

Solar Water Heating and Dairy Farming – Potential in the Peak District National Park

Review of technology & issues

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Executive summary

This report discusses the potential for solar water heating to reduce the operating costs and environmental impact of dairy farms, with particular emphasis on the Peak District National Park area, where large areas are typified by the presence of numerous small, family farms that contribute significantly to the character of the landscape.

UK energy costs have risen considerably over the past 5 years and in the long term there is no reason to expect this trend to abate. Fossil fuel use also brings about environmental damage, not least climate change arising from carbon emissions, so the development of sustainable alternatives is urgently needed. Unfortunately, these tend to have higher capital costs than conventional energy systems and although long-term running costs are lower, energy consumers have generally shown little inclination to commit resources to these wider problems.

Dairy farming in the UK has undergone a period of rapid change since deregulation of the milk marketing board in 1994. The number of dairy farms has decreased by 53% since 1995 (NFU figures). The price per litre of milk received by farmers decreased from 24.5 to 18.5p between 1994 and 2004 while operating costs have risen significantly. Any steps which reduce operating costs will therefore benefit dairy farmers, providing there is sufficient capital to invest in improvements.

Solar water heating has become a relatively popular way for households to cut long term energy costs, yet industry (and dairy farming in particular as a large user of hot water) has shown virtually no interest in taking up this technology in the UK, although there are numerous international examples.

This report is based on surveys and discussions with farmers, analysis of dairy power consumption and over 10 years experience of specifying, designing and installing solar hot water systems. It explains the technology, makes recommendations about design, construction and installation issues and suggestions for further work. A case study reviews the choice of technologies and sizing and costing scenarios. Systems need to be considered in the context of local planning guidance, in this case covered by the Peak District National Park Authority's Supplementary Planning Guidance.

The report concludes that large, modern and profitable farms may be able to justify resourcing long-term solar investments, whilst small farms operating with narrow margins will generally be reluctant to invest without external funding. Solar water heating might contribute the majority of annual dairy hot water requirements. As energy prices increase and the cost of high-performance evacuated tube systems falls, possibly to below the level of flat plate systems, efforts should be made to increase uptake, perhaps allowing, amongst other approaches, existing energy efficiency schemes to support agricultural projects.

Although this work was mostly carried out among dairy farmers in Derbyshire and Nottinghamshire, the conclusions are likely to be applicable to dairy farms nationally, and to some extent to any industry requiring moderate amounts of low-grade process heat (<100°C) including hotels, laundries, food preparation and medical facilities.

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1 Introduction

1.1 Context and Aims

This report offers an overview of the potential for the use of solar water heating in dairy units.

It is intended both for dairy farmers interested in using solar water heating to cut their energy costs and reduce their environmental impacts, and for consultants, Local Authorities, and other interested parties evaluating the benefits of solar water heating, particularly to dairy farmers.

The report documents the concepts users need to be familiar with before choosing or designing a solar water heating system, and covers the following questions:

- What are the statutory hygiene requirements placed on dairy farmers, and what does meeting these require in terms of hot water and energy ?
- Which solar water heating technologies might be appropriate, and how might they be optimised for dairy use ?
- What planning conditions may apply ?
- What is the cost of solar heated water, and how long might it take to recover the investment ?
- What performance can solar water heating deliver in terms of energy and carbon dioxide savings ?
- What needs to be considered to specify a safe and effective system ?

- How do the findings relate to the experience and concerns of dairy farmers in the area ?

It must be kept in mind that hot water is only one aspect of dairy energy use and attention should also be paid to energy used in vacuum and cooling systems. Solar energy may play a part in reducing dairy energy consumption, but should be considered in conjunction with the use of 'waste' heat from cooling and other processes on the farm. It is suggested that water heating typically accounts for 40% of electricity used in the milking parlour¹.

Although outside the scope of this report, other renewable energy technologies are outlined briefly in Section 15.4.

Ten dairy farmers inside and outside the Peak District National Park area were interviewed with a structured survey to assist with the research for this report. We would like to thank these farmers along with the Dairy Hygiene Inspectorate who have kindly clarified the statutory and 'best practice' requirements.

We welcome comments, questions and feedback from readers.

1.2 Peak District National Park

The Peak District National Park has a total area of 1,438 km², and is home to about 38,000 people. It is one of the most visited National Parks in the world. Family farms are a major feature of the region, and are central to defining its landscape and social character, although many farming businesses now rely on diverse sources of income including tourism to stay viable. For many, low 'farm gate' prices in recent years, have caused significant financial and personal stress.

Business in the Community² reported a 40% reduction in the number of dairy farmers in the Peak District between 1990 and 2003, the decline now being higher than the national average. Incomes have also decreased, with the Peak District National Park Authority reporting a 56% fall in dairy farms between 1995 and 2005. There has been a trend towards larger farm sizes to find economies of scale.

1.2.1 Peak District Planning Guidance

The Peak District National Park Authority is responsible for planning issues within the National Park. A Supplementary Planning Guidance note, (SPG), covers energy conservation and renewable energy, (see Figure 1). The implications of the SPG for solar hot water systems are considered more thoroughly in Section 6.2.

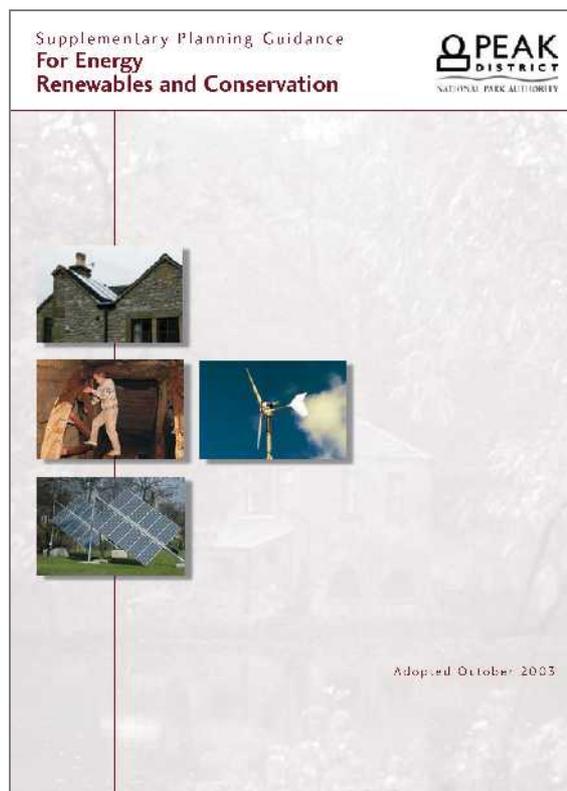


Figure 1: PDNPA Supplementary Planning Guidance for Energy – Renewables and Conservation.

1.3 Types of Dairy and Scope of Report

Traditional dairies carry out milking as a twice-daily batch process and the bulk of milking is still carried out in this way. Each milking station is used by a number of cows, then hot washed at the end. (See Figures 2 and 3.)

Once exterior surfaces have been cleaned, disinfection is carried out using one of two hot-water cleaning methods (see Section 2.1).

Recent trends have seen some farms move to continuous, fully-automated robotic milking. While automated milking has a number of benefits in terms of reduced labour intensity and improved utilisation of buildings, it may use more hot water by performing a hot

wash after milking each cow. This report will concentrate on traditional milking parlour based systems as these are standard in the Peak District National Park, but energy use in automated plant will no doubt become a significant issue in the years to come and so is discussed in Section 13.

The UK Dairy Industry produces around seven billion litres of milk per year. Over recent years, the farm end of the supply chain has seen a shift from subsidised milk production, to subsidy of a broad range of conservation activities which do not necessarily support milk production. The industry has additionally suffered due to BSE and Foot and Mouth, which have restricted animal movement, caused the culling of a significant fraction of the national herd, reduced access to markets, and damaged public confidence. At the same time hygiene and other regulations have grown more stringent, and compliance has become a greater overhead.

The retail value of milk is passed in roughly equal measure to farmers and retail outlets, (increasingly supermarkets). While large farms continue to be viable, many small farmers now claim that their production costs are greater than the wholesale milk price, so significant incentives exist to reduce operating costs if capital can be found to invest in improvements.



Figure 2: Conventional milking.



Figure 3: Typical cleaning chemical.

2 Dairy Requirements for Hot Water and Energy

2.1 Statutory Provision and Good Practice

Farmers are obliged to follow the requirements of EC regulations 852, 853 and 854 / 2004, enacted in England under the Food Hygiene (England) Regulations 2006. These are interpreted and enforced by the Dairy Hygiene Inspectorate on behalf of the Food Standards Agency.

The Food Standards Agency publish good practice guidance and the full text of the regulations to the farming community in the booklet, "Milk Hygiene on the Dairy Farm. A Practical Guide for Milk Producers to The Food Hygiene (England) Regulations 2006", which can be obtained from the Dairy Hygiene Inspectorate, on 0113 2303738 or via www.defra.gov.uk/rds/dhi.htm.

From the Practical Guide and conversations with the staff of the Dairy Hygiene Inspectorate, it is clear that the largest enforced use of hot water in the dairy is the twice-daily hot washing of the internal surfaces of equipment after each milking. This can be carried out in two ways, a circulation wash requiring 10-15 litres of water per milking unit at 85°C, or a 'boiling water wash' using as much as 10 to 18 litres at 96°C per milking unit. Both of these use chemicals in addition to hot water to kill bacteria and remove fats.

Other uses for hot water in the dairy are relatively infrequent, and alternative processes using cold water may be available to farmers for some of these. The best return on investment will be obtained by addressing the most frequent daily needs of the dairy, so it is on the provision of water for these twice

daily hot washes that this study will focus.

Some farmers have commented that dairies could carry out one hot wash per day if the bacteria counts from their milk stay in the top band. The Dairy Hygiene Inspectorate deprecate this approach, and firmly recommend the use of two hot washes per day. This study will base its assumptions about minimum hot water consumption on the use of two hot washes per day.

2.2 Typical Dairy Energy Use

Energy usage at a typical, small dairy farm was monitored over six days in May 2005. Energy consumption data was collected with a Hawk 5000 3-phase data logger (Figure 4), taking power consumption measurements at 5 minute intervals on the power feed to the dairy plant. The power factor was also logged to give an indication of when the power consumption was due to purely resistive loads (e.g. heating), or to inductive loads, (e.g. chiller compressor and vacuum pump motors with little mechanical load).

