Low carbon equipment and building regulations – A guide to safe and sustainable construction

Solar Water Heating Systems

Mar 2010

This guidance document is intended to be read in conjunction with the general introduction to low carbon equipment.

The Scottish Government

Low carbon equipment and building regulations: A guide to safe and sustainable installation

This chapter is one of a series that provides a basic introduction to different low carbon technologies and describes their relationship to the building regulations in Scotland. It should be read alongside the general introduction to this guide.

Solar water heating systems

1 Introduction to solar water heating systems

Solar water heating systems use collector panels to capture the sun's radiation and convert it into useful heat in the form of hot water. A solar collector coupled with solar water storage reduces the fuel needed for domestic hot water. Even in Scotland's often cloudy climate a well designed heating system can capture enough solar energy to deliver a substantial proportion of a household's annual demand for domestic hot water, with the majority of the solar contribution between late spring and early autumn.

This guidance highlights indirect and direct pumped systems. Other systems, such as thermosyphon systems are covered in less depth because they are rarely used for Scottish buildings. It does not directly address the use of solar water heating for swimming pools.

Solar thermal systems could make a contribution to space heating as well as providing hot water, but this is probably only practicable when used to reduce demand for electricity in a ground source or water source heat pump system.

Electricity is used to run the pump that circulates the heat transfer fluid between the collector and the hot water store, but if the electricity is generated by photovoltaic cells or a wind turbine, the system may be considered zero carbon. However, solar energy alone will not fulfil the total annual demand for hot water and solar collectors are therefore used in conjunction with another means of water heating.

Solar collectors are most commonly installed on pitched roofs, either as panels over the roof covering, or inset within the roof structure. They can also be mounted on frames on flat roofs, or on walls particularly within internal sun spaces. They are appropriate for both new build and existing buildings, provided the collector can be mounted to maximise the capture of the sun's radiation. A suitable orientation and angle of tilt without overshadowing is important to good design.

2 Types of solar water heating systems and components

2.1 Types of solar water heating systems

There are several types of solar water heating systems. This section describes the indirect and direct systems that are most likely to be used in Scotland.

An example of an indirect solar water heating system (also known as a 'closed loop' system) is shown in Figure 1:

- the sun's radiation is absorbed by a heat transfer fluid (water, anti-freeze, and corrosion inhibitors) that is pumped through a solar collector;
- the fluid then circulates through a heat exchange coil within a hot water storage cylinder, transferring the solar energy to heat the water.

An example of a direct system (also known as an 'open loop' system) is shown in Figure 2:

- the sun's radiation is absorbed by water that is drawn or pumped up from the hot water storage cylinder through a solar collector
- the heated water then returns to the cylinder;

For both indirect and direct systems, when the solar energy cannot supply sufficient hot water a second source of heat is provided. This is usually through another coil fed by a boiler, or by an electric immersion element. Both would be located within the cylinder.

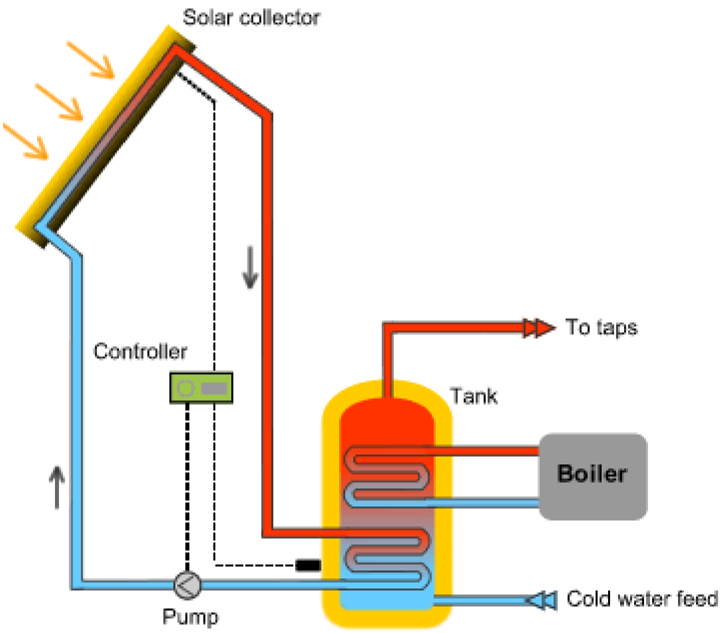

Figure 1: Example of an indirect pumped solar water heating system, with twin-coil storage
Source: www.solar-trade.org.uk

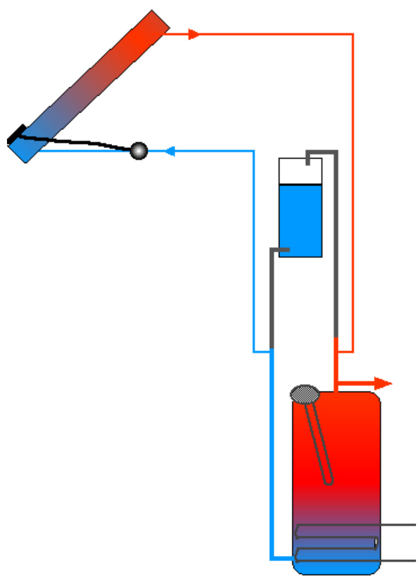

Figure 2: Example of a direct pumped solar water heating system (with PV-powered pump)
Source: Solar Twin Ltd

For indirect systems, there are two common types of systems: fully filled and drainback:

