collectors should be mounted with a minimum clearance of 500mm from gutters (roof edges) on all sides. This is to help with access around panels for installation and maintenance. It also helps with wind performance and potential runoff from rain (preventing the run-off from jumping the gutter).

Flat plate collectors

Flat plate collectors can be installed flush with the roof in most standard installations. The exception to this is with systems that do not incorporate a pressure/temperature relief valve (PTR) or air-bleed valve at the highest point in the system. In these cases, the outlet side should be mounted 10mm above the inlet side to ensure that air bubbles exit the collector.

Mounting techniques

Different mounting techniques are used for metal and tiled roofs. Key points on installations are covered below.

Tiled roofs

Support straps need to be screwed firmly onto the trusses/rafters, not the tile battens. A section of tiles will need to be removed at each strap so that the trusses/rafters are exposed. This support strap is then bent to run flush with the trusses/rafters.

The front roof tracks are then attached to the support straps, with the top manifold attachments fixed to their respective locations.

Figures 7.2 and 7.3 show mounting of flat plate collectors to tiled roofs.

Figure 7.2 Collector strap moulded to rafter (tiled roof)

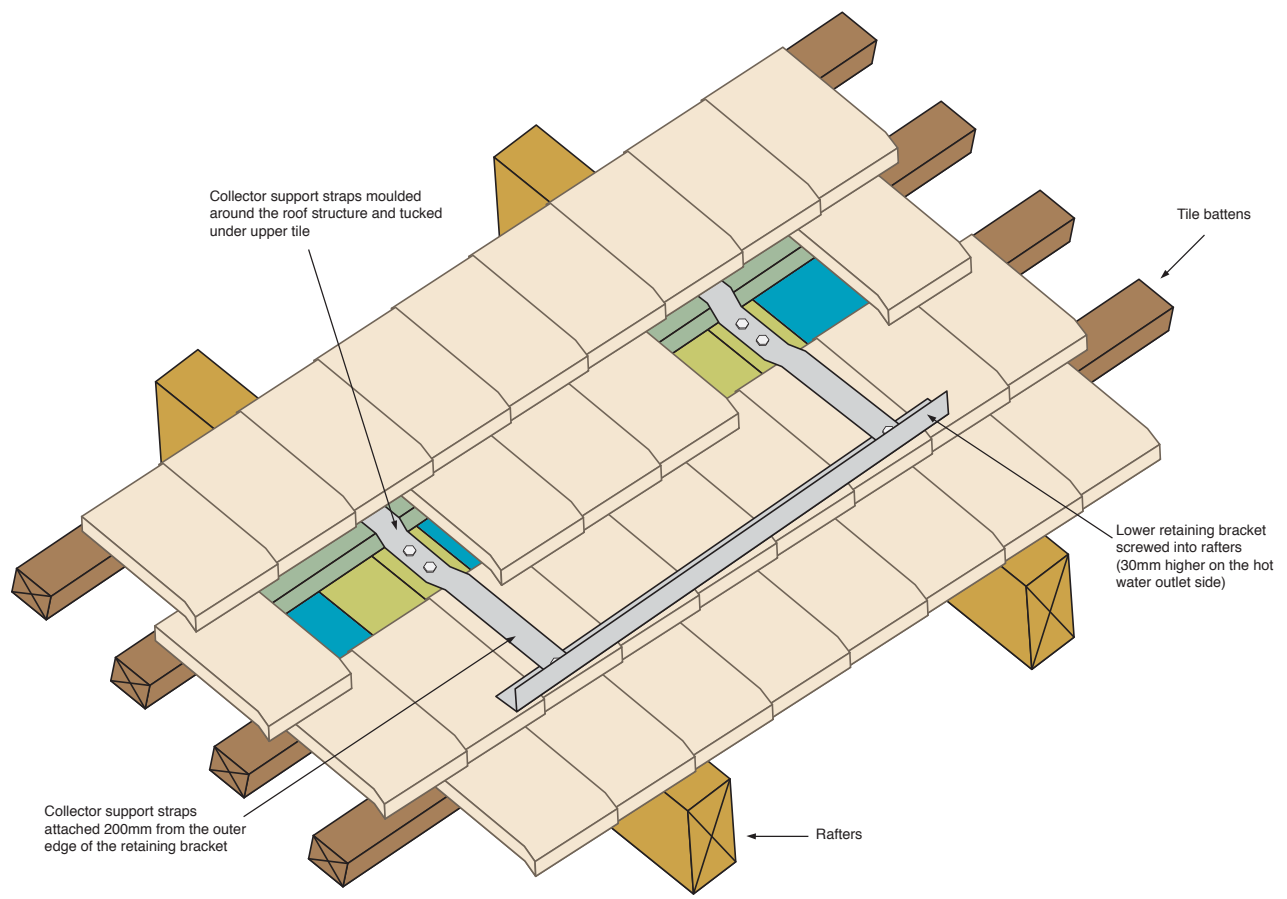
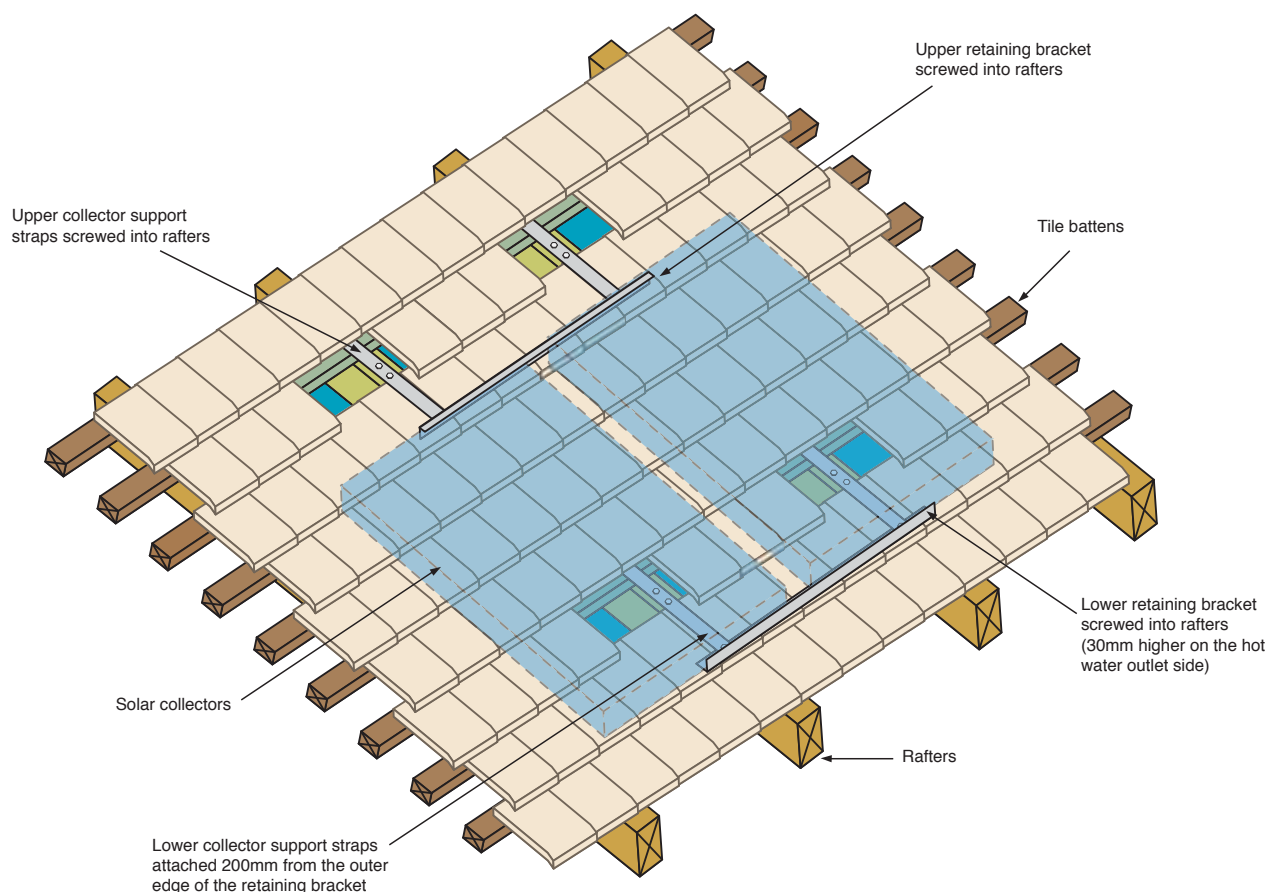


Figure 7.3 Collector straps mounted to a tiled roof.