The average daily energy use was 16.9 kilowatt hours, (kWh), with a maximum daily consumption of 25.5 kWh due to weekly cleaning of the milk storage tank.



Figure 4: Hawk power monitor installed on site.

The data shows obvious periodicity and a typical usage regime is outlined below using aggregate data (Figure 5 and Table 1).

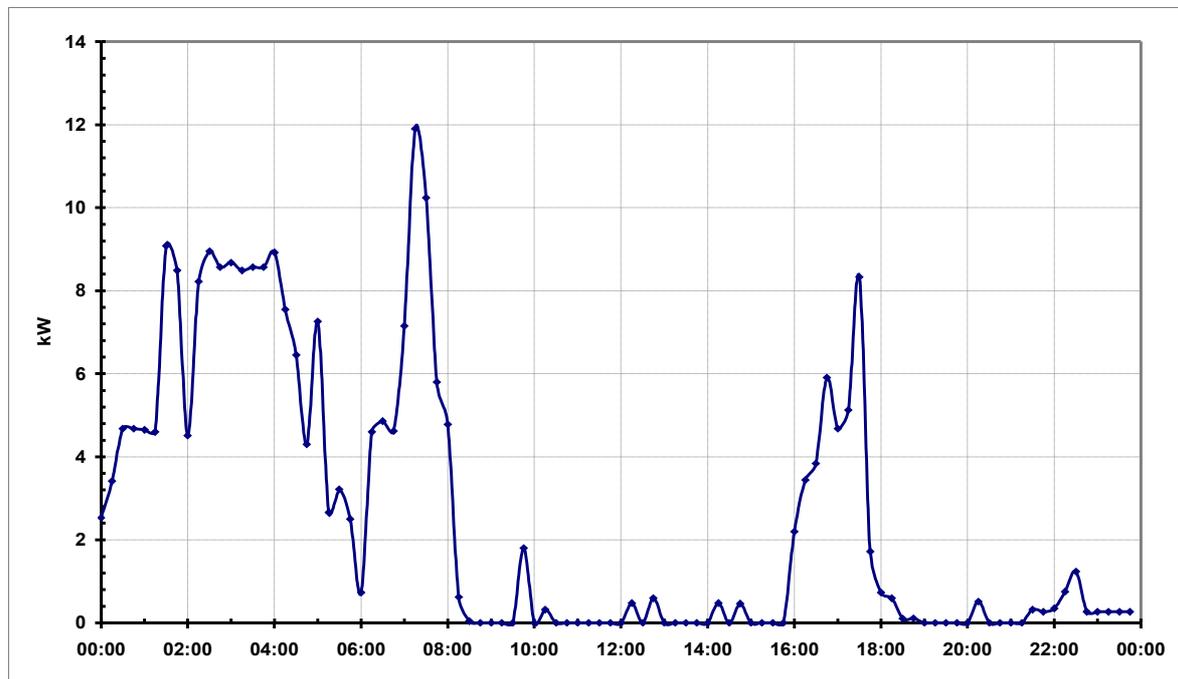


Figure 5: Pattern of daily electricity use.

Table 1: Comments on power use.

Time	Comment
Midnight – 05:20	Most significant energy demand. Cheap, off-peak electricity is used to heat water for cleaning and form ice to keep the milk storage tanks cold during the day.
05:20 – 06:00	Power consumption falls and the power factor increases to nearly 1. This may be because the main load is water heating. Consumption is lowest by 6:00, suggesting the water cylinder is hot and all ice has been formed.
06:15 – 08:20	Morning milking starts, using a vacuum pump. Other power uses are further cooling of the milk storage tanks, tank stirrer motors, and additional heating and pumping of the cleaning fluid, giving a peak power consumption of close to 12kW.
08:20 – 16:00	Morning milking ceases and the dairy is idle until evening milking at around 16:00. Brief periods of power use may be due to the intermittent operation of a small water heater used for ad hoc cleaning as well as lighting, milk collection and running a small computer and printer.
16:00 – 18:20	Evening milking, with further vacuum pumping, stirring of milk storage tanks and final cleaning of dairy parlour.
18:20 – midnight	Power use is minimal.

2.3 Energy Efficiency

Until all basic energy conservation measures have been undertaken, solar water heating, (or other renewable energy solutions), will not offer the best return on investment at current energy prices.

At events in March 2007, the Dairy Development Centre³ suggested ways to reduce energy costs, including the following.

- Installing a plate heat exchange cooler, (see Figure 6), to recover body heat from the milk.
- Switching off all equipment and lighting when not in use.
- Using low energy lighting, e.g. high intensity discharge lamps or high frequency electronic ballast T5 fluorescent tubes.
- Insulating water heaters and pipe work. (A Farm Energy Centre study showed that an uninsulated tank will lose about 50% of its heat over a 17 hour period compared to 5% heat loss for a well insulated tank⁴.)



Figure 6: Plate heat exchange cooler. Milk and water pass in opposing directions, (contraflow), to optimise heat transfer.

Further suggestions were made which would reduce bills by making maximum use of cheaper rate electricity, but these will increase carbon emissions through greater total energy use:

- Installing a hot water tank with capacity for both milkings – heat at night and top up in the afternoon.
- Installing a 2nd hot water tank (one for each milking) - heat both at night.

The same events quoted typical electricity costs of 0.25 to 0.4 pence per litre of milk produced. Work by Defra suggests that a 'good' farm will have annual electricity usage in the order of 280 kWh per cow, with 'poor' performance farms using approximately 430 kWh per cow per year. (Ref: www.defra.gov.uk/environment/waste/topics/agwaste/reduce-waste.pdf)

Farmers can compare their energy (and other cost figures) against performance of other farms on the benchmarking website www.milkbench.org.uk.

Once energy inputs have been cut to a necessary minimum and the cheapest energy supplies have been selected, the only ways to reduce energy costs are to recover process heat or produce cheaper energy locally.

Consideration should be given to the integration of a number of heat recovery, heat pump / refrigeration, and renewable energy technologies as part of a strategy to reduce costs, energy consumption, emissions and environmental impact.

The recovery of the cows' body heat from milk, can only deliver a small part of the required thermal energy required for water heating, and on some farms, water warmed by the cooling of milk is fed to cattle. This saves metabolic

energy, which is expensive as it has to be released from ingested food.

Heat which would otherwise typically be lost outside the building, may also be recovered from chilling equipment, either to heat air inside buildings, or to preheat water for the washing of equipment.

Below, one of the first chiller plants installed in the UK, to preheat water with the 'waste' heat from cooling the milk. System located just south of the Peak District National Park.

Further advice on energy efficiency is available from the following organisations.

- Milk Development Council: produce the leaflet "Energy Efficiency on Farm", <http://www.mdcfmp.org.uk/>
- Farm Energy Centre, who produce a range of leaflets on energy saving www.farmenergy.com
- The Carbon Trust provide sector-based advice, including an "Agriculture and Horticulture sector", available at the link below, although the agricultural sector is not eligible for free energy audits or energy efficiency loans from the Carbon Trust. www.thecarbontrust.co.uk/energy/starting/starting/agriculture.htm



2.4 Solar Hot Water in Dairy Farming – An International Perspective

Solar hot water for dairy farming has been promoted for several years in a number of countries, notably the USA, Canada, Australia, New Zealand and Germany.

A programme from the Government of Victoria in Australia offers a rebate of approximately 25% on solar hot water installations in a scheme which specifically includes farmers, with dairy washing being highlighted as a high energy use activity.

In North Carolina (United States), farmers are eligible for Federal grant of 20-25% of the total cost, 30% Federal tax credit and ability to depreciate the cost over 5 years. In addition there is a State corporate tax credit of 35% over 5 years.

A number of examples are given in Table 2.

While these examples beg the question “why not here?” it is worth noting that whilst the UK receives 900-1,000 kWh/m²/yr on a flat surface New Zealand may receive 1,500 kWh/m²/yr and New York as much as 1,550kWh/m²/yr ⁵.

However, uptake of solar technologies depends as much on social and economic factors as climate, with Austria achieving more than twice solar coverage of (sunnier) Spain, Portugal and Italy combined⁶. It is likely that a major factor in the lack of uptake of solar water heating in UK dairies is the availability of low cost night time electricity, rather than climate conditions. As UK electricity prices rise, solar water heating is likely to become increasingly competitive.

Table 2: International examples of solar hot water.

Location	System installed	Costs and funding	Payback
Tally Ho Farm, North Carolina, USA.	30 m ² panel with 1,135 litre drainback storage tank. Electric water heater as backup.	\$20,000 (2007). Allowing for State and Federal grants and tax credits the total cost to dairy is \$2,500 (12.5%).	Estimated at 3 years.
Goat Lady Dairy, North Carolina, USA.	18.6 m ² panel with 1,135 litre drainback storage tank. Propane hot water heater as backup.	\$10,000 (2007). Allowing for State and Federal grants and tax credits the total cost to dairy is \$1,500 (15%).	Estimated at less than 2 years as propane prices have risen 25% in a year.
J. M. Roy et Fils, Quebec, Canada.	3.4 m ² flat plate collectors with a 272 litre pre-heat tank. 20W photovoltaic pump.	\$4,995 (1999). 25% contribution from the Renewable Energy Deployment Initiative.	Estimated 5-10 years.

2.5 Solar Hot Water in Dairy Farming – UK Perspective

There are only a handful of well publicised examples of the use of solar water heating on dairy farms in the UK, the highest profile being the Highgrove dairy, owned by the Prince of Wales, who installed solar hot water in 2006.

Botton Village in the North York Moors operates a dairy and a creamery, both supplied by flat-plate solar collectors (5 and 10 m² respectively).

Testing of a variety of renewable energy technologies will take place at the Agri-Food and Biosciences Institute in Hillsborough, Ulster. Solar hot water, anaerobic digestion of slurry and wood burning will all be evaluated for the conditions in Northern Ireland (similar insolation levels to the Peak District).

Broomfield Agricultural College had a solar water heating system but this was dismantled when the herd was sold and no information seems to have been kept about its performance.

Caerfai dairy farm in South Wales uses an anaerobic digester, wind turbine and solar water heating system, although the solar water heating system is only used for a camp site shower block. Likewise, there are several examples of farms in or near the Peak District National Park area, where solar hot water systems are used to service tourist accommodation.