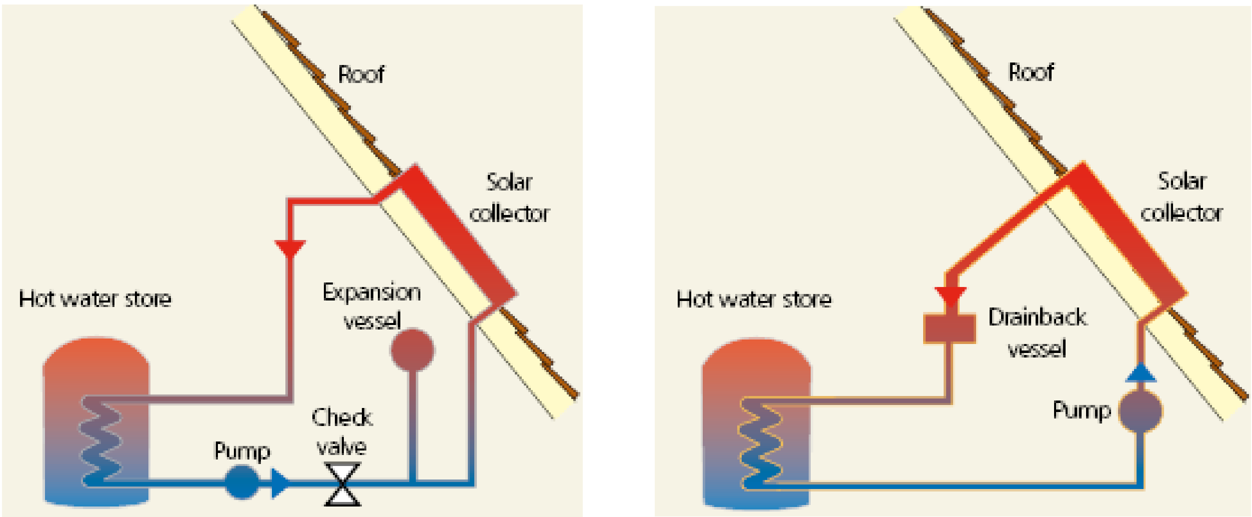

Figure 3: Schematic of a) typical fully filled indirect system b) typical drainback indirect system
Source : EST CE 13 : Solar water heating systems – guidance for professionals, conventional indirect models

Direct systems are open vented:

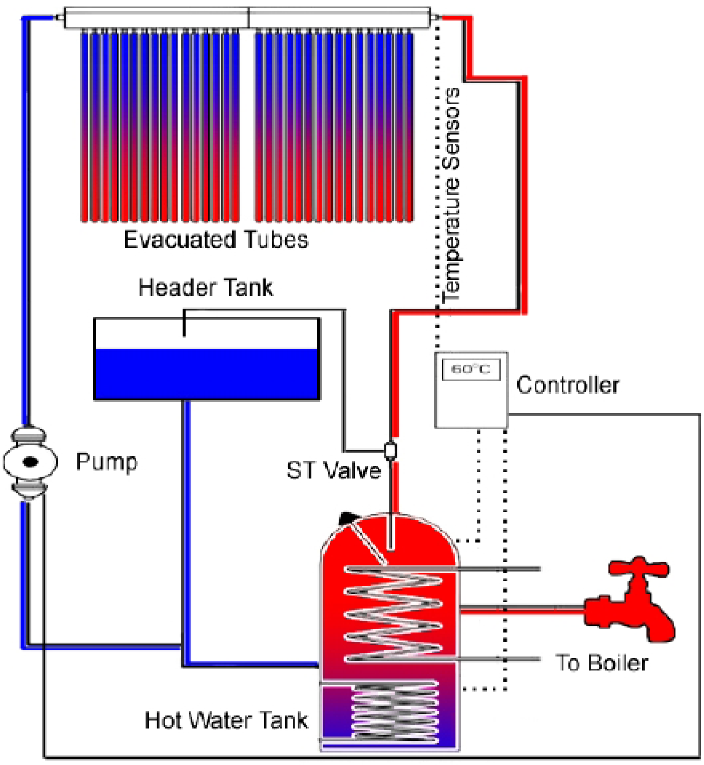

Figure 4: Example of an open vented system using evacuated tubes
Source: Solar 4 U (Powertech Apricus system)

2.2 Components of solar water heating systems

A pumped solar water heating system typically comprises the following components:

- solar collector
- heat transfer system
- hot water storage cylinder
- circulation pump
- temperature sensor and controls
- electricity supply

There will also be an auxiliary heat source to supplement the solar energy supply.

Systems incorporate one of the following types of ancillary vessels:

- an expansion vessel (for fully filled indirect systems),
- a drainback reservoir (for fully filled indirect systems), or
- a header tank (for open vented direct systems).

2.3 Solar collector

Solar collectors absorb heat from the sun's radiation. They are usually located on roofs but can also be mounted on walls, either outside or within a sunspace. Large arrays of solar collectors for swimming pools are often mounted on the ground, but such large areas are not normally needed for domestic hot water.

Types of solar collector

There are 2 main types of solar collector, which are used in both direct and indirect systems:

- flat plate collector – an absorber plate with a transparent cover
- evacuated tube collector – a row of glass tubes, each containing an absorber plate.

Low temperature collectors that are used for outdoor swimming pools are not covered in this guidance.

2.3.1 Flat plate collectors

Flat plate collectors comprise a dark metal absorber plate that contains heat transfer fluid, housed in a box that is insulated to the rear, with a glass or durable plastic cover. The plate may have a 'selective' coating to ensure high absorption and low emittance (heat loss through re-radiation). Plates with 'non-selective' coatings absorb even more radiation but lose efficiency more rapidly as the temperature rises.