Metal roofs

For metal roofs, the installer must ensure that the solar hot and cold pipes between the water storage tank and the solar collectors are:

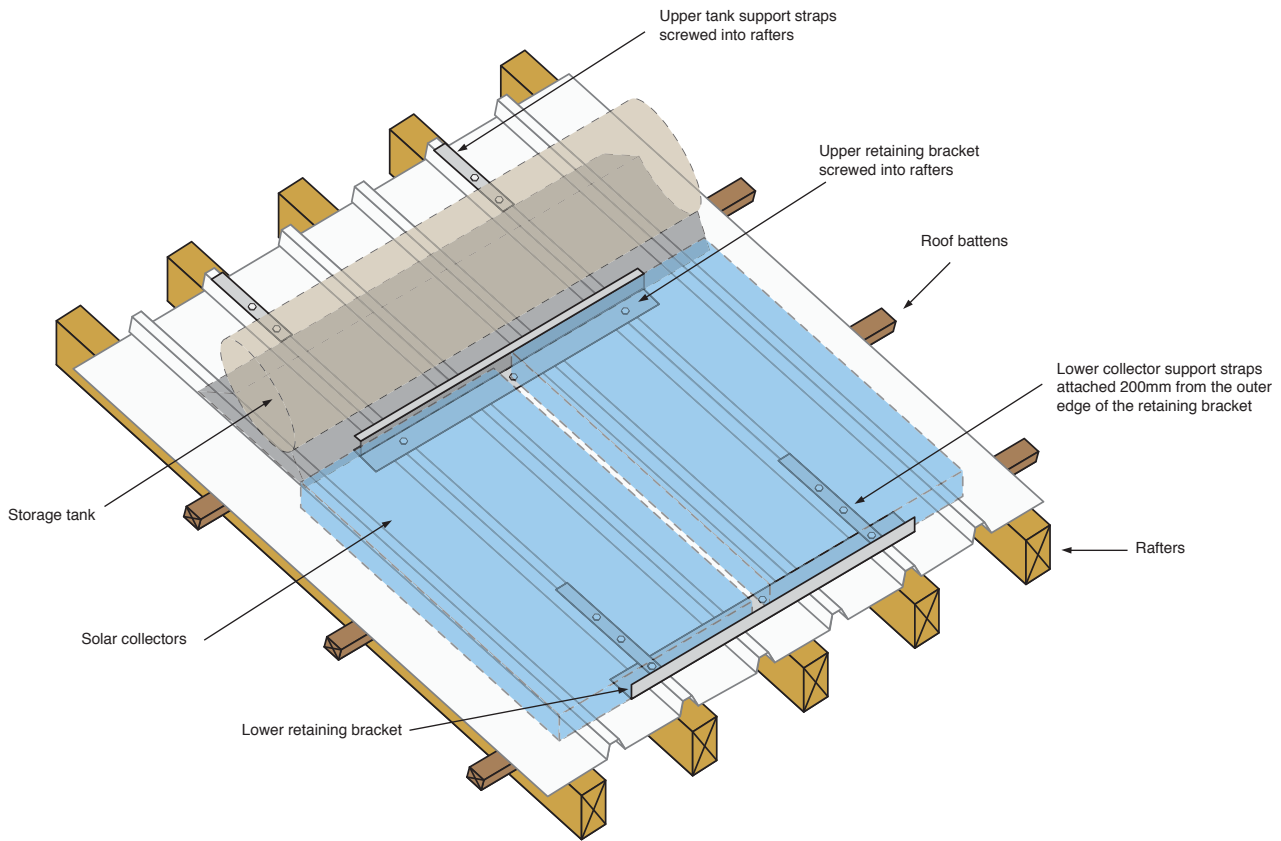
- (a) copper
- (b) fully insulated according to AS/NZS 3500.4:2003, clause 8.2.1(c) (Plumbing and drainage; heated water services), using insulation of a suitable material and thickness (minimum thickness 13mm)
- (c) weatherproof
- (d) UV resistant if exposed.

The insulation provides protection for the metal roof against any water runoff over the copper pipe. It will also reduce heat losses in the pipe and protect against accidental contact with the hot solar pipework.

Depending on the model of thermosiphon SWH installed, the insulation must be fitted up to the connections on both the solar collectors and the storage tank.

Figure 7.4 shows mounting of flat plate collectors to metal roofs.

Figure 7.4 Collector straps mounted to a metal roof



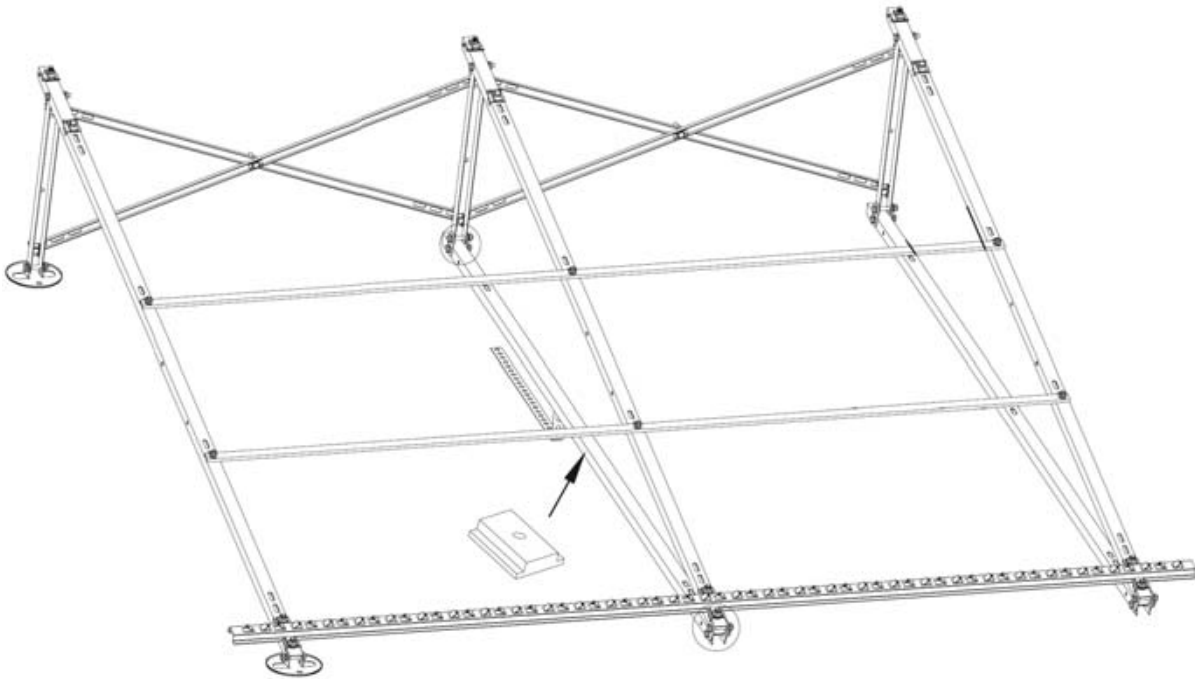
Evacuated tube collectors

Evacuated tube collectors use slightly different mounting frames from flat plate collectors. They can be attached to the roof in a similar way using straps or direct bolting; however, they have tube clips to safely hold the evacuated tubes in place.

For roofs where the evacuated tube collectors are to be installed flush to the roof plane, the system will have been supplied with the top and bottom support rails, as well as the device for securing the evacuated tubes to the top rail.

For flat roofs or roofs with insufficient pitch, the evacuated tube collectors will be mounted on a pitched frame. The system equipment will include the same top and bottom rails, plus the mounting frame for the elevation of the evacuated tube collectors. Figure 7.5 shows a typical evacuated tube raised mounting frame for use on suitably pitched roofs.