More recently, solar hot water systems for dairy parlours have been promoted by a range of organisations including the Dairy Development Centre (Wales), Energy Saving Wales, the Borders Energy Farming Forum and Scottish National Farmers Union. It is not known

if this promotion has resulted in the adoption of any solar water heating systems.

Some work has been done through the government's Clear Skies and Low Carbon Buildings Initiative to promote the benefits and fund the use of solar water heating systems in the domestic and community sectors.

As yet though, despite some training for their consultants in the potential use of renewables by the Carbon Trust, little has been done to support deployment in industry, and farmers are unlikely to receive aid from the Carbon Trust under the present funding regime.

It is ironic that funding is available to the domestic sector where hot water demand is erratic, but not to the dairy sector where the milking regime imposes a significant daily demand.



Figure 7: Farm conversion to provide tourist accommodation with solar hot water, Hognaston Derbyshire



Figure 8: Farm conversion with solar water heating system providing hot water for tourist accommodation and farm shop, Kinveton Derbyshire.

2.6 Farmers' Views on Energy Use

Ten dairy farmers, predominantly from the Peak District National Park area, were surveyed either by visit or phone interview.

Cost of energy

- 80% said they had current concerns about the cost of energy used on the farm, with 90% thinking it would be more of an issue in the future. 60% stated that energy costs noticeably impact on the income from the farm.
- All farmers knew their total energy cost, but in 90% of cases this included use at the farmhouse too. One farmer had a separate meter for a dairy building and another was about to install sub-meters. Two farmers worked out their energy costs in the range £2.50 to £3 per cow per month at 2005/6 prices.

Energy conservation

- 80% had considered energy conservation measures including the use of plate heat exchangers to pre-cool milk between the milking parlour and chilled storage to reduce refrigeration costs, but see notes in Appendix 3 re optimising their use. Insulation, low energy lighting, using waste heat from the vacuum pump and refrigeration system, the reuse of pasteuriser water for parlour wash down, and using cold washes were also considered by some.
- 60% used water heated in the plate cooler to feed cows. 10% used heat from refrigeration plant to heat water, and one used melt water

from the ice bank to cool milk in a plate cooler.

Renewable energy

- 30% had not thought about using renewable energy at all. One that had considered it had rejected all the options as impractical, but 30% expressed an interest in solar energy, 30% in wind power, 40% in biomass, 20% in ground source heat pumps, and one in the use of vegetable oil to generate electricity. All of these options may be worth exploring subject to energy prices and other circumstances.

Solar hot water

- 30% had not considered solar water heating. Three had rejected solar water heating, as "complex, expensive and unreliable", "because energy is only available half the year", or on price. Others had looked at various technologies, for use either on their homes, dairies or holiday let accommodation.
- When asked how much they knew about solar water heating on a scale of 0 to 9, most scored themselves quite low, with a minimum score of 2, an average of 3.3 and a maximum of 8. Only one had heard of a farm or food-processing company using solar hot water systems. There is an obvious need for local, practical demonstrations of this technology in the dairy context, with the performance data made available to the public and agricultural community.

3 Overview of Solar Thermal Water Heating

3.1 UK Solar Availability

In Britain each square metre of a south-facing roof receives up to 1000 kWh of solar radiation in the course of a year⁷.

About 70% of UK annual radiation is received from April to September, with a mean daily summer insolation of around 5kWh per square metre per day. Over the other six months, solar radiation can only deliver 30% of the year's total energy, with a mean daily winter insolation of around 1kWh per square metre per day⁸.

3.2 Capturing Solar Energy

Solar energy can be exploited passively by using the design of buildings to trap energy, or actively by using various kinds of solar collector.

The two main 'active' solar technologies currently in use are solar water heating and electricity production by photovoltaic cells.

Photovoltaic cells may be important in the future, but the present generation of equipment is relatively expensive and inefficient, (typical efficiencies are in the range 4% to 16%), so is not an economically competitive way to provide significant amounts of energy, except in off-grid locations. While this might be of use in isolated farm buildings with a modest demand for electricity, photovoltaics are not a useful technology for water heating and are therefore outside the scope of this report.

By contrast, in the right circumstances, collectors for solar water heating can convert much of the energy that falls on them into heat, and the more hot water

is used from the system, the greater the efficiency, so the shorter the time taken to recover the capital cost.

With appropriate equipment the sun can be used to provide most of the hot water required from about April to September, and useful pre-heating of water during the other months.

Solar water heating systems comprise a solar collector and a means of transferring heat to a heat store, (See Figure 9). The circuit of pipes carrying fluid to the solar collectors is generally referred to as the 'primary' circuit.

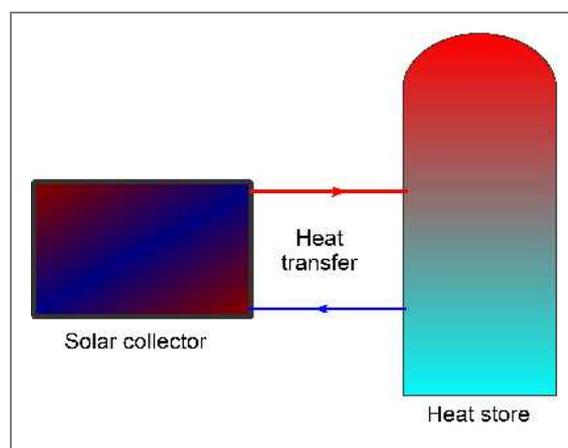


Figure 9: Key elements of a solar water heating systems. While simple convection driven systems can be implemented, these are generally not efficient. Practical equipment uses other components as described in later sections.

Systems must be controlled to ensure efficient operation, and **the system as a whole must operate safely and not be damaged, or pose any threat, even at extremes of operating temperature or pressure, or in the event of power failure, or failure of the control system.**

3.3 Elements of Solar Thermal Equipment

3.3.1 Solar Water Heating Collectors

Solar water heating collectors use a dark surface, generally of sheet metal, to absorb radiant heat from the sky and conduct it away to be used. As the metal collectors warm up they begin to lose heat to their immediate environment, so insulation is necessary to prevent this heat from being lost. Losses can also occur due to the cooling effect of wind passing over the collectors. To attain high temperatures therefore, these collector assemblies must have a very transparent front cover, (the aperture), and a well insulated enclosure.

The 'glazing' of the aperture must absorb as little energy as possible from the sun, especially short wave infra-red radiation, but reflectivity and transparency at various wavelengths, heat retention, life expectancy, weight and durability under attack from vandals or seagulls must all contribute to the final choice of glazing material and panel.

Given the critical role of the insulation in achieving good performance, some systems go as far as constructing the collectors inside a vacuum to cut heat losses via conduction and convection. Atmospheric pressure places a lot of mechanical stress on vacuum systems so these tend to be based on cylindrical tubes, while non vacuum systems can be fabricated more easily around large rectangular flat plate collectors. Solar water heating collectors are thus broadly divided into flat plate and evacuated tube devices.

In either case, performance may be

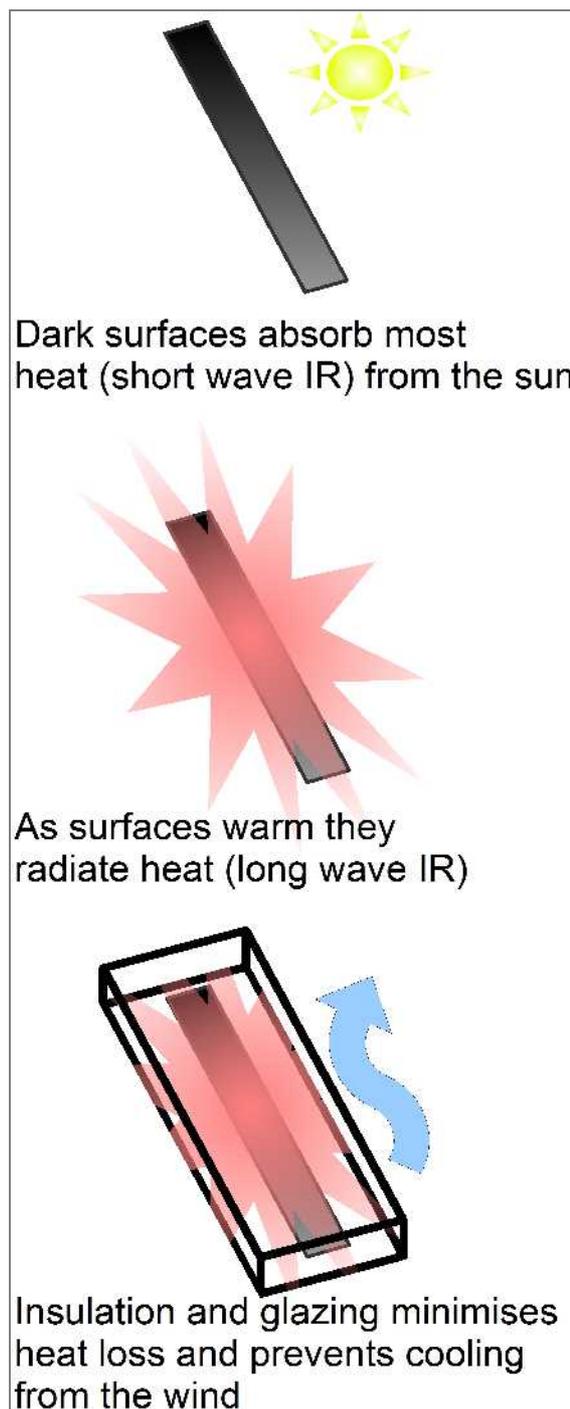


Figure 10: Principles of solar water heating collectors.

optimised by using absorbers by the use of selective surfaces. These are good absorbers of short wave infra-red from the sun, but poor emitters of the long wave infra-red produced at their typical working temperatures.

3.3.1.1 Flat Plate Collectors

Flat plate collectors typically use a thermal absorber of 1.5 to 3 square metres in a single enclosure. Larger panels are available, but may be hard to install on a roof without using a crane. These can be fabricated with,

- a length, or lengths of pipe attached to a single metal sheet,
- pipe attached to metal strips, referred to as fins, see Figure 11.
- pipe or pipes attached to multiple sheets, or
- two layers of sheet metal spot-welded together and inflated with compressed air to create a cavity through which fluid can pass.

