9 Active solar water heating

As described in Chapter 2, passive solar water heating systems have the merits of simplicity and are usually reliable. These benefits, however, come at a price. The systems are inflexible in that they need the hot water storage or heat exchanger to be positioned above the solar collectors, and they are difficult to integrate with other forms of alternative energy technologies.

Water-based active solar water heating systems use pumps to circulate the heat collection fluid between solar collector and thermal store. This gives much greater flexibility in the location of thermal stores and heat exchangers, and in the integration with other alternative energy technologies. In higher latitudes, for example, the most cost-effective use of solar collectors in a particular location could be achieved by using them to preheat the feed water to a boiler burning biomass (see Chapter 11); and, as the electrical power consumption of the pumps is relatively small, this can often be supplied by solar photovoltaics.

Several manufacturers supply so-called '**zero-carbon**' integrated solar water/solar PV systems for the domestic market. However, generally these still depend on back-up electric immersion heaters or gas fired boilers for when hot water demand exceeds solar supply.

With pumped systems it is possible to position the solar collectors in the most convenient location, which is often the roof of the building. Indeed, systems exist in which the entire south-facing slope of a roof is effectively one giant solar collector, with integrated solar hot water panels and PV panels, and often roof windows as well, all forming part of the building envelope and replacing conventional tiles or cladding. Collectors can also be integrated into the façade (see below).

Variable speed pumps add extra sophistication, especially to direct systems using potable water straight from the storage tank (see Chapter 2) Often powered by solar PV panels, the pumps run slower on cold mornings in winter, when the demand for domestic hot water is at its peak. The potable water will spend longer in the collectors, absorbing more of the available energy and reaching a higher temperature than it would if it flowed through at a fixed compromise rate. This hotter water then can be added to the top of the tank, where it will float on the cooler, denser water below – a process known as stratification – and be readily available for use. Bright summer sunlight speeds the pump up, so that the water spends less time in the collectors and is less likely to reach dangerously high temperatures.

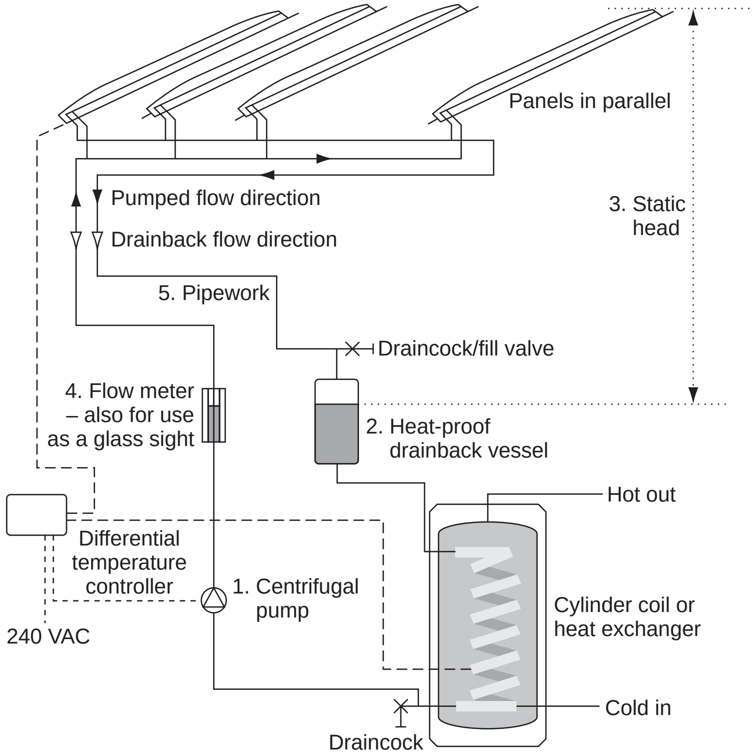
Low flow systems are offered for indirect domestic installations. These use microbore copper piping to carry the heat transfer fluid through the collectors and back into the heat exchanger. Advantages claimed include a much-reduced loss of heat from the primary loop – up to 50% – and a significantly reduced power demand for the circulating pump, typically 3 W as against 50 W or more in a conventional domestic installation. This makes it easier to power by integrated solar PV cells. Temperature rise in the heat transfer fluid as it passes through the collectors is said to be much higher –30°C as against 3°C – but obviously the quantity of heat transferred to the storage tank will not be significantly greater, as the volume of heat transfer fluid will be smaller.