Figure 7.5 Example of mounting structure for evacuated tubes on a flat roof



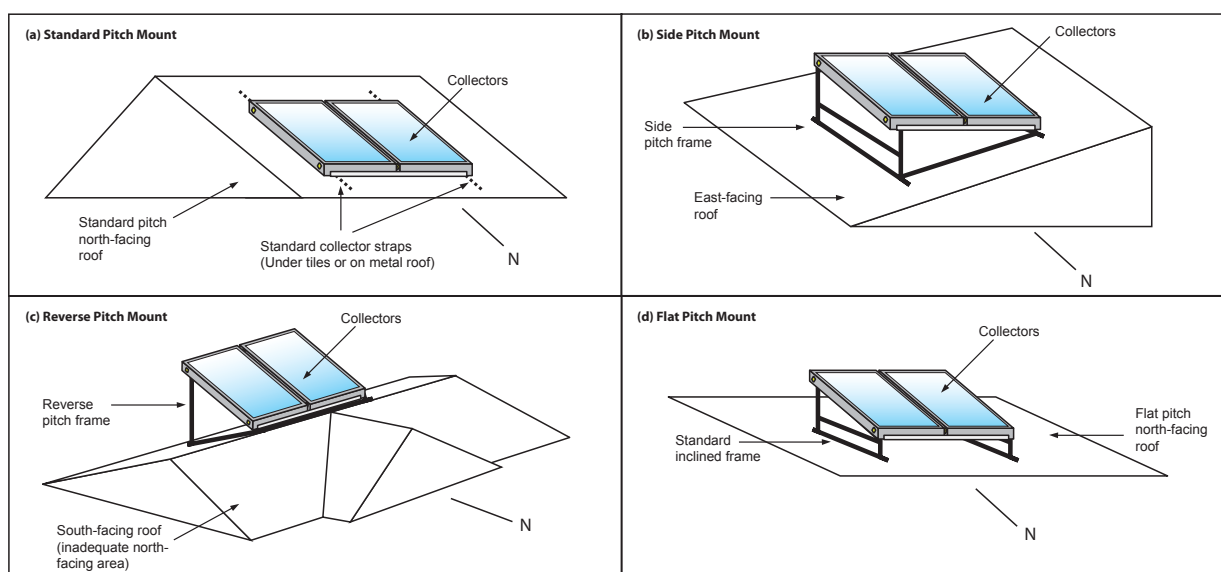
It is important to remember that the evacuated tubes should be exposed and connected as late in the installation process as possible, as a stagnant evacuated tube can generate temperatures above 170°C.

7.2.3 Mounting frames

Roofs do not always face north or have the correct tilt for an SWH system. To overcome this, a number of different mounting frames are commercially available to assist with installing SWHs in difficult locations. Figure 7.6 shows the different mounting orientations available. If any variation from standard installation is to be carried out, the manufacturer's instructions are required. If a frame needs to be modified for a particular installation, it is advisable that an engineer be consulted regarding structural integrity, especially in wind-prone areas.

Any mounting frame used must be 'fit for purpose'. Manufacturers of SHW and heat pump systems offer a range of purpose-designed and purpose-built framing that has been designed and manufactured for installation of the water heater equipment in a specified location.

Figure 7.6 Examples of different mounting techniques for difficult roof sections



Standard mounting

The standard mounting frame kit for an SWH system includes:

- (a) two horizontal mounting rails
- (b) four vertical straps to attach the rails to the roof
- (c) appropriate screws.

Timber is not a suitable framing material.

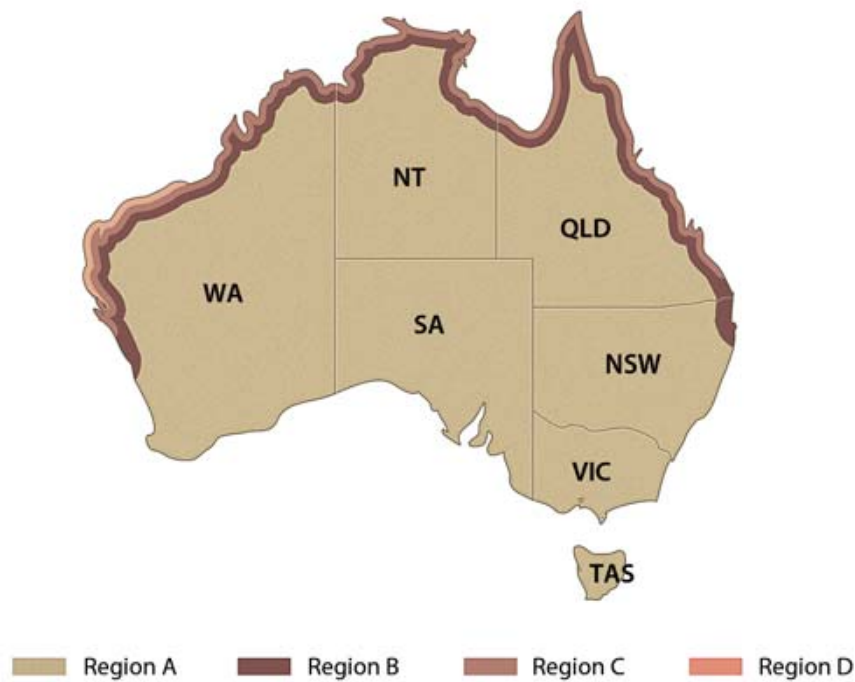
Cyclone frames

In areas prone to high winds or cyclonic conditions, collectors need to be mounted on a frame that will support wind loading in accordance with AS/NZS 1170.2 (Structural design actions—wind actions).

Cyclonic frames typically have both horizontal and vertical rails and additional roof attachment points.

Regions C and D in the map in Figure 7.7 are classified as cyclone risk areas.

Figure 7.7 Cyclone risk areas in Australia



Non-north-facing roofs

For roofs that are not north facing, mounting frames can be:

- (a) side pitched (for placement on east or west-facing roofs); it is important to ensure that the roof will not shade the system
- (b) reverse pitched (for placement on south-facing roofs).

Mounting frames must comply with AS/NZS 1170.2.

Flat roof frame

A flat roof frame is required if the customer has a flat roof or wants a ground-mounted system. The frame provides tilt.

Most flat roof frames come with a fixed pitch.

It is important to ensure that the frame complies with AS/NZS 1170.2.

Note: AS/NZS 1170.2 excludes areas affected by snow, which are covered by AS/NZS 1170.3 (Snow and ice action).

7.2.4 Thermosiphon systems

When installing a thermosiphon (close-coupled) system, the roof must be able to support the weight of the collectors and the tank full of water, which will be up to 700kg.

Upper retaining brackets are secured to the collectors so that pipe connections can be made without the connecting joints being stressed. It is important that the tank supporting straps are tight as these straps prevent the tank from moving down the roof when it is filled with water.

Usually only normal 15mm or 20mm copper tube and fittings are required.

The height difference and slope between the collector and the thermosiphon tank can dramatically affect performance. The following are general rules, but the manufacturer's installation instructions should always be followed:

- (a) The slope of pipes between collectors and tanks for thermosiphon units should be greater than 1:20—that is, for every 20cm of horizontal distance, the rise must be 1cm
- (b) A greater slope than 1:20 will result in better circulation
- (c) The top of the collectors should be at least 300mm from the base of the tank
- (d) If this cannot be achieved, an anti-reverse thermosiphon valve can be installed—this is a one-way valve that lets water through in only one direction.

7.2.5 Heat pumps

Heat pump systems have very different requirements for positioning and installation from SWH systems.

Heat pump systems:

- (a) will be more efficient if placed in a warmer location, as they will be required to run for a shorter time to heat the water to the set temperature
- (b) need to be well ventilated so that cold air can move away freely—check the manufacturer's recommendations
- (c) can be noisy, so they should be placed away from bedrooms and windows, and any night-time operation of the unit should be kept to a minimum.

Figures 7.8 and 7.9 show details of positioning of heat pump systems.