This assembly is placed in a waterproof insulated housing, with insulation underneath the plates to prevent heat loss into the roof. All the insulating materials must be selected to withstand temperatures well in excess of 300°C so that the panel can withstand exposure to direct summer sunlight with no thermal load, a condition referred to as 'stagnation'.

A variety of transparent materials can be used to form the front of the collector, (see Figure 12), though this must be transparent to infra-red radiation as well as visible light, able to withstand heavy snow, hail and the worst case temperature the panel will reach and ideally weigh little. The use of glass is traditional, but soda glass is best avoided as it can absorb up to 30% of the energy in sunlight. Low iron glass performs better, but among others acrylic, Tedlar®⁹ and triple wall polycarbonate plastics may be used and offer a weight advantage. Where systems are 'glazed' with triple wall polycarbonate sheet, experience with conservatory roofs suggests the

user should anticipate replacing this material at least once during the life of the system which is likely to exceed 25 years.

Flat plate collectors are relatively efficient at low and medium water temperatures, though as system temperatures rise, heat is lost to the surroundings by re-radiation from the collector, conduction through the insulation and the heating of air in front of the absorber plate which circulates by convection, transferring energy to the window at the front of the panel which is cooled by the outside air. Sometimes more than one layer of glazing may be used at the front of the collector to reduce heat losses to the air, but these also reduce the levels of radiation reaching the collectors, and most collector designs go no further than single glazing. Flat plate solar collectors may be mounted over existing roof tiles, or set into a roof. An alternative is to mount the collectors below glass tiles, e.g. Figure 13.



Figure 11: Detail of flat plat collector before glazing added.



Figure 12: Flat plate panel mounted 'in roof' before installing side flashings and tiles.



Figure 13: Flat plate panels under glass tiles. Perhaps not the most efficient design for UK use as the air is relatively cold for much of the year, and gaps between the glass and frame allow it to circulate over the panels. Dirt may also accumulate between the tiles reducing the effective aperture.



Figure 14: (See also following page.) Panels may be mounted at ground level, but the design must still minimise the risk of wind damage.

For flat plate collectors mounted on the ground or flat roofs, some suppliers recommend as much as 220kg of ballast per square metre of collector installed to stop the collector being blown away in high winds. This limits the use of flat plate, and to a lesser extent evacuated tube solar collectors on flat roofs unless the roof has been designed to accommodate the mounting of the solar collectors to structural elements of the roof, or it is known that the roof can carry the necessary ballast loading.

As far as possible from an environmental perspective, the use of large amounts of concrete should be avoided as significant amounts of carbon dioxide are produced during its manufacture.

Where the weight of ballast or wind loadings arising from the use of flat plate collectors is a problem, evacuated tube collectors might be considered as an alternative as they are less prone to be lifted by the wind. The manufacturers should be contacted to check the mounting or ballast requirements.



Figure 15: In the context of the Peak District National Park, the mounting of panels on the ground might reduce the loss of visual amenity incurred by siting collectors on traditional buildings, though as some heat may be lost from longer out door pipe runs, the area of panel required might be larger than a roof mounted system. Note reverse return pipework on left hand side (see Page 40.)



Figure 16: Twenty four tube Consol double wall heat pipe evacuated collector, located on the roof of the tourist accommodation at a Derbyshire farm.



Figure 17: Sixty Thermomax single wall heat pipe evacuated tubes, mounted at angle on the roof of a Derbyshire school. Heat pipe evacuated tubes must generally be inclined by at least thirty degrees to operate effectively.

3.3.1.2 Evacuated Tube Collectors

Evacuated tube solar collectors also use dark surfaces which transfer heat to pipe-work via sheet metal, but these are mounted inside a tube which encloses a thermally insulating vacuum. The evacuated tube of the collector has to be fabricated in glass to withstand the force imposed by atmospheric pressure. The comments on handling and implosion hazards identified in Section 9 should be noted with care.

In simple designs the fluid to be heated is circulated inside the tube, but other designs use heat-pipes to transfer heat from the tube to a manifold at the top. The collector may either be sealed into a tube such that the light passes through a single layer of glass before striking it in the evacuated space, or it may be mounted inside a double wall vacuum tube, effectively a vacuum flask, such that the light passes through two layers of glass before striking it. In either case the vacuum prevents heat loss by convection, so systems based on these collectors may be more efficient than flat plate designs, especially in cold climatic conditions or at high working temperatures.

Where the collector uses a glass to metal seal (e.g. Figure 18) this is critical to performance as the vacuum depends on it. Elimination of this seal in the double wall flask designs may improve their robustness in the long term, but at the expense of the light having to penetrate more layers of glass, perhaps reducing the efficiency of the collector. As glass to metal seals are vulnerable to shock-cooling after stagnation, heat-pipe designs are more commonly used (e.g. Figure 19).



Figure 18: Obsolete heat pipe design showing glass to metal seal

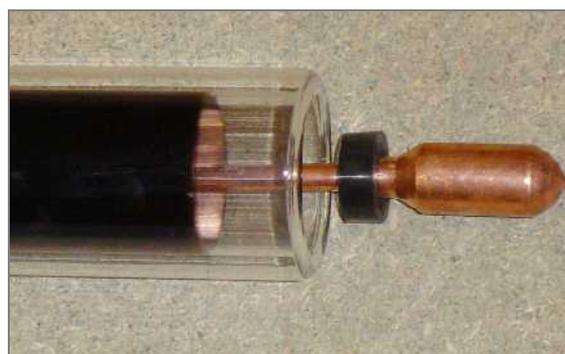


Figure 19: Modern heat pipe tube assembled ready for insertion into manifold, showing double walled glass tube construction.

Evacuated tubes are mounted into manifolds, where heat is transferred from the tubes to the circulated fluid (see Figure 20). Manifolds are well insulated to minimise heat loss at this hottest part of the system. Where heat pipes are used, a heat transfer compound is applied during installation to increase efficiency (Figure 21).



Figure 20: Manifold arrangements



Figure 21: Heat transfer compound being applied to end of a heat-pipe

Tubes and manifolds need to be securely attached to the roof, generally through a framework arrangement, see for example Figures 22 and 23.

Although evacuated tube collectors are generally mounted above roof tiles (Figures 16 and 17), products are emerging to integrate them into the roof, though these rely on covering them with yet another sheet of transparent material which will further reduce operating efficiency.



Figure 23: Nippon Electric Glass DP6 tubes. These heat the circulated fluid directly in pipes inside the tubes. Note the sturdy mounting arrangement.



Figure 22: Apricus® evacuated tubes mounted in their manifold (top of image) at a house in Derby.

3.3.2 Heat Transfer

In most designs of solar water heating system, used in the UK, heat is stored remotely from the solar collector. Mass flow of water is generally used to transfer heat from the solar collector to the heat store. While it is possible to use convection to move water between the collector and the heat store, this requires wide bore pipe, raising the thermal capacity of the primary circuit which reduces the speed of its response to sunlight. It also imposes the requirement that the heat store be higher than the collector, and is relatively inefficient because the flow of convecting water is not adequate to transfer heat from the panel at full efficiency. Some estimates suggest that only 60% of available heat is delivered to the heat store by convection driven systems, and it is now normal practice to pump water through the collector and heat store, though this requires a control system to work most efficiently.

3.3.3 Solar Heat Stores

All solar water heaters require a well insulated heat store. Although these may be integrated with the collector, they are generally a separate water cylinder, calorifier or accumulator, either:

- as a pre-heat cylinder prior to an existing hot water tank, or
- combined with the existing hot water tank (e.g. Figure 24).

These are generally larger, taller and thinner than domestic hot water cylinders used for conventional heating systems as this gives the best stratification. A balance has to be sought however, as taller, thinner tanks will have a greater surface area to volume ratio, resulting in higher temperature loss, although the actual losses will depend on the pattern of use and quality of insulation.

The efficiency of solar collectors, especially flat plate, falls as the operating temperature rises, so the cylinder or part of the cylinder which is heated by solar energy, should be as cool as possible. Solar heat is generally delivered to the bottom of the heat store as that tends to be the coolest part (the warmer water stratifying at the top) as well as giving access to the greatest volume of the cylinder.



Figure 24: Domestic heat store, before all insulation fitted. Note the 2 heating circuits: solar (lower) and gas backup.

Heat stores may contain water in a gravity fed or unvented system, or use some other medium to store the heat, perhaps involving the latent heat of a phase change to improve the energy storage density, i.e. kWh per cubic metre of heat store.

3.4 Direct and Indirect Solar Thermal Heating Systems

Solar water heating systems may be divided into direct and indirect configurations, depending on whether water from the heat store is heated directly in the solar collectors, or if a separate circuit of heat transfer fluid is used (Figure 25).

3.4.1 Direct Systems

Direct systems circulate water from the heat store through the collectors to transfer heat. They are simple, efficient and quickly plumbed in, as the existing water cylinder is usually retained when they are retrofitted, and relatively little access is needed to existing pipe work.

Direct system collectors are prone to damage caused by hard water however. Before the installation of a direct system at a site with hard water, steps must be taken to reduce the risk of harm to the collector due to the deposition of limescale as the water is heated (Figure 26), and periodic descaling of the collectors may be required. In general we advise against the use of direct systems in hard water

areas as the benefits are only moderate, and the maintenance overheads significant.

3.4.2 Indirect Systems

Indirect systems use a heat exchange coil in the heat store which isolates the stored hot water from the fluid that circulates through the solar collectors. This heat exchange coil is frequently made of Intergron, an alloy of copper and nickel that facilitates the efficient transfer of heat. As a rule of thumb this should have a surface area of about 0.5m² per square metre of installed collector.

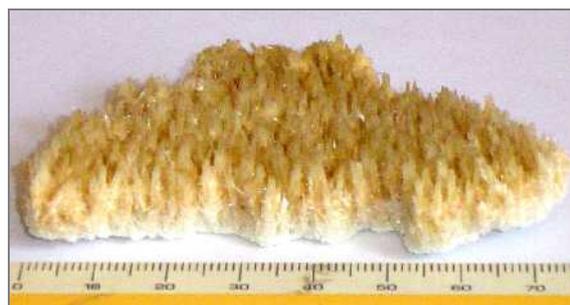


Figure 26: Limescale removed from a 4 year old water cylinder in Nottingham.