All active solar water heating systems use a more or less sophisticated electronic controller. In its simplest form the controller simply monitors the temperature difference between the fluid in the solar collectors and the water in the heat store/storage tank, and switches the pump on when the former is a predetermined value higher than the latter. More sophisticated controllers will be programmed to deal with the risks of freezing temperatures or the problems of high stagnation temperatures in the collectors on sunny summer days, when available solar energy is at its peak but hot water demand is low (see Chapter 2). On larger installations this control function will almost certainly be integrated into a more complex building environmental management system.

Active solar water heating systems adopt a number of ways of dealing with high stagnation temperatures. The most simple and reliable is the drainback system, most commonly used on indirect installations with distilled water in the primary loop. When the temperature in the thermal store reaches its safe limit the controller will shut the pump down, allowing the circulating fluid to drain back into either a separate, insulated tank or the thermal store itself, to be replaced by air. This drainback principle can also be used to protect the system during sub-zero temperatures, although in areas where prolonged frosts are increasingly rare, burst-proof polymer piping could be a more reliable option. Drainback systems also depend on the collectors being far enough above the thermal store for drain back to occur reliably, but they do eliminate the need for expensive heat transfer fluids with anti-freeze – distilled water is often used instead.

Stagnation temperatures in closed loop indirect systems without drainback can be as high as 200°C above ambient. This can raise the pressure within the primary loop to dangerously high levels. Such systems are normally protected by safety valves, set to release when pressures reach either 3 or 6 bar, and expansion tanks. Dependence on safety valves implies enhanced maintenance costs. Drainback systems, which typically operate at around 0.5 bar, would seem to be inherently safer, anywhere the collectors can be positioned well above the drainback tank.

Some active direct solar water heating systems actually reverse the flow during cold weather, sending a small quantity of warm potable water through the collectors to prevent them freezing. However reliable such recirculating systems might be, there is an inevitable loss of energy during recirculation; so overall efficiency is compromised. However, systems now coming onto the market that use flexible stainless steel tubing surrounded by high density foam insulation within an expandable aluminium outer casing in conjunction



Typical large scale drainback indirect solar water heating system

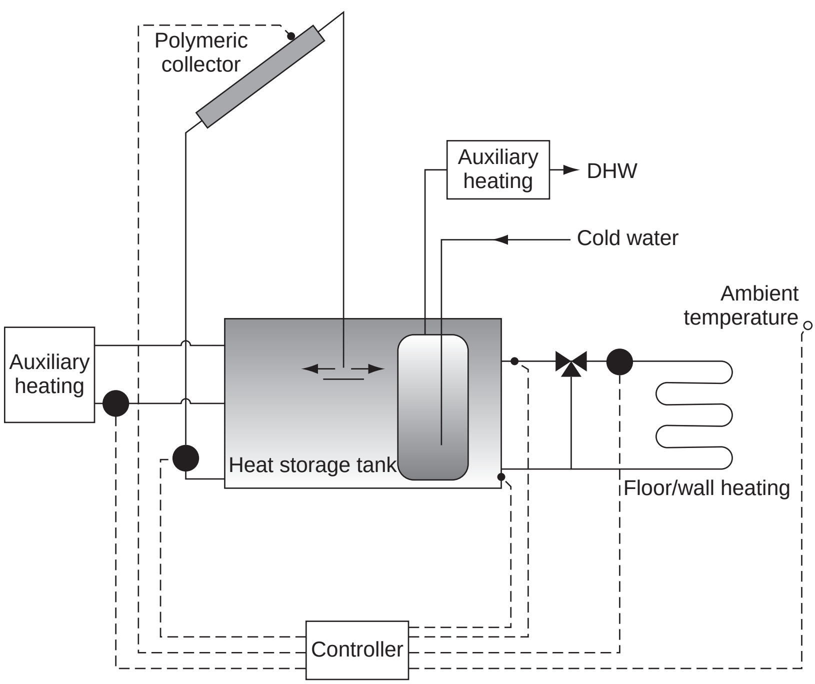
with hot water recirculation to protect the collectors would seem to offer an attractive combination of ruggedness and low-maintenance costs – the reduced heat losses through the insulated pipework is said to more than make up for the small amounts of heat needed to keep the collectors frost free.