Flat plate collectors are most commonly mounted over the roof covering (see Figure 5), or are integrated, like rooflights, into the roof plane (see Figure 6). Solar thermal tiles, that replace roof tiles, are also available (see Figure 7).

Figure 5: Flat plate collector located above the roof covering *Source: Sabre systems*

Figure 6: Roof integrated flat plate collector
Source: Velux

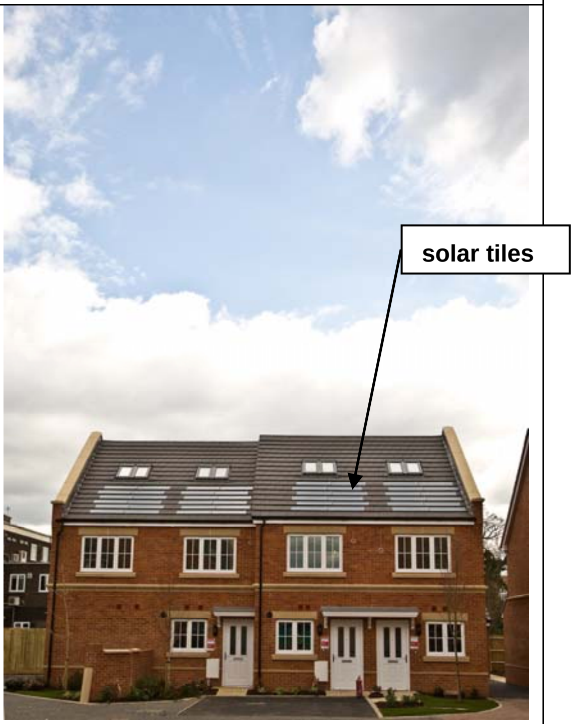

Figure 7: Solar thermal tiles.
Source: Solar Century

2.3.2 Evacuated tube collectors

Evacuated tube collectors (Figure 8) have a series of metal absorbers mounted within glass vacuum tubes. The vacuum greatly reduces heat losses from convection and conduction. The tubes are connected to a manifold that contains the heat transfer fluid. In some systems, the heat transfer fluid is circulated directly through the absorbers. In others, the absorbers enclose heat pipes that contain alcohol and are capped with a heat exchanger that projects into the manifold to transfer heat to the fluid.

Some evacuated tubes incorporate curved reflectors to maximise the absorption of the sun's rays at low angles.

Evacuated tube collectors cannot be integrated within the roof plane and are always mounted over the roof tiles or slates. The performance of an evacuated tube collector is usually better than that of a flat plate collector for the same surface area.

a) b)

Figure 8: Evacuated tube collectors
Sources – a) Llani Solar and b) Baxi

2.4 Heat transfer system and hot water storage

The heat transfer fluid used in an indirect solar water heating system typically consists of a mixture of water, antifreeze and corrosion inhibitors. The antifreeze must be non toxic, in case of leakage, and specifically designed for solar systems.

Once the available solar energy has been absorbed by the heat transfer fluid circulating through the solar collector, the fluid is then circulated to a heat exchanger. It is important in order to maintain the system's efficiency, that the heat exchanger is sized and located correctly to ensure that the transfer fluid is cool when it returns to the collector.

The solar water storage can be either the lower part of a combined, multi heat source cylinder, or a separate solar cylinder. Whatever the type of storage, it should be well insulated.

The solar water heat exchanger in an indirect system is usually located towards the bottom of a twin-coil cylinder. By placing the heat exchanger as the lower of the coils, the whole water volume becomes available to absorb this renewable energy. The upper coil is connected to an auxiliary source such as a boiler, to provide 'top -up' heat only when needed. Such combined cylinders are generally used in new buildings.

For an existing building, it may be preferable to install a new twin-coil cylinder rather than the option of installing a pre-heat cylinder that feeds into an existing cylinder. Minimising the risk of Legionella (see sections 2.6 and 4) is a factor in this decision as would be whether the existing cylinder is in poor condition or if there is insufficient space for a second cylinder.

Solar thermal systems can make a contribution to space heating as well as providing hot water, but this is unlikely to be practicable when used to supplement heating by a gas or oil boiler, because this would probably require twice the area of collector and three or four times the volume of hot water storage, for relatively little return. However, solar thermal systems can be used effectively to reduce demand for electricity in a ground source or water source heat pump system (see Figure 9).