Figure 7.8 Heat pump installation, showing clearances

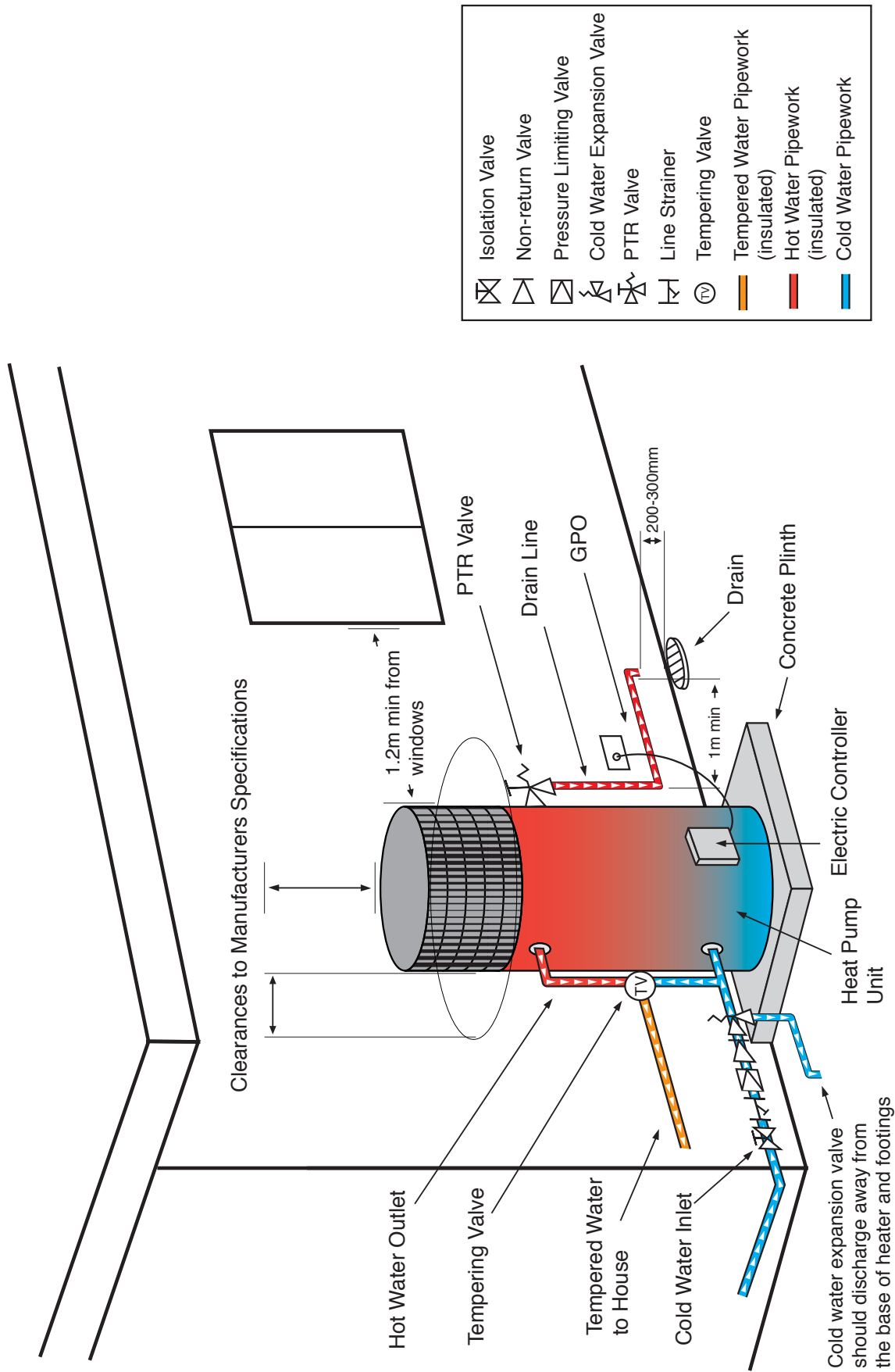
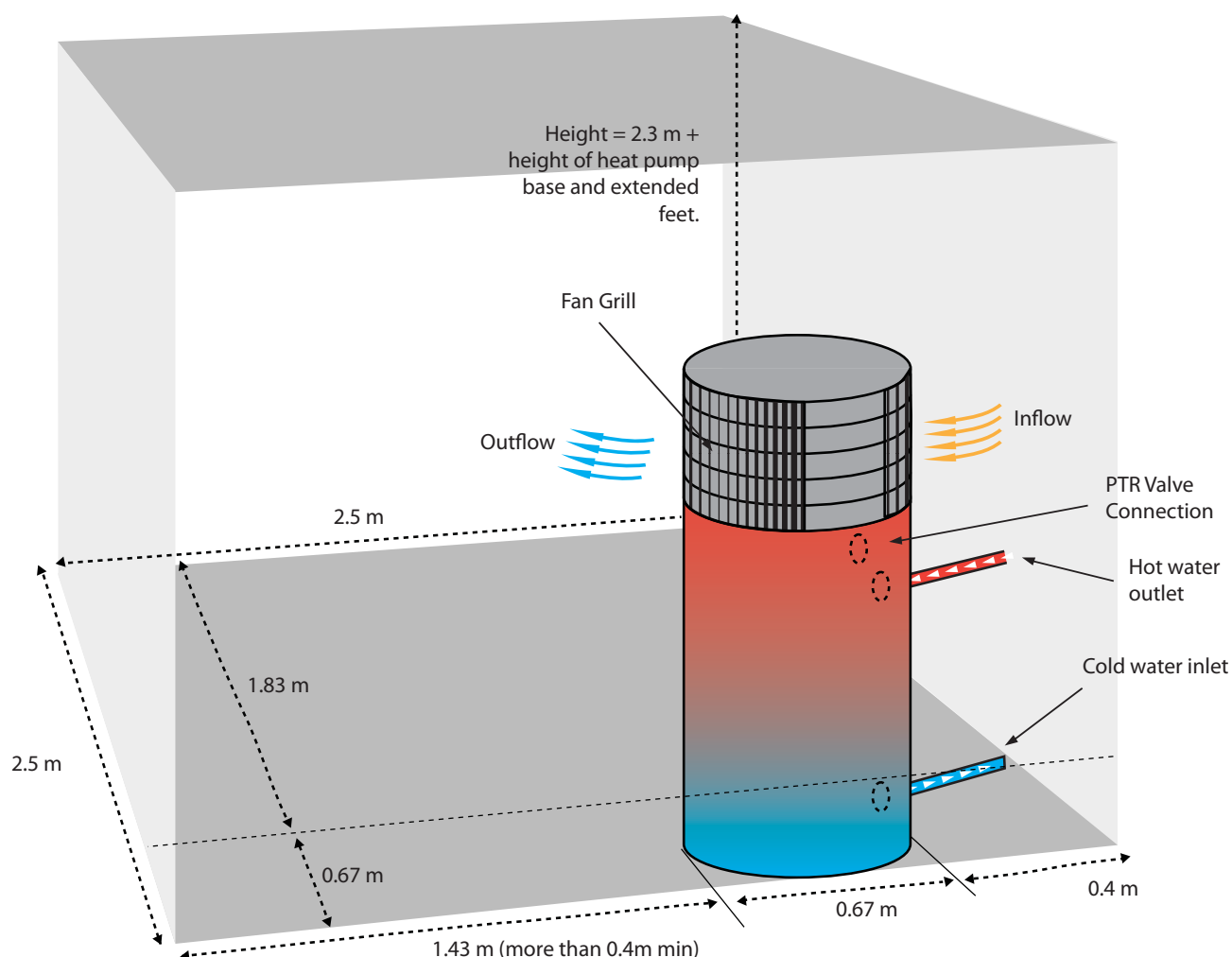


Figure 7.9 Example of a heat pump system in an enclosed room



In this installation, a flue may be required to the outside of the building.

If a heat pump unit is mounted incorrectly, the system fans can cause vibration and oscillation. It is important to check the clearances on all sides of the heat pump, as well as the fastening guidelines, to ensure that the system will not vibrate when it operates. Installation in areas where two parallel walls are close together should be avoided, as this can act to amplify the sound produced by the system and decrease user satisfaction.