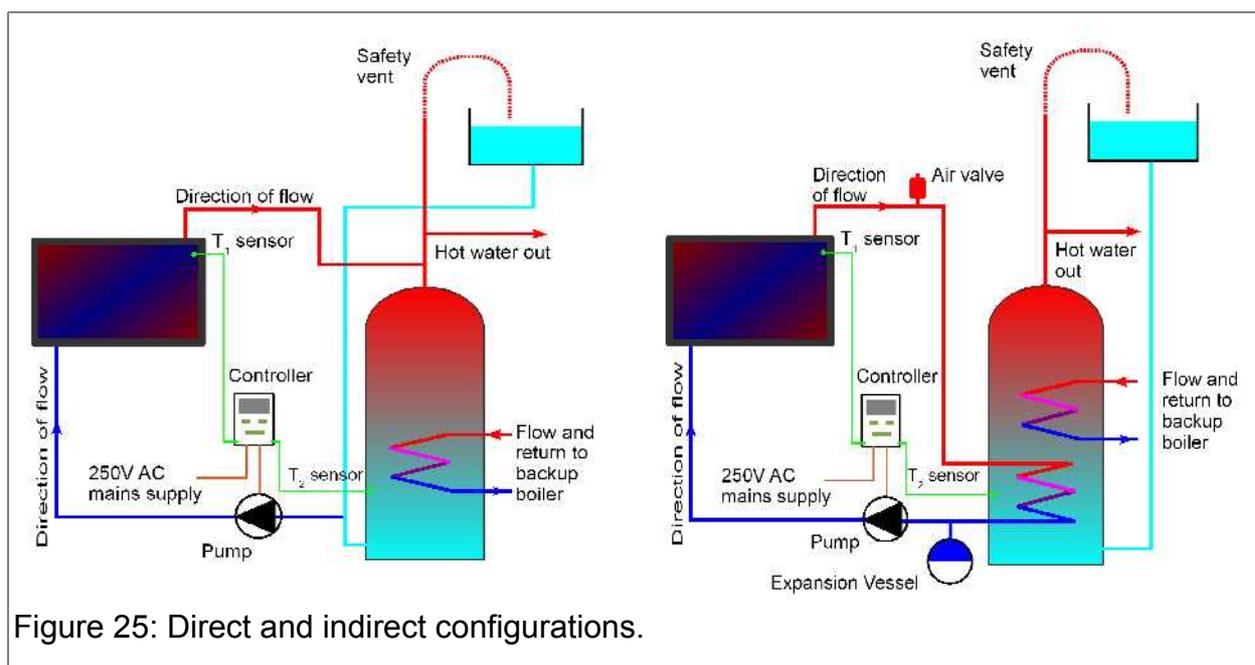


Figure 25: Direct and indirect configurations.

3.5 Frost Protection

All solar water heaters used in the UK require protection from frost. If this is not adequate, damage to the system will result sooner or later. A number of strategies have been developed, summarised in Table 3.

Freeze Tolerance

The collector and external pipes work are fabricated from materials which will withstand freezing, remaining intact by expanding and contracting around any ice that forms inside them. This severely limits the choice of collector and pipe, and the range of materials that can be used in their manufacture.

Water Movement

Water is kept moving using the pump once the exterior temperature drops below a few degrees above freezing. This function is supported by many solar controllers, but in addition to the risk of misconfiguration of the equipment and lack of opportunity to check this behaviour when the system is installed, running the pump at night consumes electricity, has a vulnerability to power cuts and pump failure, and cools the heat store.

Antifreeze

Perhaps the most common approach is to add antifreeze to the circulated fluid to eliminate the possibility of freezing in indirect systems. Enough antifreeze should be added to protect against at least '50 year frosts', i.e. the system should withstand the lowest temperature that is likely to occur within a fifty year period. The cost of glycol antifreeze is not prohibitive given the quantity required, but care must be taken to select an appropriate product.

Automotive antifreeze, generally based on the toxic ethylene glycol or methanol, is not safe to use.

A number of products are available based on propylene glycol which is of relatively low toxicity, and available as a food-grade material. In the dairy industry a product aimed at food chilling applications with certified low toxicity is required. See Section 10.2 for information about filling.

Drainback Systems

The water that transfers heat is allowed to drain from the collector into an intermediate storage vessel when not in use (Figures 27 and 28). All the primary circuit pipe runs must slope towards the drainback vessel (1 in 50 slope) and may not run flat. If this storage vessel is in part of a building which can be guaranteed to be frost free, no antifreeze will be required but it must still be well lagged to avoid heat losses.

As drainback systems sometimes have other advantages (Section 5.2.2), they may on occasion be used with the drainback vessel outside the heated envelope of the building (e.g. in loft space or an unheated milking area), but with antifreeze added to the circulated water.



Figure 27: Copper drainback vessel fabricated with insulating foam coating.

Most drainback vessels are proprietary designs sold for use with a particular manufacturer's equipment. T4 can supply a design for a universal copper drainback vessel, which is capable of being used in any system, though on the whole, drainback vessels tend to be more expensive than expansion vessels.

From the point of view of system life expectancy, the number of dissimilar metals in the system should be minimised. Expansion vessels tend to be fabricated in steel, as do some drainback vessels. However, it is possible to obtain drainback vessels fabricated in copper, which may offer better corrosion protection.

Drainback systems are usually filled at atmospheric pressure, but in use the pressure will rise, and systems should include a pressure relief valve. Extremes of pressure are seldom seen however, because if the pump turns off in hot weather, fluid drains back to the drainback vessel and is not heated further.

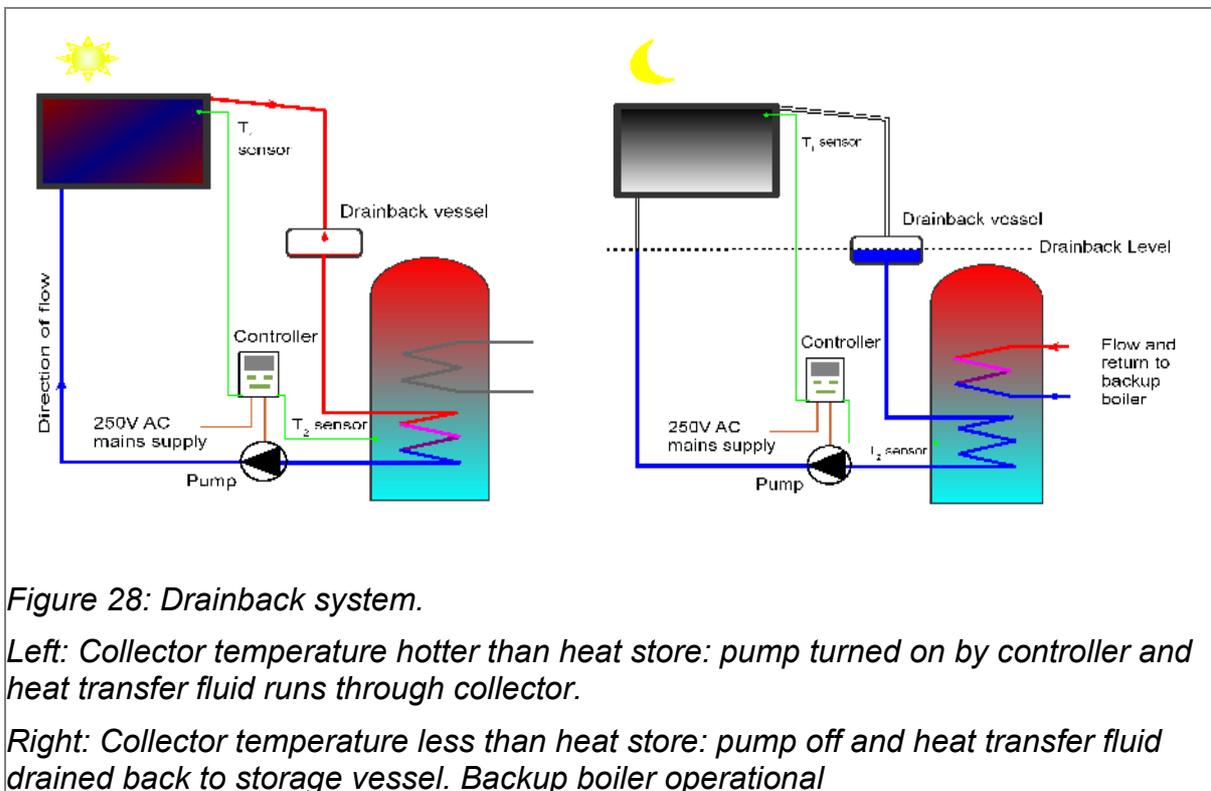


Table 3: Freeze protection techniques currently available for different configurations.

Freeze protection technique	Configuration			
	System		Collectors	
	Direct	Indirect	Flat plate	Evacuated tube
Freeze Tolerance	Yes	Yes	Limited, e.g. Solartwin	No
Water Movement	Yes	Yes	Yes	Yes
Antifreeze	No	Yes	Yes	Yes
Drainback Panels	No	Yes	Yes	Yes

3.6 Pressurised Systems

Systems must be designed to cope with the expansion of water as it is heated, and the production of steam if it is over-heated. On a sunny day, water in a stagnated solar water heating system may boil. This is more significant in dairy applications with a target temperature of at least 80°C, than for domestic systems, which typically aim to reach 60°C.

Gravity-fed, systems are open to air via the header tank feed and vent pipes. This arrangement allows expansion and the safe return of any steam to the header tank, but these are now seldom used because they allow oxygen to enter the system which promotes corrosion. They will not be discussed further in this document.



Figure 29: Expansion vessel for a 16m² system. A range of vessel sizes is available from a few hundred millilitres to hundreds of litres. .



Figure 31: Automatic air vent, (AAV). It is normal practice to isolate AAVs a few days after installation to avoid steam loss during periods of stagnation.



Figure 30: Automatic air vent in situ above panels. Note pipe insulation.

Pressurised systems are characterised by the use of an expansion vessel, (See Figure 29).

As solar controllers are generally programmed to switch the primary circuit pump off to prevent overheating of the heat store, it is normal to see significant expansion of the contents of pressurised primary circuits as the temperature of the fluid in the collectors rises in stagnation. On hot days, steam may form in the collector and adjacent pipework. This displaces fluid, which without an adequately sized expansion vessel, may give rise to significant pressure increase, and loss of the heat transfer medium via the pressure relief valve.