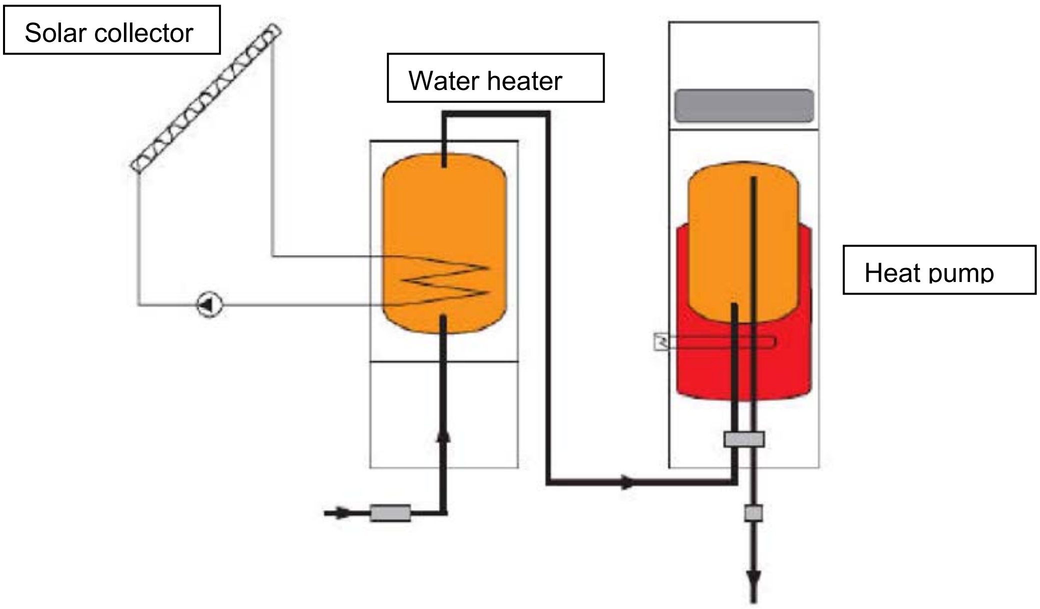

Figure 9: Solar water heating supplementing heating by a ground source heat pump
Source: based on diagram by NIBE (provided by Ecoliving)

Systems must incorporate measures to mitigate risks arising from extremes of temperature. Liquids in solar collectors can attain very high temperatures and potentially present a risk of scalding, while low external temperatures risk damaging the system through freezing of the heat transfer fluid.

Some systems incorporate a drainback reservoir, which allows the heat transfer fluid to drain out of the solar collector. The controller turns off the pump when a temperature sensor in the collector detects extremes of temperature. Fully filled systems should incorporate an expansion vessel to accommodate excessively hot water and steam, while direct systems are open vented to a container.

To avoid the risk of freezing in indirect systems antifreeze is added to the heat transfer fluid. But for direct systems where heat is transferred to the hot water that will be circulated to the taps and other outlets, this is not an option. To deal with this some direct systems use freeze tolerant components and connectors.

Systems should also avoid the possibility of reverse circulation, where heat would be lost from the hot water store to the outside. This can be achieved by either valves or by drainback.

2.5 Circulation pump, temperature sensors and controls

Solar water heating systems commonly use a pump to circulate heat transfer fluid, and a temperature control system. These are typically powered by mains electricity but can also be powered directly from small photovoltaic modules.

In some circumstances ‘thermosyphoning’ can be used to circulate the fluid, instead of a pump. Thermosyphoning is the natural circulation of fluid due to the difference in its buoyancy at different temperatures. The collector would have to be of a compatible design and installed at the lowest point in the system, allowing the heated fluid to naturally rise out of it, but this is difficult to achieve.

Pumped systems incorporate a temperature differential controller which compares the temperature of the heat transfer fluid in the solar collector with the temperature of the water in the cylinder. When the temperature in the collector rises the controller activates the circulation pump, circulating the heat transfer fluid through the collectors and the heat exchanger. The controller can also limit the maximum storage temperature and provide a readout of the systems performance.

2.6 Auxiliary heat sources

Whilst a solar system can supply very hot water, it depends on energy from the sun to do so and it is therefore usual to have a auxiliary heat source. As well as providing hot water when the solar thermal supply is inadequate, this secondary heat source should ensure that the temperature of the entire volume of stored water can be raised once every week to 60º. This is important to limit the development of pathogens such as Legionella. Electric immersion heaters can be used to achieve this.

Solar water heating systems should be compatible with other methods of using energy to heat water in a storage cylinder. Low carbon options would include a traditional condensing gas boiler, biomass boiler, heat pump, district heating system, or an electric immersion heater where the electricity is supplied by renewables or by combined heat and power (CHP).

However solar water heating systems can also be used with less efficient systems such as oil boilers or immersion heating with grid electricity. Here they would still reduce the demand for energy and therefore contribute to lowering CO_2 emissions.

A solar system should only be used with instantaneous water heaters such as combination boilers (‘combi’) if they are specifically designed to work together, and the manufacturer of the water heater provides written permission to do so. Some combi boilers can operate with warm water as input, others cannot. Those that cannot would either mix in cold water to reduce the input temperature or use the solar heated water only when it is hot enough without auxiliary heating. Such measures reduce the effectiveness of the solar system

2.7 Electricity supply and power management

Apart from the auxiliary heat supply, the only power required for a solar thermal system is electricity to run the pump.

Electricity may be supplied from the mains but for a system to be truly zero carbon, local renewable sources such as photovoltaic cells or a wind turbine could be used. No special power management arrangements are required other than the power conditioning usually associated with local electricity generation. Some systems simply integrate small photovoltaic panels with the collector (see Figure 10).

Figure 10: Solar collector with integrated photovoltaic module
Source: Solartwin

3 Building regulations: Solar water heating systems

3.1 Building regulations and building warrants

All solar water heating installations serving a building must comply with the requirements of the Building (Scotland) Regulations 2004, as amended, including the functional standards listed in Regulation 9, Schedule 5. .

For a new building, the solar water heating system should be covered by the building warrant.

For an existing building, a building warrant may be required due to the impact on the structure of the building. The Building Standards Division issued advice to local authorities on 8 July 2011 on the procedures for dealing with the installation of solar thermal equipment on a house.

Planning permission

Certain installations will need planning permission. Guidance is available in Planning Advice Note 45 Annex: Planning for Micro-renewables. However 'permitted development rights' have been extended to existing domestic buildings in specified circumstances thus removing the need to apply for planning permission. These rights cover solar PV, solar thermal, ground and water source heat pumps and flues for biomass and combined heat and power systems. Guidance is contained in Circular 2/2009. Detailed consideration of planning requirements for non-domestic microgeneration equipment will follow. An Order for microgeneration in non-domestic buildings is required by section 71 of the Climate change (Scotland) Act 2009.

3.2 Technical Handbooks

Guidance on complying with the building regulations is given in the Domestic and Non-domestic Technical Handbooks 2009.