The manufacturer's recommendations should be followed about appropriate water pressure for cold-water inlets. Where water pressure is too high, a pressure-limiting valve may be necessary.

Installation in ceiling cavities or roof spaces is not recommended for heat pump systems due to the heat pump's requirement for ventilation. Without sufficient ventilation, the roof space will quickly cool and the heat pump will not operate. In summer, roof spaces can be very hot, and may cause the heat pump system to overheat.

7.3 Installing balance of system

7.3.1 Tanks

Tanks can be either integrated or remote (stand alone). Regardless of tank location, there must be sufficient room for maintenance access, including the replacement of sacrificial anodes.

Interior tanks must be sat on a safe tray that drains to the outside of the building or to the floor waste. If the system is gas boosted, there must be sufficient ventilation to prevent build-up of exhaust gases.

Exterior tanks should always be installed on a concrete plinth according to manufacturers' specifications. The plinth must be level to prevent the unit vibrating and to prevent water entering the unit in wet conditions.

7.3.2 Pipework

It is essential that all pipework, connectors and fixtures used in an SWH or heat pump system are copper or metal to avoid the potential for melting and deforming of polymer pipes.

If the water pipe system contains conductive (e.g. metal) water pipe that is accessible within the building and is continuously conductive from inside the building to the point of contact with the ground, this pipe must be equipotentially bonded to the earthing system of the electrical installation. All electrical wiring, including connections of earth wires, must be undertaken by suitably licensed persons.

7.3.3 Insulation

All hot and cold water pipes and valves running between a storage tank and the solar collector or heat pump should be insulated when installing an SWH or heat pump system. This is to prevent heat loss from the pipes, which can have a significant effect on system performance. Insulation is also important for safety as the temperature of water exiting an SWH can be far higher than that in a standard hot water system; some components of a solar collector system can reach as much as 170°C.

Temperatures experienced in different locations will affect the thickness of insulation required; however, all insulation should be between 13mm and 25mm, with thicker insulation used wherever possible.

Where the insulation is outdoors or exposed to the elements, it should be UV rated and weather resistant to ensure longevity and effectiveness.

AS/NZS 3500.4:2003, sections 8.2 and 8.3, provide more details on the insulation requirements for hot water installations, including the requirement that all pipework connecting the tank and collectors should be insulated. This applies to both hot and cold water flow and return lines.

7.3.4 Electrical connections

All electrical connections to a solar or heat pump water heater system should be made by a qualified electrical contractor.

It is generally understood that the replacement of a conventional hot water system with a solar or heat pump hot water service does not constitute a 'like for like' replacement. Therefore, a restricted electrical licence is not sufficient in this case. Until there is a nationally consistent licensing scheme, different jurisdictions could have different regulations covering restricted electrical and plumbing licences, and it is advisable to check with the local authority.

The requirements for access to the electricity supply can differ between SWH and heat pump systems, either for their primary operation (heat pumps) or to run booster elements (SWHs) or pump controllers. These differences include whether the electrical connection can be hardwired from a 240V AC circuit or whether the mains supply must be via a dedicated powerpoint, and whether an isolator is required at the point of electrical connection.

As noted below, the electric or gas booster for an SWH is required to ensure water quality safety—hot water cannot be stored at less than 60°C, to ensure that *Legionella* bacteria cannot be present in the water. An electrical circuit is necessary for electric boosters to provide the primary power, and is also required for gas-boosted systems because the electrical circuit provides the starter ignition for the gas system.

Points relating to electrical connections for various components are provided below.

Pumps and pump controllers

- (a) Many manufacturers have the pump unit wired into a standard power plug
- (b) An electrician may be required to install a powerpoint. If this is to be installed outdoors, the unit must be rated for outdoor use
- (c) The pump and pump controller must be connected to continuous tariff electrical supply to ensure that the pump and/or controller can operate at any time of the day or night (e.g. for frost protection).

Electric booster element

- (a) Electric booster elements are typically hardwired into a separate electrical circuit dedicated to the water heater
- (b) The booster element can operate on either continuous or off-peak tariff
- (c) Any electrical connections to roof-mounted SHW systems (e.g. thermosiphon systems) will require adequate waterproofing.

Gas booster ignition

- (a) Gas booster ignitor are typically connected either through the same plug and general power outlet as the pump system, or through a separate general power outlet or hardwired connection
- (b) All gas booster ignitors should be connected to continuous tariff electricity as they must be able to function at any time so that water can be raised to 60°C to prevent the development of *Legionella*.

Heat pumps

- (a) Heat pumps require a standard 10A connection. Depending on the manufacturer's requirements, this can be either hardwired or connected through a general power outlet.

7.3.5 Cold water supply

The way in which the cold water supply is connected to an SWH or heat pump system can, as in traditional hot water services, dramatically affect performance. Following are some specific circumstances where a particular valve should be used.

Isolating valve

For close-coupled or remote thermosiphon systems, AS/NZS 3500.4:2003 requires that the isolating valve is 'readily accessible from floor or ground level'.

Readily accessible means 'capable of being reached quickly and without climbing over or removing obstructions, standing on a chair or using a moveable ladder and in case not more than 2 metres above the ground, floor or platform' (AS/NZS 3500.4:2003, clause 5.9.3(a)).

An isolating valve at the storage tank is also advisable. It should be installed in compliance with AS/NZS 3500.

Expansion valve

The expansion valve should also be readily accessible from floor or ground level.

Leakage

The isolating valve and expansion valve should be located where leakage is not a problem—for example, above a floor drain.

7.3.6 Frost protection

Frost protection is essential to protect against low or freezing temperatures. It can involve either an indirect heating system with glycol or glycerine in collectors, a heat exchanger, or frost-protection valves.

Valves are cheaper but less reliable and are usually installed opposite the air-bleed valve.

Split systems use pumps to circulate water through the collectors when the temperature drops below a certain point. However, this could be risky if the power supply is unreliable.

See Chapter 5 for details.

7.3.7 Tempering valve

AS/NZS 3500.4:2003, clause 1.91, requires that heated water in the tank is stored at a minimum of 60°C to avoid the growth of *Legionella* bacteria.

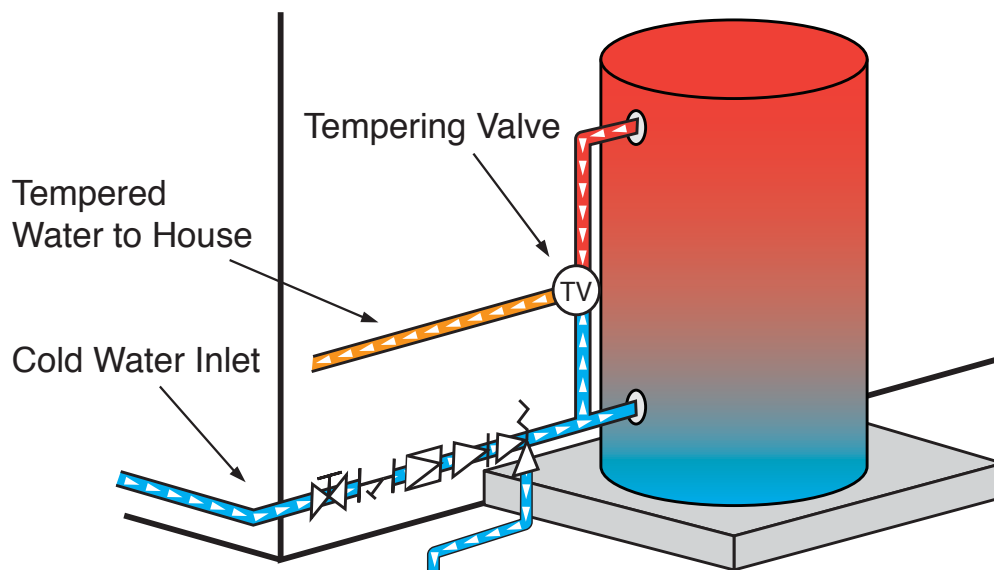
Installation of a tempering valve is required under AS/NZS 3500.4:2003 for all new and replacement water heaters. It is an important safety requirement to reduce the risk of scalding. A tempering valve mixes hot and cold water to ensure that heated water delivered to sanitary fixtures is at less than 50°C (AS/NZS 3500.4:2003, clause 1.92). If a tempering valve is not installed, temperatures close to 100°C can occur in hot water pipes.