Well-insulated pipework and warm water recirculation is a new alternative to antifreeze in solar water heating installations (Reproduced with permission from Powertech Solar)

Involuntary recirculation can also occur on cold nights in closed loop indirect systems. As the heat transfer fluid in the collectors cools, its density increases. Gravity will tend to generate a reverse thermosyphonic flow back through the inactive pump into the bottom of the thermal store, with lower density hot water from the top of the store flowing into the collectors. Overnight much of the hot water in the store can be cooled down to levels at which the back-up heating system will have to kick in to ensure adequate hot water supplies in the morning. This waste of energy can be prevented simply, by the installation of one or more one-way spring-loaded check valves in the primary loop.

Another cold weather option for active direct systems is draindown. A thermostatic valve, typically set at 38°C, opens as ambient temperatures drop towards freezing, allowing the water in the collectors and exposed pipework to drain away. The problem is that in areas where frosts are relatively uncommon, the valve only operates intermittently, and if it should fail to open the water in the collectors could freeze and damage them beyond repair.

Developed in Sweden by Solarnor is a new concept in active solar water heating in which the heat transfer fluid is the water that circulates through the space heating system – either wall radiators or underfloor heating. The heated water flows first into a large thermal store that entirely surrounds a DHW tank. Some form of backup heating is needed to ensure that both the space heating and DHW is at acceptable temperatures at all times (see Chapter 2).



Combined space heating and DHW is possible in this integrated system (Reproduced with permission from Powertech Solar Ltd)

Some form of easily monitored flow indicators are now recommended for all solar water heating installations. These soon pick up any problems, such as obstructions in the pipe network, pump failures, and leaks, and can prevent serious damage to the system. Such indicators add little to the overall capital cost. Research has also shown that the parasitic costs of the electricity used by the system should not be ignored. In one of the few exhaustive side by side tests of active solar water heating systems ever carried out – by the Energy Monitoring Company on behalf of the UK government's Department of Trade and Industry in 2001 – the parasitic costs varied enormously, with the system using solar PV panels to drive the pumps showing up best.

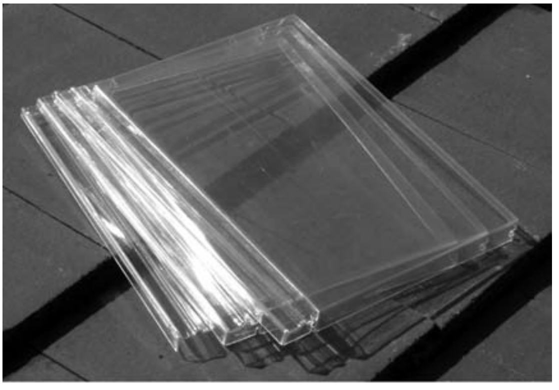
Eight commercially available domestic scale systems were set up side by side and exposed to identical solar conditions in Bedfordshire, north of London. The temperature and volume of hot water produced by each system was measured and recorded for six months. Various types of flat plate and evacuated tube collectors were involved; all but one system used conventional circulation pumps driven by mains electricity. A short power cut occurred during the trials, which caused two systems to boil, resulting in component damage. Extrapolated annual hot water production ranged from 928 kWh to 1340 kWh, extrapolated parasitic energy consumption lay between zero and 108 kWh Evacuated tube collectors were found to be most efficient, yielding around 500 kWh/m^2 per annum as opposed to the 400 kWh/m^2 per annum of the flat plate collectors. However, the evacuated tube collectors were generally smaller, so total energy production was of the same order.

Many commercially available systems have progressed significantly over the last few years, especially in the areas of dealing with high stagnation temperatures and different patterns of demand. The focus is still largely on the domestic market; however, a number of major manufacturers can now offer sophisticated systems for larger buildings.

In order to maximise solar gain and hence supply a greater fraction of the hot water demand, including space heating, proportionally larger solar collectors are sometimes used. This could well lead to stagnation occurring more frequently in non-drawback installations. On larger projects solar gain in the collectors could be controlled by variable shading (see Chapter 2) or by the use of active collectors (see below) that can be aligned away from direct sunlight when required.