This chapter highlights the issues in each section that should be considered when installing a solar water heating system, but you should check the Technical Handbooks for any other standards and guidance that are relevant to the individual installation.

For any further advice on specific projects please contact your local authority's Building Standards office. Find them in your phone directory, the local authority website, or from the website of the Scottish Association of Building Standards Managers (SABSM).

3.2.1 Section 0 General

Section 0 gives an explanation of Regulations 1 to 17. It includes guidance on appropriate standards of durability, workmanship and fitness of materials.

A particular consideration for a solar water heating system is that sufficient space should be left around the components to enable access for maintenance or repair work (see Regulation 8).

3.2.2 Section 1 Structure

Section 1 aims to ensure that the structure of a building does not pose a threat to the safety of people in or around buildings.

For solar water heating systems, including associated water storage tanks, the following issues should be considered, to avoid damage to the structure of the building:

- the weight and design of solar collectors varies and so does the structural design of buildings, therefore risks should be assessed.
- solar collectors may change the loads imposed on the structure of the building or require changes to the roof and all such changes should be assessed by a chartered engineer or other appropriately qualified person.
  - collectors mounted above the roof covering will add to the load and the structure of a supporting roof needs to be strong enough, or made strong enough, to resist the loads imposed by the solar collector and any liquid it may contain;
  - collectors that are inset within the roof plane in the manner of a rooflight may require alteration to the structure of the roof;
  - if a solar collector replaces tiles or slates, their relative weights should be assessed; if the weight of collectors is less and they cover a substantial area of the roof, additional tying down of the roof may be necessary to take account of wind uplift forces;
  - solar collectors fitted on roofs, and frames supporting solar collectors, should be fixed back to load-bearing structure and not to sarking boards or tiling battens alone;
  - solar collectors fitted to frames on cavity walls, for instance within a conservatory, should be fixed back to load-bearing structure, the outer leaf alone may not be designed to resist such lateral loads, and additional reinforcement may be required.
- water storage vessels may change the loads imposed on the structure of the floors and changes in loading should be assessed by a chartered engineer or other appropriately qualified person;
  - a supporting floor or attic floor needs to be strong enough, or made strong enough, to resist the loads imposed by water storage vessels, including the weight of water;
  - for timber floor structures, loads should normally be shared across at least two joists and it may sometimes be necessary to add members to provide sufficient support for water storage vessels.
- solar collectors could cause serious injury if they were to fall from their mountings. Fixings should be suitable for the supporting structure and be selected to take the weight of the collector.

As with any system that distributes water from one place to another in a building, consideration should be given to the installation of pipes and ductwork:

- the installation of pipework and ductwork should not detrimentally weaken the structure of timber roofs, floors, or walls:
  - notches and holes should not be cut in rafters, roof ties, collars or hangers;
  - lightweight trussed rafters should not be cut, trimmed, notched or drilled;

- o notches should not be cut in wall studs, cripple studs or lintels unless a full structural appraisal has been carried out by a chartered engineer or other appropriately qualified person;
- o Figure 11 shows the safe locations and sizes for notches and holes in floor joists and studs - if in doubt, ask a chartered engineer to check the proposed installation.

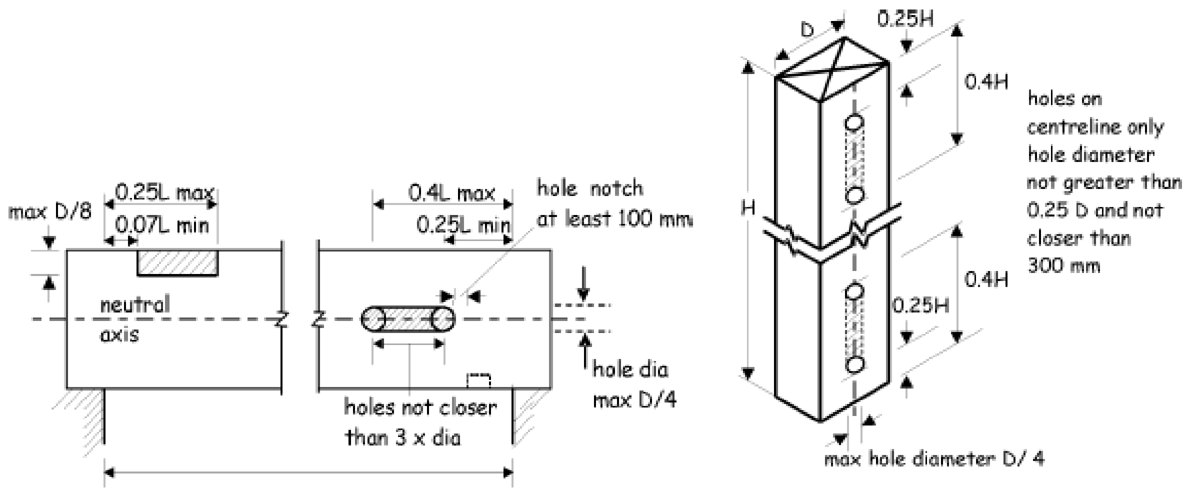

Figure 11: Notches and hole locations in timber floor joists and studs
Source: Domestic Technical Handbook, Section 1 Annexes E and F

3.2.3 Section 2 Fire

Section 2 aims to ensure that the risk of fire is reduced and if a fire does occur, there are measures in place to restrict growth and the spread of fire and smoke to enable the occupants to escape safely and fire-fighters to deal with fire safely and effectively.