The pressure must be the same for hot and cold water at each side of the tempering valve.

According to AS/NZS 3500.4:2003, the tempering valve must be installed in a position that is readily accessible (Figure 7.10).

It is the responsibility of the installer to check local requirements as there can be different regulations between jurisdictions in relation to the installation of tempering valves across domestic and commercial hot water supplies.

Figure 7.10 Location of tempering valve



7.3.8 Use of rainwater

Acidity can be a problem if rainwater is used as the water supply. A filter with an internal cartridge may be needed to reduce acidity and suspended solids.

7.3.9 Flashings

Suitable flashings are needed for supply and return lines, such as:

- (a) Dektite
- (b) lead collars
- (c) silicon rubber
- (d) Ethylene Propylene Diene Monome (EPDM).

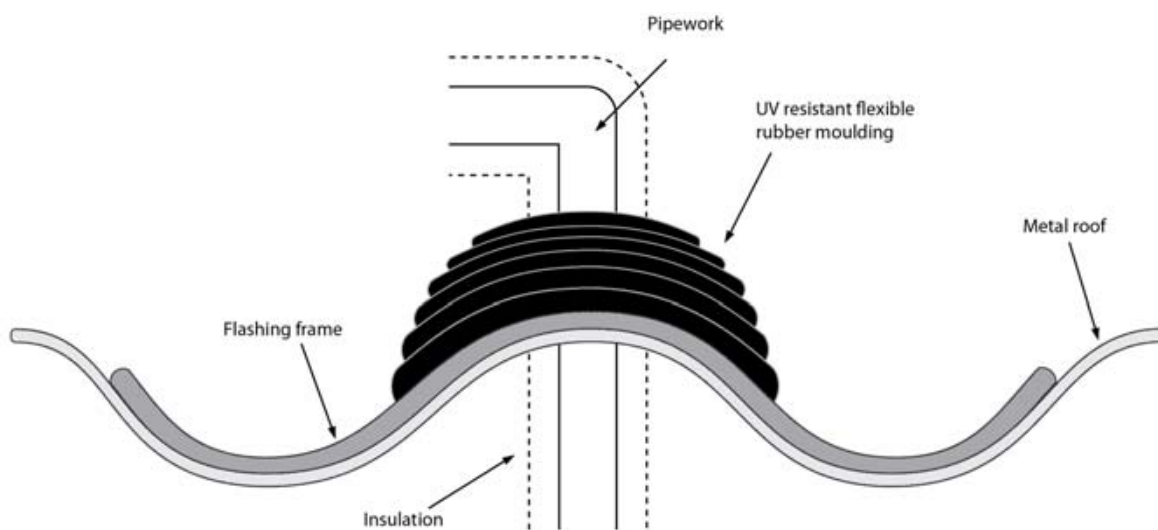
Where possible, roof penetration should be made on the high part of the roof profile to avoid the possibility that water will pool around the penetration located in the valley of the profile (Figures 7.11 and 7.12).

If a flashing cannot be held securely by silicone alone (e.g. a curved roof), screws should be used to fasten the flashings in place. These screws should not compromise waterproofing.

Figure 7.11 Example of penetrating the roof on the elevation of the profile using Dektite



Figure 7.12 Cross-section of roof penetration



7.3.10 Building consents and development applications

In some cases, a local council development application or building consent may be required before an SWH or heat pump system is installed. This could be due to the need to:

- (a) strengthen or check the roof structure
- (b) install collectors on a frame
- (c) comply with local council regulations.

It is best to check with the local council to determine the local requirements before commencing an installation. In most instances, this is the responsibility of the installer, in consultation with the client.



Chapter 8

Compliance and OH&S

Compliance and OH&S

8.1 General compliance

Plumbers will have varying requirements across the states and territories to provide a certificate of compliance to the relevant authority with jurisdiction over the work, as well as to the householder for the installation of the water heater.

8.2 'WaterMark' compliance

The WaterMark is a statement of certification of compliance with required specifications and standards in accordance with MP 52 (Manual of authorization procedures for plumbing and drainage products). The 2005 edition of MP 52 shows only one certification mark, 'WaterMark Level 1 and Level 2'. The levels denote the level of risk of the products and the need for certification; Level 1 has more stringent requirements than Level 2. Level 1 requires compliance with ISO/IEC Guide 67.2004, System 5; and Level 2 requires compliance with ISO/IEC Guide 67.2004, System 1b.

To date, the Plumbing Code of Australia (2004) includes the requirements for conformance with WaterMark Level 1 and Level 2. State and territory governments will progressively introduce this code into their legislation so that MP 52 is replaced.

Plumbers and suppliers need to check whether WaterMark compliance is required for any solar water heater (SWH) or heat pump equipment under the legislation in their respective state or territory.

Further information can be found at www.watermarkstandards.org.au

8.3 Occupational health and safety

8.3.1 General

The Australian Government Department of Climate Change and Energy Efficiency cannot accept responsibility for any errors or omissions contained in this information. This section is intended as a guide to the principles of occupational health and safety (OH&S) as they relate to the domestic installation of solar water heating and heat pumps.

Specialist advice is recommended, especially for current health and safety requirements.

Installers need to be aware of:

- (a) height hazard assessment
- (b) procedures for working at height
- (c) assessment, use and wearing of correct height safety equipment (harnesses, etc.)
- (d) all other relevant safety factors specific to the work
- (e) OH&S regulations and codes.

OH&S legislation, regulations, codes and principles must be observed for all SWH and heat pump installations. These differ between the Australian states and territories. State- and territory-specific requirements can be found online (see training reference).

8.3.2 Installers' obligations

All employers and self-employed people are required under Australian Commonwealth, state and territory laws to:

- (a) provide a safe workplace and system of work so that employees and the general public are not exposed to any hazards
- (b) give employees training, information, instruction and supervision to allow them to work in a safe manner
- (c) consult with their employees about safety issues
- (d) provide protective clothing and equipment to protect employees where it is not possible to eliminate hazards from the workplace.

Employers also need to develop policies for each workplace—or each job site—to make sure that they maintain a safe standard of work. This is done through:

- (a) hazard identification, risk assessment and control processes
- (b) specified safe work procedures
- (c) monitoring performance and reviewing control measures regularly
- (d) consulting with employees
- (e) training programs covering how to report hazards, any hazards relevant to each worker, and how to access health and safety information that the law requires employers to provide
- (f) maintenance programs
- (g) a system for reporting hazards or important safety information
- (h) emergency rescue procedures.

This is as vital for SWH and heat pump installations as for any other workplace or activity.

8.3.3 Risk assessment

For every SWH and heat pump water heater installation, installers must comply with local regulations and undertake an on-site risk assessment or safety audit before beginning any work.

The assessment or audit means that the installer takes the time to inspect the job and assess the likely hazards with any particular job, including any potentially dangerous electrical faults. While undertaking this risk assessment, it is usual to plan how to safely undertake the job.

The risk assessment considerations for traditional hot water installations and for heat pump and SWH installations are very similar, but the installation of solar and heat pump water heaters also involves some specific risks.

This section highlights the major safety concerns relating to the installation of heat pumps and SWHs. This list is not comprehensive, and concerns can differ between installation sites, so an installer must still carry out a full risk assessment for every site before commencing work.

8.3.4 Working at heights

Installers should know and work according to relevant requirements for lifting and working at heights. In addition to general OH&S and work safety legislation, the National Code of Practice for the Prevention of Falls in General Construction deals with safe work practices when working at heights of more than 1.8 metres. Further information, including existing or updated instructions or standards, can be obtained from WorkCover or the links provided in this section.

The National Code of Practice can be accessed at:

http://www.safeworkaustralia.gov.au/AboutSafeWorkAustralia/WhatWeDo/Publications/Documents/247/NationalCodeofPractice_PreventionOfFalls_GeneralConstruction_2008_PDF.pdf

State and territory governments also produce information guidelines and codes of practice for working at heights and working in or on roofs.