The expansion vessel should be sized to be able to accommodate all the fluid in the collector and adjacent pipework in which fluid might boil when the system stagnates, without exceeding the safe operating pressure of the system.

In case of malfunction or poor design, a pressure relief valve, (PRV), is used to maintain a safe working pressure within the system in extreme situations, see below.



As a safety device, it must never be possible to isolate PRVs from the rest of the system, and material discharged from PRVs may be above boiling point.

Under pressure, water can boil at temperatures well over 100°C, so the PRV exit port must point away from any area that people might frequent, or a pipe must be provided to a location where discharged material can be released safely.

If releases from the PRV are routine, the system will need refilling frequently which is a significant maintenance issue. Investment in a generously sized expansion vessel is the better approach.

PRVs used in solar water heating systems are generally rated to open at between 3 and 3.5 bar, though they tend to operate at somewhat above the rated figure, typically 3.5 to 4.5 bar. PRVs should be tested periodically to ensure that they are not stuck shut due to corrosion or sludge around the valve seat.

Manual and automatic air vents may be used to allow the escape of air and dissolved gasses when commissioning pressurised systems, though automatic air vents, (see Figures 31 and 30), are normally isolated after a few days to eliminate the risk of steam being discharged when the system stagnates. Bleed valves should be installed at all raised points in pipework. If in doubt, the provision of more bleed valves is likely to be a worthwhile investment, as removing air locks from systems during commissioning can be time consuming and frustrating.

All system components including PRVs, AAVs, and insulation, must be manufactured to withstand higher temperatures than are routinely encountered in central heating systems. Take care when ordering components to make sure that they are appropriately rated for solar applications.

3.7 Control Systems and Displays

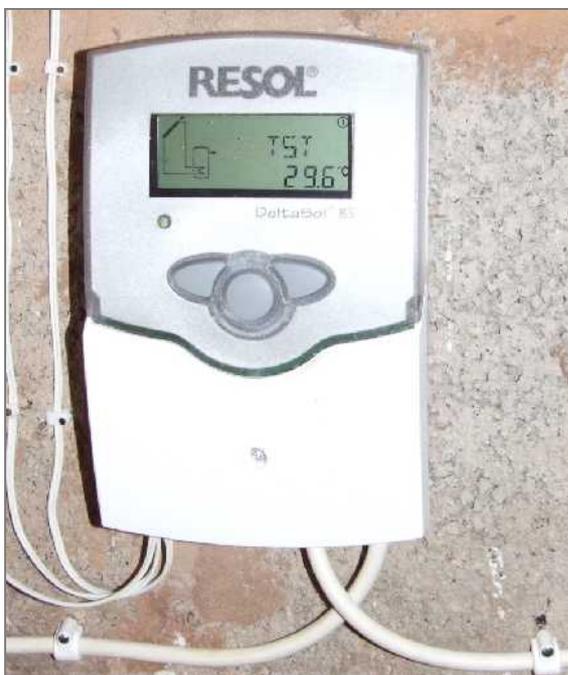


Figure 32: Modern Resol controller with diagrammatic and text display.

The most basic of solar water heaters that integrate the collector and heat store, or use convection to move heat from the collector to a heat store need no control system, but may benefit from a temperature display.

Where heat is transferred by the movement of pumped fluid, the pump needs to be controlled to prevent operation when the temperature of the water in the solar collector is cooler than the thermal store (except during 'water movement' freeze protection). One approach is to run a low voltage DC electric pump from a small photovoltaic solar collector. As pump speed is roughly proportional to the amount of sunshine, this gives good 'first order' control of the system, but does not guarantee that the pump will never run when the collector is colder than the heat store, or not fail to run when the sun fades but the collector is still

warmer. On the other hand, if the pump runs from solar electricity, there is no ongoing electricity cost to running the pump. Such systems have the virtue of extreme simplicity, but both the pump and PV panel may be expensive items, and any temperature display will be completely separate.

The most widely accepted approach is to use a mains powered electronic controller, (see Figures 32 and 33). This compares the temperature of water available in the collector with that in the coolest part of the solar heat store, and switches the pump on when the collector temperature becomes a little hotter than the store. This is referred to as differential temperature control.

The precise amount by which the panel must be hotter than the store to switch the pump on, and then how much it must cool before switching off are usually adjustable, and many controllers include additional functions to display temperatures at a number of points in the system, to run the pump for direct systems in freezing conditions, and to turn off the pump should the heat store over-heat.

Small mains powered central heating circulating pumps, (See Figure 34), are generally used. While cheap, these are generally larger than is desirable, and in small and moderately sized systems can frequently be used on the pump's lowest speed setting.

It is now possible to purchase energy A-rated pumps, which bring large savings due to improved energy efficiency. Although more expensive, low energy pumps are already likely to pay for themselves in a small number of years, and as electricity prices increase, should become the norm in solar and other applications.

Many domestic circulating pumps only operate up to 5 metres head. Higher head pumps may also be useful in drain back systems where the drainback vessel is a long way below the top of the panel.

Where the controller provides only on / off pump control, the primary circuit flow should be set using a flow gauge (see Figures 34 and 35). Most flow gauges also incorporate a ball valve to allow adjustment of the flow rate. Most of the industry accepts a flow rate through the collectors of about one litre per minute per square metre of collector, though significant deviations may not have a greatly adverse effect on performance.

Most controllers can only switch the pump on and off, but a few can vary the pump speed electronically in proportion to the temperature difference between the panel and the heat store giving better heat transfer control and improving electrical efficiency. These systems should be left with any flow adjusting valve fully open.

More advanced controller functions include data logging, computer interfaces, remote displays, provision for multi panel 'east / west' systems in which panels facing east and west gather most heat at different times of the day, and interfaces to integrate with other heating systems. Little more than a basic differential temperature controller is usually required, however, and there are many commercially available products to choose from, at a range of prices.



Figure 33: Controller showing incoming power, power to pump and three sensor inputs.



Figure 34: Pump - with flow gauge at top of image.

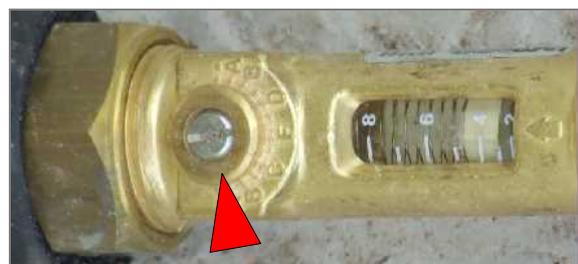


Figure 35: Flow gauge and built-in ball valve.

Table 4 summarises the options discussed in Section 3.

Table 4: Summary of options generally available for solar hot water systems.

Element	Options
Collectors	Flat plate or evacuated tube
Heat transfer	Convection or pumped (solar or mains pump)
Heat stores	Integrated with collector or separate (either as a pre-heat store or combined with existing water cylinder). Vented gravity-fed, or unvented or mains pressurised.
System configuration	Direct use of water from cylinder or indirect heating using a separate circuit
Frost protection	Freeze tolerance, water movement, anti-freeze or drainback
Expansion	Open-vented, drainback, or expansion vessel with over-pressure safety valves
Control	Self-controlling (convection), solar water pump, or electrically controlled pump based on temperature difference.
Pump	Solar powered DC, or AC domestic circulator, low energy or high head variants.

4 Performance

There have been a number of medium-scale performance assessments of solar hot water systems (Table 5) but these have generally looked at domestic settings, where the required water temperatures are lower than in dairy applications. The following two factors are used in the reports listed below to compare performance,

- solar Fraction – % of hot water load provided by the solar hot water system,
- and useful Solar Output – solar energy delivered to the system, in kWh.

Table 5: Summary of solar hot water performance assessments.

Report	Aim of report	Main findings
DTI, 1999 "Active solar heating system performance and data review" ETSU S/P3/00270/REP.	Review of domestic performance from 4 EU countries, discussion of relevance to the UK + recommendations for performance monitoring. All but one unit was flat plate.	<ul style="list-style-type: none"> • Payback period of 5.5 to 16 years • Swedish systems tended to have a larger collector area – water used for space heating. • Dutch systems had smaller heat stores, so greater rates of temperature rise, but smaller solar fraction. • Solar fraction of 49-61%. • Average energy output 429 kWh per m² per year.
DTI, 2001 "Analysis of performance data from four active solar water heating Installations" ETSU S/P3/00275/REP.	Four systems installed on domestic properties.	<ul style="list-style-type: none"> • Reliable solar fractions of 61 to 76% forecast. • Good results even for collectors facing 30 or 40° west of south.
DTI, 2001 "Side by side testing of eight solar water heating systems" ETSU S/P3/00275/REP/2.	Testing of 8 units (2 evacuated tube) on a standard rig supplying a pre-heat cylinder.	<ul style="list-style-type: none"> • Performance figures of 264-549 kWh per m² recorded per year. • Evacuated tube efficiency was higher, even at domestic hot water temperatures. • Flow indicators are very important for spotting system errors or problems .
DTI, 2002 "Further testing of solar water heating systems" ETSU S/P3/00275/REP/3.	Re-testing of 2 of the above units with backup heating installed. Testing against (new) international standards.	<ul style="list-style-type: none"> • Backup heating can reduce solar performance (due to raised cylinder temperatures) under some water-use regimes. • Operating with pre-heat cylinders removes this inefficiency but increases general system heat losses and bulk.
Energy Savings Trust, 2001 "Solar hot water systems in new housing" GIR88.	Study of 8 solar hot water systems installed on Housing Association developments in Wales.	<ul style="list-style-type: none"> • Useful solar output & solar fraction are within range of other EU countries if insolation levels are taken into account. • Energy savings were not maximised because hot water use was low. • Payback forecast at 10-20 years with higher hot water use.
SPF, 1994 "A comparison of three different collectors for process heat applications".	Testing 2 evacuated tubes vs flat plate for temperatures up to 150°C.	<ul style="list-style-type: none"> • Evacuated tubes outperformed flat plates over the temperature range required for dairy.

Efficiency of collectors is often expressed against operating temperature. As noted previously (Section 3.3.3) flat plate collectors tend to perform better at lower input temperatures, and evacuated tubes better at higher temperatures (see Figure 36).