It is important to identify whether walls and floors are required to have a fire resistance rating and to ensure that the installation of a solar water heating system does not reduce their integrity; these include:

- separating walls or floors, which are walls and floors constructed to prevent the spread of fire between buildings or between parts of a building, for instance between flats or attached houses;
- walls and floors of compartments, which are parts of non-domestic buildings that are constructed to prevent the spread of fire to or from another part of the building.

For solar water heating systems, care should be taken to limit the risk of the spread of fire through gaps in walls, floors, or ceilings, between cavities, and between cavities and any other room or space in the building:

- walls and floors that are required to have a fire resistance duration and are made of combustible materials, for instance timber frame separating walls, should not contain any pipes or wiring, although pipes, wiring and ducts (other than a ventilating duct) can pass through such walls. For instance, pipes from a solar collector on the roof of a block of flats should not be run down through timber frame walls between flats;
- cavity barriers should not be compromised by the pipes or ductwork associated with the solar water heating system – particular care should be taken not to disturb cavity barriers separating roof spaces or at the head of a cavity wall, or at the edges of intermediate floors;

- where pipes of less than 40mm diameter pass through any wall or floor required to have a fire resistance duration (such as separating walls or floors), or through a cavity barrier, no fire stopping is required provided a tight fit is achieved; but for pipes with diameters of 40mm or more, fire stopping should be provided to preserve the integrity of the wall, floor, or cavity barrier;
- if a roof is required to be fire-rated to prevent the spread of fire from one building or part of a building to another, the same limitations on pipework apply.

In any event, consult the relevant clauses of the Domestic and Non-domestic Technical Handbooks 2009 for more detailed guidance on service penetrations.

Solar water heating systems also must not compromise the fire performance of the roof. For instance, solar collectors must not increase the risk of external spread of fire:

- solar collector covers within 6m from the boundary must be made of materials with a low vulnerability to fire; low vulnerability includes glass at least 4mm thick, polycarbonate rigid solid sheet at least 3mm thick, and polycarbonate or thermoplastic sheets that meet certain levels of performance in tests conducted to British or European Standards; those solar collectors that are between 6m and 24m from the boundary can be made of materials with a medium vulnerability to fire. For more detailed information on low and medium vulnerability, see Annex 2D of the Domestic Technical Handbook and Annex 2F Non Domestic Technical Handbook**.**

The risk of fire due to electrical installations is covered in Section 4 Safety.

3.2.4 Section 3 Environment

Section 3 aims to ensure that buildings do not pose a threat to the environment, and that people in and around buildings are not placed at risk from various sources, including the effects of moisture in various forms.

For solar water heating systems, particular care should be taken to avoid moisture damage to the building:

- any pipes, collectors, or fixings that penetrate the roof should be properly weather protected to prevent the ingress of rainwater or dampness, using flashings;
- any pipes or fixings that penetrate an external wall should be properly weather protected to prevent the ingress of rainwater or dampness, for instance by caulking small gaps around pipes;
- pipes or fixings that penetrate an external wall should be installed in a way that does not adversely affect any existing damp proof, waterproof or breather membranes: if a membrane is damaged or disturbed, it should be reinstated.

3.2.5 Section 4 Safety

Section 4 aims to ensure that the risk of harm to users of a building is limited to an acceptable level by identifying hazards in and around buildings.

For any solar water heating system that incorporates hot water storage, care should be taken to avoid risks of scalding and burns from the discharge of steam or hot water:

- unvented hot water systems are used to avoid the need for a cistern at high level and allow mains water to be supplied directly to the storage cylinder, but present risks of burns and scalds. So if an unvented system is used:
  - systems should incorporate appropriate safety devices and controls to regulate temperature and pressures within the system;
  - installations should be carried out by people with appropriate training and practical experience, usually members of a registration scheme operated by a recognised professional body such as the Scottish and Northern Ireland Plumbing Employers Federation (SNIPEF);
- the fluid in solar water heating collector circuit can attain very high temperatures and where a system includes a means of venting fluid or steam, this should not result in the risk of scalding to people or damage to building fabric:
  - temperature and pressure relief valves should vent into pipes or containers that are designed to receive hot water or steam, and discharge it safely;
- to control the risk of legionella and similar pathogens, stored water temperatures must rise periodically;
- as in any system where stored water is heated to control the risk of pathogens, provision must be made to prevent scalding, with a device such as a thermostatic mixing valve to limit the temperature of water delivered to a bath or bidet.

Additional good practice advice is given in Chapter 4: 'Additional Guidance' on the risks associated with solar hot water systems on controlling Legionella, and on burns from hot surfaces that people can reach.

For solar water heating systems that use an electricity supply, care should be taken, as with any electrical installation, to avoid risks of electrocution and fire:

- to avoid the risk of electrocution and fire, the air source heat pump system should be installed in accordance with BS 7671, also known as the Institute of Electrical Engineers (IEE) Wiring Regulations 17th edition.

In addition, care should be taken so that an installation does not encroach on the requirements of accessibility in Standard 4.1.

3.2.6 Section 5 Noise

Section 5 aims to limit the transmission of noise to a dwelling from another dwelling, other parts of the same building or an attached building, to a level that will not threaten the health of residents. Noise from services is not controlled by the building regulations, however it is worth noting that the only noise from a solar water heating system should be that of the circulation pump, probably no louder than a modern central heating pump.

- the installation of a solar water heating system and distribution pipe-work should not adversely affect the existing sound insulation of a separating wall (including in the roofspace between flats) or a separating floor;

3.2.7 Section 6 Energy

Section 6 aims to ensure that effective measures for the conservation of fuel and power are incorporated into buildings, and that emissions of carbon dioxide are limited.