As a general guide to thinking about the risks involved in working at heights, the following factors should be considered:

- (a) Surface of the roof. Is it unstable, fragile or brittle, or slippery? Is it a combination of different surface types? Is it strong enough to support the loads involved? Is it sloped (more than 7°) or heavily sloped (more than 45°)?
- (b) The ground. Is it even and stable enough to support a ladder, scaffold or work platform, if necessary?
- (c) Scaffolding or work area platforms. Are these crowded or cluttered? Are they erected and dismantled properly and safely?
- (d) Hand grips. Are there hand grips provided where workers are working at heights?
- (e) Unsafe areas, including openings, holes or unguarded excavation sites; there may also be powerlines close to the work area.
- (f) Access and egress. Are there any obstructions or safety hazards in the entrance or exit routes for the work site?
- (g) Lighting. Depending on weather and location, is there sufficient light for workers to work safely? This is especially relevant when working in roof cavities.
- (h) Inexperienced employees. Inexperienced staff or installers on site, who are unfamiliar with a task, can present a risk or hazard that needs special attention and risk control measures.
- (i) Possible requirement for a confined space licence if the installation requires working inside roofs. The installer should ensure that the enclosed working area is safe and all hazards are identified.

IMPORTANT NOTE: This list is not exclusive. The total list of risk factors to be assessed will differ for every installation, depending on the site, the residence, the type of system being installed and the installer's methods.

8.3.5 Risk of falls

The first priority when working at heights is **always** fall prevention, including safe working procedures and suitable barriers.

National and state and territory OH&S regulations in Australia do not specify a particular height at which it becomes necessary to introduce safe procedures for 'working at heights'. However, the New South Wales *Safe Work on Roofs* publications specify that, if a physical restraint or harness is used, it needs to be able to stop a fall from 2m or more.

Three types of control measures and safe operating procedures are:

1. provision and maintenance of a stable and securely fenced work platform (including scaffolding or any other form of portable work platform)
2. provision and maintenance of secure perimeter screens, fencing, handrails or other physical barriers to prevent falls
3. personal protective equipment to arrest the fall of a person.

According to national and state and territory regulations and guidelines, fall-arrest equipment is a type of personal protective equipment and should not be chosen unless other systems that provide a higher level of fall protection—such as scaffolding or elevating work platforms—are impracticable.

Fall arrest systems

These are the most common option when installing SWHs and heat pump water heaters.

Under national OH&S regulations, an installer is required to use a fall-prevention system of type 1 or 2 (see previous page) when working at heights, unless it is impractical to do so.

In most residential homes, the installation period (less than one day) and the small area of roof that the installer will be working on mean that scaffolding, platforms and perimeter screens are impractical options for SWH installations.

A fall-arrest system is preferred in some special cases, including where there is a chance that a worker may fall through the surface of the roof due to fragile roofing material.

These systems require significant skill to use safely. In the event of a fall, it is likely that there will still be some physical injury to the user, even when the system works correctly.

People using a fall-arrest system must always wear head protection.

Fall-arrest systems consist of:

- (a) an anchorage point of static line (also known as the safety line or horizontal lifeline)
- (b) an energy absorber
- (c) an inertia reel or fall-arrest device
- (d) a fall-arrest harness
- (e) a lanyard or lanyard assembly.

Systems differ, so installers need to consult their safety equipment suppliers for details on the use and maintenance of their systems.

Installers are required by national and state and territory regulations to ensure that the fall-arrest harness is connected to a **static** anchorage point on the ground or on a solid residence or construction.

An anchor point must be carefully chosen to minimise the distance of a fall, and to ensure that the line does not encounter snags, obstructions or edges, which could cause the fall safety system to fail.

Installers are also required to make sure that the fall-arrest system used does not create any new hazards, including trip hazards.

Fall-arrest systems and harnesses can be used for only one person at a time. However, they must never be used unless there is at least one other person present on site to rescue an installer after a fall. In some cases, two people will be needed for a successful rescue.

All fall-arrest systems must comply with AS/NZS 1891 (Industrial fall-arrest systems and devices).

8.3.6 Roofs steeper than 45°

Where a roof pitch exceeds 45° on an SWH installation, an additional risk assessment needs to be made, taking into account the additional difficulty associated with steep roof pitches. Workers installing the system on the roof will usually require additional safety measures, which will vary from site to site. For example, they may be required to use a wider platform, a higher guardrail, scaffolding or a cherry-picker as well as, or instead of, a fall-arrest system.

8.3.7 Brittle or fragile roofs

Where portions of the roof are brittle or fragile, an employer must ensure that the risk is controlled by either:

- (a) permanent walkways or
- (b) appropriately secured temporary walkways over the affected parts of the roof.

8.3.8 Other relevant Australian standards for working at heights

State, territory or local council authorities should be consulted for additional requirements.

8.3.9 Common risks in solar and heat pump water heater installations

Working on rooftops—danger from falling objects

Potential risks associated with working on rooftops include:

- (a) falls of collectors, tanks or equipment while they are being lifted to roof height or installed at height
- (b) on tile roofs, a high risk of tile falls (tiles are slid aside so that the straps to support the tank can be attached to trusses/rafters or trusses underneath)
- (c) on tile roofs, falls of heavy plastic sheet or aluminium sheet (which is laid under hot water storage tanks when they are roof mounted to ensure that if the tank weight fractures a tile, no debris falls into the roof space), or small equipment or tools falling through to the roof cavity or puncturing ceiling material.

Employer/installer obligations include:

- (a) ensuring that all staff have received adequate training for any work that is carried out
- (b) providing a safe means of raising and lowering equipment, material or debris on site
- (c) where possible, creating a secure physical barrier to prevent objects falling from buildings or structures in or around the site
- (d) where it is not possible to create such a barrier, introducing measures to stop the fall of objects—these could include a platform with scaffolding, a roof protection system, or a toeboard on a guardrail
- (e) ensuring that all workers wear personal protective equipment to minimise the risk from falling objects.

Control and safety measures include creating a perimeter fence on top of scaffolding around a house during installation. This may be practicable when a house is having solar or heat pump water heaters installed during its construction phase. It offers a work platform for plumbers and protects workers from falling objects.

8.3.10 Working with heavy equipment

Lifting

As a general guideline, it is recommended that a standing person does not lift any object of more than 16kg without mechanical assistance or team lifting. Local state and territory guidelines will differ, but for all objects of more than 16–20kg, use of mechanical lifting equipment is recommended. Providing adequate mechanical lifting equipment for collectors, tanks and other equipment is another OH&S obligation.

As most solar systems (collectors only, or collectors and tank) are roof mounted, installers need to devise a plan to move all equipment onto the roof before work begins.

Some common solutions are to use a small crane to lift roof components quickly and safely, or to use suppliers who deliver all components to the site and onto rooftops. Rope and pulley solutions are slow and can easily result in injury to installers; they are not recommended.

Wherever mechanical lifting equipment is being used, installers must assess all risks associated with the equipment of choice and introduce appropriate control measures to reduce the risks. For example:

- (a) The risk of manual handling injuries to workers while using the equipment can be controlled by guarding the drive mechanisms and nip points on an elevator belt.
- (b) The area around the equipment can be barricaded to prevent access by untrained people and reduce the risk of falling objects hitting people below.
- (c) To reduce the risk of misuse of equipment, all workers must be adequately trained. In some circumstances, they must also hold the required certificate of competency for equipment, such as a builder's hoist.

8.3.11 Roof security

There will be risks involved in mounting heavy equipment onto a residential roof or ceiling when installing remote thermosiphon systems (tank installed in a domestic roof space) or a close-coupled thermosiphon system (tank installed on the rooftop).

Before lifting any equipment onto the roof or into the ceiling cavity, a check needs to be made that the roof or ceiling is strong enough to carry the equipment weight.

Control measures for roofs or ceilings that are insufficient to hold total equipment weight include:

- (a) strengthening roof structures to hold the weight of the system (see installation instructions for details)
- (b) locating system equipment over the roof-supporting framework only
- (c) locating collectors so that they span at least two roof-supporting trusses or trusses/rafters to adequately support the collector weight
- (d) introducing weight-bearing pathways within the ceiling cavity to ensure that all weight rests on trusses, rafters or support beams.