Combining the solar collectors with the building envelope, in the form of solar slates, solar tiles, solar roofing or roof-integrated and façade integrated collectors can produce both cost effective and aesthetically acceptable solutions. Solar slates and solar tiles replace their conventional equivalents on conventional pitched roofs of traditional construction. Definitions vary according to manufacturer, but solar slates are usually made of toughened glass, solar tiles of polycarbonate. They allow sunlight to pass through the roof and strike black-absorber plates fixed below, between the roofing battens. These absorbers are connected into a conventional active solar water heating system. Local planning authorities are said to look more favourably on this form of collector than on conventional panels. Thermal storage capacity must be carefully matched to the potential energy capture of the roof if high stagnation temperatures are to be avoided, or a drainback system adopted.

Toughened glass solar slates can replace an entire south facingroof (Reproduced with permission from Solex Energy Ltd)



Translucent polycarbonate solar tiles are another option (Reproduced with permission from Solex Energy Ltd)

Replacing the entire south-facing roof of a low rise office or factory building with high-efficiency evacuated tube collectors would normally not be cost effective, as peak energy capture would almost inevitably be higher than the building's thermal storage could cope with. Replace expensive evacuated tube collectors with simple unglazed collectors over the entire roof area, and the equations become more attractive. Both polymeric and stainless steel solar roofing is available and, while the heat capture efficiency is significantly lower, this is compensated for by the lower unit cost, allowing it to be used economically over a much larger area. This type of collector is usually lighter, easier to install and much more rugged than conventional solar water heating panels. Aesthetically it is much less obtrusive, and a range of colour finishes is available. Stainless steel systems can also be curved for a more dramatic effect. A drainback system is probably the most practical in such applications.

Unglazed extruded polymer collectors first made their mark in the outdoor domestic swimming pool sector in the USA. The pool's standard circulation pump is used to circulate

Unglazed stainless steel flat plate collectors can be curved for architectural effect (Reproduced with permission from Energy Solaire)

the pool water through the collectors, raising water temperatures to little more than 25°C. High stagnation temperatures are unlikely, given the relatively large heat storage capacity of the pool, and outdoor pools are normally drained down and covered during the winter in higher latitudes. For such applications the low capital cost and general ruggedness of the simple collectors more than outweighs their lower heat capture efficiency. Larger, public swimming pool complexes and leisure centres also need large volumes of relatively low temperature solar heated water – for which solar roofing could be an attractive option – but they also need smaller volumes of higher temperature water for showers, space heating and so on. This could well be supplied by other low or zero carbon technologies, or a relatively small array of high efficiency evacuated tube collectors could operate independently of the pool collectors to feed a separate hot water system.

Solarnor of Norway now offers polymeric flat plate collectors glazed with twin wall polycarbonate, although these do have an aluminium perimeter frame. Absorber plates are triple wall sheets of polyphenylene oxide/polystyrene copolymer. Low weight is one of the advantages claimed: filled with water, the imposed load from the collectors is only 8 kg/m^2. Unit cost is also low, and such collectors are being used increasingly to supply both DHW and underfloor space heating (see Chapter 10).

In winter at higher latitudes the low elevation of the sun minimises the difference in heat collection potential between inclined and vertical collectors. Architectural or planning considerations may also make inclined roof mounted collectors less desirable. In such circumstances façade-integrated collectors may be the preferred solution. A growing range of systems is now available in Europe, in a range of colours and surface textures. Unglazed metal or polymeric collectors may replace conventional cladding. Absorbers can be positioned behind sections of visually conventional glazing. Buildings can be designed with their south-facing elevations sloped back to maximise the solar collection efficiency. The insulation that backs self-contained solar water heating panels is effectively replaced by the conventional wall insulation.

Façade cladding may be replaced by unglazed stainless steel or polymeric collectors in higher latitudes (Reproduced with permission from Energy Solaire)

Roof integrated and façade integrated solar collectors will effectively minimise passive solar gain all the year round. This is an obvious benefit during the summer, reducing cooling needs, but might be seen as a drawback during winter. Using solar heated water directly or indirectly for space heating (see Chapter 10) is probably more effective overall than relying on the passive solar gain of the building fabric, especially if the building is of reasonably conventional design.

The orientation of passive solar collectors is inevitably a compromise. Even when the collectors can be set up so that they face directly towards the Equator – which is not always the case – their angle of inclination is never ideal. In summer the most effective inclination can be calculated as latitude minus 15°, in winter latitude plus 15°, a 30° variation. Normal practice is to choose an inclination between these values. The obvious setting, for DHW heating at least, is the angle of latitude. This will reduce the risk of high stagnation temperatures on sunny summer days, at the cost of reduced efficiency during the depths of winter, when water heating demand can peak.