Installation of a solar water heating system should not prejudice the energy performance of the building:

- if insulation within the walls, ground floor, or roof, or on pipe work is disrupted it should be reinstated;
- if membranes or seals that contribute to the airtightness of the building are disrupted, they should be repaired and the junctions around pipes or ductwork made airtight;
- gaps should be filled where any pipes or ducts penetrate external walls, incorporating insulating material to limit heat loss.

Various measures can help to ensure that the installation of the solar water heating system is energy efficient:

- pipes and ducts within the system should be well insulated to minimise heat loss:
    - see BS 5422: 2001 'Methods for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range – 40°C to + 700°C; for example a 22mm diameter copper pipe should be insulated with 23mm of insulation with a thermal conductivity of 0.035 W/mK;
    - the correct grade of insulation needs to be used to withstand the very high temperatures generated by solar collectors;
    - for external pipes and ductwork, the insulation will need to be resistant to the effects of weathering.
- means of control should be provided for energy efficient performance:
    - optimise the useful energy gain from the solar collectors into the system's dedicated storage vessel(s);
    - minimise the accidental loss of stored energy by the solar hot water system, whether originating from solar collectors, cold intake or auxiliary heat sources;
    - ensure that hot water produced by auxiliary heat sources is not used when adequate grade solar pre-heated water is available;
    - the inlet temperature of any separate domestic hot water heating appliance where provided (such as a combi boiler) should be limited as necessary (see the boiler manufacturer's instructions);

Correct use and maintenance of a solar water heating system is essential if the benefits of enhanced energy efficiency are to be realised.

- the whole system, including the auxiliary heating and any electricity generation, should be properly commissioned and tested, taking account of the manufacturer's recommendations to achieve optimum energy efficiency; and,
- written information should be made available for the use of the occupier of the building on the operation and maintenance of the whole system, including the . recommended frequency of scheduled maintenance.

4 Additional guidance

In addition to the issues covered by the Technical Handbooks, the following good practice guidance will enhance the system.

4.1 Prevention of scalding and burns

Solar collectors can become very hot. When mounted on a roof, there should be no risk of burns except during maintenance, but there can be a risk of burns with systems mounted in locations that people can reach:

- if collectors are mounted in or on accessible places, such as a balcony, guarding should be considered so that people cannot touch the collector.

Protection from scalding during maintenance of the system should be taken into account:

- a low level drain down facility should be provided to allow the safe draining of the heat transfer fluid.

4.2 Legionella

For any solar water heating system that incorporates a pre-heat cylinder or other hot water storage particular care should be taken to avoid risks of bacteria because solar water is generally used for heating domestic hot water rather than for space heating. The risks require consideration because the solar heating by itself will not always be able to raise the storage temperature to a level high enough to sufficiently destroy pathogens such as Legionella:

- to control the risk of Legionella and similar pathogens, a secondary heat source, typically an immersion heater coil is needed to raise the temperature of the stored water, once a week for a short time, to at least 60°C, in accordance with guidance to the Water Byelaws.

5 Making the most of a solar water heating system

The performance of solar water heating systems will vary according to the patterns of use of the hot water and, therefore, the use of auxiliary heating. There are several factors that affect the performance in practice of a system, and therefore affect the amount of fuel used by auxiliary water heating:

more energy efficient	less energy efficient
✓ select a collector with: large aperture area; higher performance; and low heat loss factor	× smaller aperture area, lower conversion factor, high heat loss factor
✓ evacuated tubes (but check for aperture area and efficiencies)	× flat plate collectors (but the most efficient can out-perform some types of evacuated tubes)
✓ correctly sized collector and hot water storage, appropriate to the household	× under-sized collector, so auxiliary heating used
✓ weather resistant external pipe insulation	× external pipe insulation not weather resistant
✓ the hot water storage cylinder and all pipes in the hot water system are well insulated	× the cylinder and pipes are uninsulated, or the insulation is too thin, or is unsuited to very high temperatures
✓ collectors ideally face south, but south east and south west orientations are generally next best, followed by laying collectors flat	× pairs of panels on both east and west orientations are worthwhile, but not orientations to the north of east or west
✓ a tilt of 40 - 45°, but tilts between 35° and 55° can give worthwhile results ✓ for flat roofs or walls, support collectors by a frame designed for optimum orientation/ tilt ✓ extra collector area for buildings where the pitch and orientation of roofs is not optimal	× a very shallow tilt (would gain little solar energy when the sun is low in the sky and would tend to accumulate dirt) × an excessively steep tilt would limit the periods of solar gain
✓ shade-free is preferred, but reasonable performance across the year if south facing and partially shaded by for example, a dormer or deciduous trees	× would not be worthwhile if over-shadowed for much of the day by a nearby hill, large building, or by evergreen trees
✓ the occupants understand how to use the solar supply of hot water, for instance by taking showers only in the morning so the system has the rest of the day to heat up	× occupants empty the tank in the early evening so they will use more auxiliary heating overnight and in the morning
✓ the system incorporates a display of performance that helps occupants to manage their use of hot water and alerts them to malfunctions, e.g. a broken pump	× occupants waste hot water so that too much auxiliary heating is used, perhaps because they have unrealistic expectations of the solar supply
✓ the system is checked and maintained according to manufacturer’s instructions and safe access for any necessary cleaning of the panels is allowed for.	× the system is inadequately maintained

Fuel costs for a solar hot water system will vary with the price of grid electricity, unless the electricity is generated on site. Very little electricity should be needed, probably less than the cost of electricity used to run a gas boiler.