Any in-roof tanks must be mounted over internal joining walls in accordance with the Australian Building Standard.

See also Section 8.3.9, relating to the risk of broken tiles.

8.3.12 Working with metal and collectors

Heat hazards

As for all installations that involve use of metals and glass, any site and risk assessment needs to consider the danger from materials overheating and injuring workers. These risks are multiplied when installing an SWH as collectors are designed to become hot on exposure to solar irradiation. This can occur even on overcast and cold days.

Measures to control the burn risks of working with metal, dark-coloured plastics, glass and solar collectors include:

- (a) ensuring that all equipment is stored in a shaded or covered location before and during installation
- (b) if necessary, organising covers for solar collectors during roof installation, when collectors are placed on roof scaffolding or a platform while tiles are moved or the collectors' security lines or installation points are checked.

Note that metal can also include metal fittings in a fall-arrest system (buckles and D-rings, snaphooks on lanyards, karabiners and other specific system fittings).

Metal hazards

Aside from general heat concerns, installers are required to cut down metal lengths for the installation of tanks and collectors, creating risks of cuts and injuries. Measures to reduce these risks include personal protective gear, such as covered boots, gloves and protective eye-wear.

8.3.13 Hazards for working outdoors

As for any site work, installers must include hazards relating to working outdoors in their risk assessment. The major risk factor is working in the sun, especially from September to April.

The most effective means of reducing sun exposure is a combination of protection methods. Controls, ranked from most effective to least effective, include:

- (a) reorganising work times to avoid the UV peak of the day
- (b) making use of natural or artificial shade
- (c) use of appropriate protective clothing, hats and sunglasses
- (d) use of sunscreen.

Other weather hazards include heavy rain, dew or wind, as well as poor light under some weather conditions. These conditions need to be assessed and hazards avoided, where possible, keeping in mind OH&S regulations and best practice.

8.4 Licensing

Several additional licences may be needed for installers of solar hot water and heat pump systems. They include:

- (a) a restricted electrical licence (for plumbers)
- (b) a restricted plumbing licence (for electricians)
- (c) a Restricted Split System Air Conditioning Installation and Decommissioning Licence (heat pumps)
- (d) solar and heat pump installation licence endorsement (e.g. as required in Queensland)
- (e) OH&S licence (e.g. as required in Queensland).

The 'restricted' classification of licence is intended to allow a tradesperson to carry out work on the installation of 'like for like' (i.e. the same) equipment—that is, the equipment being installed requires the same electrical, plumbing or air-conditioning connection or disconnection as the equipment being replaced.

Check with your local licensing body for the licensing requirements in your jurisdiction. Local governments may have additional requirements that will need to be considered. For example requirements that cover the way in which a system is installed on a roof in cyclone-prone areas.

The states and territories may also have their own requirements (see below).

8.4.1 National restricted electrical licence

A National Restricted Electrical Licence is required if a worker wants to work as an employee to disconnect or reconnect electrical equipment, where this is necessary to perform their primary job function. This licence is not intended to allow people to carry out disconnection or reconnection work as a principal activity.

The restricted electrical licence does not permit installation of, or alteration to, any part of the fixed electrical wiring system (electrical installing work).

Table 8.1 shows the units of competency required for the National Restricted Electrical Licence.

Table 8.1 Units of competency required for the National Restricted Electrical Licence

Unit of competency	Unit description
UEENEEP001B	Disconnect and reconnect fixed wired electrical equipment connected to a low-voltage supply
UEENEEP002B	Attach cords and plugs to electrical equipment for connection to a single-phase 250V supply
UEENEEP003B	Attach cords and plugs to electrical equipment for connection to 1000V AC or 1500V DC supply
UEENEEP007B	Locate and rectify faults in electrical low-voltage equipment following prescribed procedures

For water plumbing equipment, the plumber applying for the restricted electrical licence must receive an endorsement for electric water heaters and motors. This endorsement is required for UEENEEP001B and UEENEEP007B.

Table 8.2 lists the requirements for obtaining a restricted electrical licence or permit as a plumber.

Table 8.2 Requirements for obtaining a restricted electrical licence or permit as a plumber

Restricted— electrotechnology systems plumbing and gas fitting	<p>The applicant has:</p> <ul style="list-style-type: none"> • completed restricted electrical licensing modules National Restricted Electrical Licensing 1 and National Restricted Electrical Licensing 2 or equivalent; and • a trade certificate in plumbing and gas-fitting; <p>and either:</p> <ul style="list-style-type: none"> • completed the restricted electrical licensing log book in not less than four months; or • 12 months experience with the completion of not less than 75% of the electrical licensing log book <p>OR</p> <p>The applicant has:</p> <ul style="list-style-type: none"> • a current restricted electrical licence authorising systems plumbing and gas fitting issued under the <i>Electrical Safety Act 1971</i>; or • previously held a restricted electrical licence incidental to plumbing and gas fitting issued under the <i>Electrical Safety Act 1971</i>, within a 5-year period before making the application, and is not unlicensed as a result of disciplinary actions.
Electrotechnology systems restricted permit— electrotechnology systems plumbing and gas fitting	<p>The applicant has:</p> <ul style="list-style-type: none"> • completed the restricted electrical licensing modules National Restricted Electrical Licensing 1 and National Restricted Electrical Licensing 2 or equivalent; and • a trade certificate in plumbing and gas-fitting; and • is undertaking incidental electrical work under the supervision of a licensee with a licence of the same class or an unrestricted class to complete either the restricted electrical licensing log book in not less than four months, or not less than 75% of the restricted electrical licensing log book within 12 months.

8.4.2 Restricted plumbing licence—Queensland

A restricted licence states the plumbing, drainage or other work that a person is entitled to perform. For example, a restricted plumber's licence may only permit water plumbing work to disconnect and reconnect a replacement electric hot water heater.

Restricted water plumber—electrical	<p>(a) Hold, under the <i>Electrical Safety Act 2002</i>, an electrical mechanic licence or an electrical fitter licence; and</p> <p>(b) Either</p> <ul style="list-style-type: none"> (i) Completion of a course approved by the Board; or (ii) A qualification at least equivalent to the qualification mentioned in (i). <p>The holder is entitled to disconnect and connect water plumbing pipes or fittings to an electrical hot water system where necessary for replacement or repair to such systems in the same location.</p>
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8.4.3 Restricted plumbing permit—Western Australia

A restricted plumbing permit authorises the holder to disconnect, remove, install and connect:

- a compression union
- a pressure/temperature relief valve
- an expansion control valve

in the course of removing, removing and re-installing or replacing a water heater.

The Western Australian permit does not allow the complete installation or replacement of an SWH or heat pump in the place of an electric water heater. This work would not be considered 'like for like'.

8.4.4 Restricted plumbing licence—Victoria

Water supply—restricted to domestic hot water services—is the disconnection, reconnection, servicing and replacement of domestic hot water services and boiling water units.

It includes the replacement of components connected to, or directly adjacent to, the hot water service and boiling water unit, including temperature, pressure-relief, pressure-limiting, pressure-reduction and ball float valves.

8.4.5 Restricted Split System Air Conditioning Installation & Decommissioning Licence

The Restricted Split System Air Conditioning Installation and Decommissioning Licence is covered by a Certificate II in Australia Refrigeration Code RS303, and covers heat pumps and air conditioning.

Under the Australian Government's Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995, it is an offence of strict liability to handle refrigerant without a refrigerant handling licence.

8.4.6 Restricted Split System Air Conditioning Installation & Decommissioning Licence (2 years)

This licence provides for the handling of a refrigerant for the installation and decommissioning of a single-head split system air conditioner of less than 18 kW cooling capacity.

Qualifications eligible for this are:

- MEM20105 Certificate II in Engineering
- MEM20198 Certificate II in Engineering Production—Air conditioning
- UEE20107 Certificate II in Air conditioning Split Systems
- UEE20106 Certificate II in Air conditioning Split Systems
- 40488SA Certificate II in Split Systems Air conditioning.