One way round this is to increase the tilt to latitude plus 15°, another is to make the collectors 'active' in the sense that their inclination can be varied during the course of the year. Such collectors can also be tilted away from the sun to reduce solar gain and hence stagnation temperatures during peak solar gain periods. This naturally increases the capital and maintenance costs of the collectors: but if active collectors reduce the use of back-up fossil fuel-generated heating and replace other stagnation temperature mitigation measures they can be cost effective. There are also potential savings to be had from the greater overall efficiency of active collectors, not least the smaller area needed for any given end use.

Some solar PV installations use PV powered solar tracking to maximise their power output (see Chapter 4), but simply substituting evacuated tube collectors for solar PV panels is unlikely to be straightforward. In lower latitudes there are some solar power stations which use active arrays of parabolic mirrors to focus the sun's rays on evacuated tube collectors and produce heat transfer fluid temperatures of up to 300°C. These track the sun from

Conventional flat plate collectors can also be used on façades (Reproduced courtesy of Solarnor) east to west to maximise solar gain, but are expensive to maintain, and are subject to significant wind loading and vandalism risks. Potential efficiency is high, however, and ground mounted arrays, in a secure compound, could be the answer for light industrial applications.

This type of collector has been used to power large-scale solar cooling systems (see Chapter 13), although cooling systems that work well with the latest generation of evacuated tube collectors are under development. So-called passive trackers are now becoming available for solar PV installations and might be cost effective for solar water heating. These use the solar induced expansion of a low boiling point compressed gas fluid (the same principle used in glasshouse ventilation actuators) to keep the panels pointing at the sun, and viscous dampers to minimise wind shake.

Even on an installation where the collectors are basically passive and set to a compromise inclination, similar self-powered actuators could be used to tilt the collector array away from the sun when temperatures in the fluid approach undesirable levels. This could be a simpler option than similarly powered shading: the actuators, developed for the horticultural sector, are relatively cheap and reliable.

The simplest way of determining true south at any particular location is to record the alignment of shadows cast at solar noon – which is midway between local sunrise and sunset. Local sunrise and sunset times can be obtained from a number of sources, but without them, a reasonable approximation can be obtained by recording the alignment of the shortest shadow.

A simpler way of increasing the efficiency of heat collection is to use evacuated tube collectors where the individual tubes are far enough apart to minimise mutual shading early and late in the day. Several proprietary designs are available. A recent development is the optimised parabolic collector – basically a series of evacuated tube collectors suspended above rows of modified parabolic reflectors. These are claimed to maximise solar capture early and late in the day, and during the winter months.

'Oversizing' the collectors may be necessary if they are shaded for part of the day by nearby features such as other buildings, trees or high ground, or if the orientation is significantly different from the ideal.

Problems with high stagnation temperatures and winter freezing disappear if air is used as the heat transfer medium (see Chapter 3). Solar air heating is mainly used for space heating, but the addition of a suitable heat exchanger can produce a combined space and DHW heating system. Various forms of solar roof or façade-integrated collectors are normally preferred to traditional TAPs (see Chapter 3), when this type of system is chosen. Most heat exchangers use the finned tank principle – a double skinned water storage tank with fins in the cavity over which the hot air is blown. Some integrated systems recover hot air from attic spaces and use this as supplementary heating for the DHW system.

Using air as the heat transfer medium will reduce the risk of legionellosis (see Chapter 2) but not eliminate it. Precautions must still be taken.

Used DHW from showers, baths etc. still contains useful energy. This is usually lost as the DHW goes to waste – and even when it is stored as 'grey water' for flushing toilets and garden irrigation, the energy it contains is usually no more than an undesirable factor, as it encourages bacterial growth in the storage tank. Installing a heat recovery system in the waste pipe or a heat pump in the grey water storage tank can be an attractive option. Recovered heat is transferred to the building's thermal store.

Thermal stores are central to the success of active solar water heating installations. With a large enough thermal store a very high proportion of a building's DHW needs can be met by solar power alone. The larger the thermal store the more efficient it becomes. On new-build projects with significant DHW and/or space heating demands, active solar water heating is almost always going to be a realistic option. The technology is well established, there are many competing systems on the market and there is adequate practical knowledge of operation and maintenance needs.