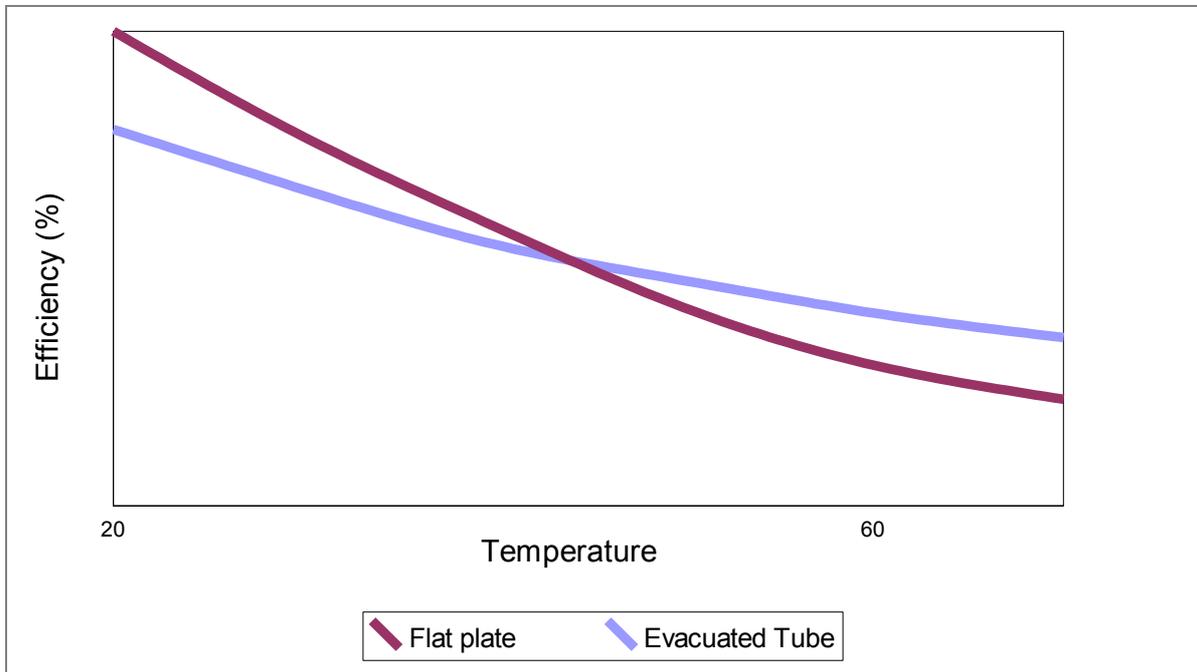


Figure 36: Illustrative graph of collector efficiency against incoming water temperature.

Efficiency graphs for a range of collectors are available from the SPF website, www.solarenergy.ch, and others.

It is important that the collector be appropriately sized to deliver the power and temperatures required.

Two (non-dairy) farms with solar hot water installed are known to the authors, in or around the Peak District National Park area, with T4 having specified and installed one, and advised on the second. One system uses a 4m² AES flat plate collector, the other 2.7m² of Focus evacuated tubes.

A third system is now being installed in the area using glass tiles as glazing. The farm having wound down its dairy herd some years ago, the new roof-integrated flat plate panel will be used for water and space heating in diversified eco-tourism and community applications.

Although performance has not been formally monitored, both farmers are very pleased with the outputs from their systems.

5 System Design

Various factors should be considered at the design stage to ensure that the system is efficient and effective.

5.1 Direct Systems

There are relatively few direct systems on the market, with the Solartwin flat plate unit being the most widespread. Although it is generally possible to 'pick and mix' the components used in solar water heating systems, the Solartwin panel, pump and photovoltaic system have been designed to work together in such a way that the use and expense of a differential temperature controller is avoided. Replacement of the key components with parts from other manufacturers will, in all probability, result in less efficient operation.

Direct systems may also be constructed using, evacuated tubes, (e.g. Apricus), in soft water areas fed from the gritstone areas of the Peak District.

5.2 Indirect Systems

5.2.1 Pressurised

Although indirect solar water heating systems can be gravity fed to fill and pressurise the primary circuit, this is seldom seen in modern installations which seek to minimise contamination and oxygen ingress. Many systems are pressurised through a double check valve to a working pressure of 1 to 2 bar on installation. An expansion vessel is used to prevent excessive pressure increase as the system heats up.

Where systems are filled from the rising main there is a duty to comply with the Water Supply (Water Fittings) Regulations 1999 (which replaced Water Bye-laws) that specifically forbid any filling arrangement which may allow

back-flow to the main and it is normal practice to use a 'fill tail' hose when charging the system, which is disconnected when not in use to isolate the main from any possibility of contamination by back flow.

Assuming flux residues are washed out of the pipes when they are commissioned, the main source of contamination in solar water heating systems is the decomposition of the antifreeze, used in almost all pressurised indirect systems. Rather than filling from the rising main, good practice is to premix antifreeze with water, and introduce it with a pump (hand operated or electrical) from the bottom of the system. This makes it easier to administer the correct concentration of additives, and eliminates the risk of contaminating the water supply. Precautions must be taken however, to keep the filling and flushing equipment clean.

Suitable valves must be installed to allow for filling, (see Figure 37), explained further in Section 10.2, and this type of configuration also makes draining for maintenance and flushing easy.



Figure 37: Valving for filling system.

5.2.2 Drainback

Drainback systems are an alternative to the use of antifreeze. These are normally filled at atmospheric pressure, but are sealed and run under pressure while the sun is shining and the contents are hot. They may also be controlled to restrict temperature by turning off the pump when the desired cylinder temperature is reached (without boiling of the heat transfer fluid and its displacement to the expansion vessel in pressurised systems), and have the advantage that in the event of power cuts or other periods of non-use, the circulating fluid will neither be boiled off nor thermally degraded. All the commercially available drainback systems we are aware of are indirect.

5.3 Larger Scale Systems

Solar water heating systems of any size may be constructed, but large systems require the flow of water through multiple panels to be balanced, (have equal flow – Figure 40), and drainback pipework must be set up so that water will drain from all panels, see Figure 39.

The system in Figure 38 combines both flat plate and evacuated tubes, though such systems require careful design.

Pump and pipe-work must be sized to carry the heat collected and if an expansion vessel is used as in conventional indirect systems, this must be sized to accommodate the worst case expansion of the circulated fluid should the collectors and adjacent pipe work fill with steam. These calculations are not always easy, so err on the large side if in doubt.

There is no advantage to using bigger pumps or pipes than are required to move the maximum amount of heat the panel or panels can deliver.

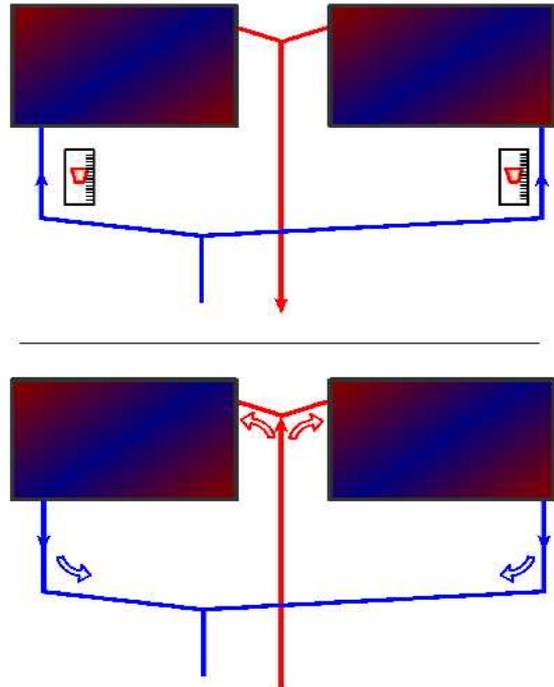


Figure 39: Top: flow to each panel is balanced. The use of low gauges is advised to verify this. Note that in drainback systems, the pipes must be installed at a gradient of 50:1 or steeper.

Bottom: When drainback systems are turned off, all pipework drains back by syphoning. Air is drawn in from the top of the panels, and fluid returns to the drainback vessel via the cylinder heat exchange coil.



Figure 38: Multiple panel system in Derby.

Where more than two panels are connected a pipe layout, sometimes referred to as 'reverse return' may be employed. This ensures that as far as possible, the length of pipework encountered by fluid passing through each collector is equal. It may still be useful and wise to have a flow meter / adjuster on each collector, but little adjustment should be required if flow through each collector encounters similar hydrostatic resistance. In these circumstances, the flow gauges also serve to confirm that air locks are not precluding flow through individual panels.

A reverse return configuration is shown on Figure 15.

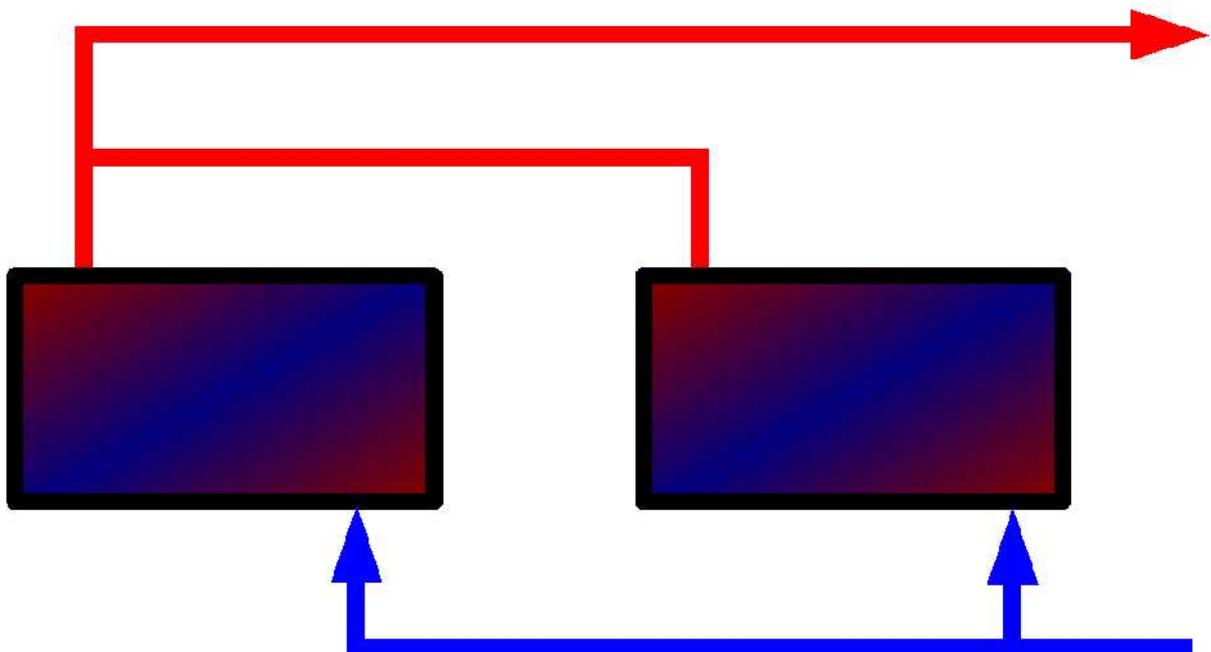


Figure 40: Above, Balancing the flow through groups of two or more solar collectors involves ensuring that the resistance to flow through each collector is the same by ensuring that the length of the pipe run through each collector is the same.