5.1 National Calculation Methods

The Government's Standard Assessment Procedure (SAP) is used for domestic buildings to assess compliance with the energy standards in the building regulations and for the production of EPCs in new homes. The SAP calculation gives a value of the solar contribution to domestic water heating over a standard occupancy pattern and is not intended as a design tool for a particular installation. However, an analysis of the SAP calculation can give an indication of how to maximise the solar contribution to water heating. SAP can currently take into account different input values of:

- Collector aperture area
- Orientation, tilt and overshading
- Collector performance – heat loss and efficiency
- Daily hot water use and annual energy load for hot water use, both based on floor area

If certified performance data for solar collectors is available then this can be input, otherwise SAP provides default values that tend to be give more pessimistic results for annual solar input measured in kWh. Currently SAP's values for annual solar radiation are based on a UK average.

RdSAP, the software that produces energy performance certificates (EPCs) for existing domestic properties, currently uses standard assumptions for collector type, size and orientation as well as a limited selection of hot water cylinder storage sizes.

The Simplified Building Energy Model (SBEM) can be used for non-domestic buildings to assess compliance with building regulations and produce energy performance certificates (EPCs). However, dynamic simulation modelling (DSM) is used for more complex buildings. SBEM calculates the annual useful domestic hot water supplied by the solar energy system (kWh) by multiplying the aperture area (m^2) by the global solar radiation at the collector surface, based on the orientation (to the nearest 45º) and inclination (to the nearest 15º); and by a value of 38% that is assumed for the annual system efficiency of conversion. Therefore SBEM has limitations in recognising the benefits of efficient collectors and different solar pre-heating strategies. More accurate calculations can be performed using DSM.

6 Product standards

6.1 British Standards

There are a number of European and British Standards that are relevant to solar water heating systems. These include those listed below, but this list should not be regarded as exhaustive.

Only those that **are** cited in the relevant section of 2009 Technical Handbooks have an asterisk by their number reference.

6.1.1 Standards for solar collectors

Standards mostly address flat plate, indirect systems; some parts are also relevant to evacuated tubes and direct systems.

BS EN 12975	Thermal solar systems and components. Solar collectors.
Part 1: 2006 *	General requirements
Part 2: 2006	Test methods
BS 476: Part 3: 2004 *	Fire tests on building materials and structures. Classification and method of test for external fire exposure to roofs.
BS EN 13501 Part 5: 2005	Fire classification of construction products and building elements. Classification using data from external fire exposure to roof tests
DD ENV 1187:2002 *	Test methods for external fire exposure to roofs

6.1.2 Standards for solar water heating systems

BS EN 12976	Thermal solar systems and components. Factory made systems.
Part 1: 2006	General requirements
Part 2: 2006	Test methods
DD ENV 12977	Thermal solar systems and components. Custom built systems.
Part 1: 2001	General requirements
Part 2: 2001	Test methods
Part 3: 2001	Performance characterisation of stores for solar heating systems

6.1.3 General standards for hot water storage vessels, and associated fittings

BS EN 1490: 2000 *	Building valves. Combined temperature and pressure relief valves, tests and requirements.
BS EN 1491: 2000	Building valves. Expansion valves. Tests and requirements.
BS 1566:	Copper indirect cylinders for domestic purposes –
Part 1: 2002 *	Open vented copper cylinders – Requirements and test methods
Part 2: 1984 (1990) *	Specification for single feed indirect cylinders.
BS 3198: 1981 *	Specification for copper hot water storage combination units for domestic purposes.

BS 5422: 2009	Methods for specifying thermal insulating materials for pipes, tanks, vessels, ductwork and equipment operating within the temperature range – 40°C to + 700°C. (BS 5422: 2001 is cited in the Technical Handbook)
BS EN 12897: 2006	Water supply. Specification for indirectly heated unvented (closed) storage water heaters. (Replaces BS 7206 which is cited in the Technical Handbook)
BS EN 13831: 2007	Closed expansion vessels with built-in diaphragm for installation in water

6.1.4 Standards for water heating systems

BS 6700: 2006	Design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages. (BS 6700: 1997 is cited in the Technical Handbook)
BS EN 15316	Heating systems in buildings. Method for calculation of system energy requirements and system efficiencies.
Part 1: 2007	General
Part 3-1: 2007	Domestic hot water systems, characterisation of needs (tapping requirements)
Part 3-2: 2007	Domestic hot water systems, distribution
Part 3-3: 2007	Domestic hot water systems, generation
Part 4-3:2007	Heat generation systems, thermal solar systems

6.1.5 Product and materials standards

BS 7431: 1991	Method for assessing solar water heaters. Elastomeric materials for absorbers, connecting pipes and fittings
BS 3734-1: 1997	Rubber. Tolerances for products. Dimensional tolerances
BS 6920: 2000	Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water.

6.1.6 Other relevant standards

BS 7671 *	Requirements for electrical installations
BS EN ISO 9488: 2000	Solar energy. Vocabulary
BS EN 61725: 1997	Analytical expression for daily solar profiles

6.2 CEN Keymark scheme for solar thermal products

Keymark is a voluntary product labelling system, developed by the European Committee for Standardisation (CEN), which indicates compliance with the European Standard(s) covering the product. The Solar Keymark indicates compliance with BS EN 12975 for collectors and

BS EN 12976 for systems. However, because testing is voluntary, absence of a keymark does not necessarily indicate that a collector or system is not a quality product.

Most of the Solar Keymark test houses are in Germany and many certificates are only in German; the relevant terms for modelling calculations are: *Konversionsfaktor η0* (zero-loss collector efficiency η0), *Wärmedurchgangskoeffizient* (heat loss coefficient a1), *Bruttofläche* (gross area), and *Aperturfläche* (aperture area).

The Scottish Government