6 Selecting Buildings for Solar Installations

To justify the installation of a solar water heating system, a dairy or adjacent building must be in an unshaded location, with an appropriate orientation and a compatible hot water system.

6.1 Orientation of Solar Collectors and Time of Use of Hot Water

Although useful amounts of solar energy can be extracted from buildings with roofs facing east and west, sites should ideally have a south-facing roof which is unshaded for a significant proportion of the day and will not become shadowed by growing trees or anticipated building development. The following principles should be borne in mind.

- Most buildings receive sunlight for at least part of the day, but for a shorter period in winter than summer.
- A solar collector will gather most power when it is at 90° to the rays coming from the sun, i.e. pitched up from the horizontal.
- The sun's rays deliver most power when the sun is high in the sky, (when the atmosphere scatters and absorbs less of the energy).
- The sun is highest in the sky in the middle of the day and higher in summer than winter. In summer there may be a surplus of solar energy if the collectors are large relative to the volume of hot water to be heated, so it may be appropriate to pick a more vertical collector orientation that is optimised for spring and autumn performance to extend the season of use.
- Heat is lost slowly from the thermal store – reasonable quality domestic hot water cylinders will typically lose about 2.5kWh per day at 60°C, and more if the cylinder is unusually hot. Bigger stores lose less heat per unit volume of stored water. The sooner heated water is used, the more efficiently heat can be delivered. A domestic hot water cylinder might typically get up to 50 or 60°C during the day if heated by a flat plate collector, but even with no water use, the cylinder temperature might fall by 10 degrees between dusk and dawn.
- Evacuated tubes may provide higher storage temperatures by dusk. While this will result in greater heat losses over night, they should still deliver higher water temperatures than flat plate the following morning given similar patterns of usage. The quality of the heat store insulation is critical. 50mm of foam coating the cylinder seems to be an appropriate minimum standard.
- It helps to collect the heat just before it is used. The sun may not be in the sky for long before morning milking even in the summer, so east of south-facing collectors may bring less benefit, even though the length of time between collecting and using heat would be small. For evening milking, collectors facing somewhat west of south will minimise the delay before water use, and any excess heat can be stored for use during morning milking the following day. However, the available temperatures may not be as useful if the design of the heat store significantly dilutes the solar heated water with cold, refilling the heat store cylinder with cold water from the bottom as hot water is consumed from the top. A better

approach might be to avoid such dilution, using the solar heated water in batches.

6.2 Aesthetics and Planning

Although 'permitted development' on non listed building in many places outside of National Parks and Conservation Areas, roof-mounted solar hot water systems currently need planning permission, especially in the National Park area as they may constitute "development" and a "material alteration" of the roof line. It is always advisable to speak with the local planning authority about such projects in good time.

The Peak District National Park Authority has produced Supplementary Planning Guidance (SPG) covering energy efficiency and renewable energy systems. Issues highlighted include the degree to which a roof line is altered, matching the colour of existing roofing, the use of non-reflective materials, visibility from other locations, and the shape and positioning of the collector. The SPG is available to download from www.peakdistrict.gov.uk/index/pubs/htm.

6.3 Alternative Installation Configurations

Solar collectors do not have to be put on a pitched roof. If buildings are listed or in conservation areas, or if the construction or condition of the roof imposes health and safety constraints, panels can be mounted at an angle on walls, on stands on the ground, horizontally on a flat roof, or on an inclined frame on a flat roof, e.g. Figures 17, 41 and 42. When designing frames, it is important to think in terms of the structure, panels, and roof, surviving the highest winds that may be encountered

in a 50 to 100 year period. Consult the equipment manufacturer for mounting specifications. Evacuated tubes are generally less vulnerable in high winds than flat plate collectors because of the gaps between tubes.

Frames on flat roofs can either be bolted to the roof or weighted down with ballast. Ballast weight can be significant, with one supplier recommending 600kg for a 2.75m² collector.



Figure 41: Ground-mounted flat plate panels.



Figure 42: Wall-mounted evacuated tubes.

Steps can also be made to increase the extent to which panels are integrated with the roof, for example through the use of lead flashing (Figures 43 and 44). Painting exposed bright metalwork also offer an opportunity to mitigate the loss of visual amenity that shiny extrusions and manifolds present.



Figure 43: Use of lead flashing to minimise impact of panel.



Figure 44: Lead flashing – detail. Compare this to the edge of the panel shown in Figure 12.

6.4 Backup Hot Water System

While making significant energy savings, for many days of the year, even the best solar water heating systems will not meet the full temperature requirement for washing dairy equipment. As a result it will always be necessary retain a backup heating system using a conventional energy source such as oil, gas, biomass, or electricity. In winter the backup may need to provide up to 100% of the heat required, but it may not be needed at all on some summer days.

Solar water heaters can only be integrated with existing water heating systems if the input temperature and pressure ranges are matched with the existing system, including heat store cylinder requirements.



Above and below, Navitron panels on roof. The shiny manifolds obscure the ridge tiles, break up the roof line, and reflect the sky.



Below, the same type of Navitron collector, but with the manifold painted black. This satisfied the planners that the installation would be acceptable in a conservation area.



6.4.1 Temperature Requirements

Solar heat is generally delivered to the bottom of the heat store as that tends to be the coolest part. Other energy inputs to the heat store / cylinder should be made as late as possible to allow the most efficient delivery of solar heat from the collector for as long as possible. This will also optimise fuel savings.

In retrofit situations with a pre-existing heat store, the existing store can be replaced and possibly enlarged, or a second cylinder added to preheat water for use in the original store. Where water is heated 'on-demand' with no heat store, a preheat cylinder may still be used in some circumstances, but the on demand heater must be tolerant of the preheated water temperature, raising the water temperature further as necessary under thermostatic control.

6.4.2 Pressure Requirements

Most solar water heating cylinders and heat stores are gravity fed, vented systems at an operating pressure of no more than 1 bar. If water is required at a higher pressure than a gravity fed system can deliver, it is possible to use pressurised unvented heat stores, though these are more expensive than their conventional gravity fed counterparts. These must be installed by accredited installers.

The backup heating equipment must withstand and match the available pressure. For example, a standard gravity fed hot water cylinder might fail catastrophically if supplied with preheated water at high pressure from an unvented cylinder, and a 'combi' on demand gas heater might fail to pass sufficient water to operate if supplied with pre heated water from a low head gravity fed system.

6.5 Findings from Farms Surveyed

Eight of the ten sites visited were determined to be suitable for the installation of solar hot water systems, in terms of having a south-facing, unobstructed roof.

Most dairy water heaters T4 has seen in the Peak District National Park area provide heated water at low pressure, some using electrical level switches to sense water level and solenoid valves to control the ingress of water to be heated. Hot water cylinders were of a similar volume to domestic systems (see Figure 45). These may provide heat to an entire dairy, or have dedicated applications such as tank washing. It seems likely that the majority of these might be fed preheated water, their thermostats reducing other energy inputs automatically.

All systems used electricity, though one farmer who also made cheese and had a very high energy demand, also uses a biomass boiler and claims significant cost savings. Equipment ranged from 3 to 15 years old.



Figure 45: Typical dairy electric heater / storage tank.

7 Case Study

It is useful to look at an example to consider what the cost, payback and impact of a typical solar water heating system might be. The calculation below makes assumptions for a typical small to medium size dairy unit based on observations of dairy farms in the area, and the procedures specified by the Dairy Hygiene Inspectorate for a circulation wash.

7.1 Sizing and Costing a Typical System

Step 1: Establishing requirements

Hot water required

Two washes a day:

300 litres of water at 85°C

Power required

(Assuming the delivery of cold water at 10°C. This demonstrates the benefits of using heat-recovery, even if it provides only a small increase in water temperature.)

Temperature increase required	= 75°C
Energy to raise 1 litre of water by 1°C	= 0.001161 kWh
Energy required to raise 300 litres of water by 75°C	= 26.1 kWh

Heat losses from cylinder	= 3.9 kWh
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(Assume slightly higher than domestic cylinder due to cylinder size, and higher water and lower ambient temperatures.)

Total heat requirement	= 30 kWh
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Step 2: Choosing a system configuration

Direct or indirect systems?

There should be little performance difference between direct and indirect systems as long as water hardness does not compromise the equipment in direct systems. This distinction will thus be ignored from the point of view of performance and cost benefit comparisons.

Flat plate or evacuated tube collectors?

Given that the target system temperature of 85°C or more is high relative to typical domestic applications, the use of evacuated tube systems may be preferable, but both flat plate and evacuated tube systems will be considered.

Note: If the solar water heating system is undersized and heats a preheat cylinder, it may be that there will be no net benefit to the use of evacuated tubes as the preheat cylinder will never get warm enough for the efficiency of flat plate collectors to reduce significantly (refer back to Figure 36).

Step 3: Selecting a size

Any energy contribution has a cash value even if the full daily requirement is not met. One common approach is to aim to just meet the daily energy requirement on the hottest day in summer. This typically offers the best solar energy contribution per unit investment, but greater energy savings are possible by increasing the size of the collectors to improve the contribution in spring and autumn. As size continues to increase, however, returns diminish as it would require massive investment to harvest significant power in winter. 60% of farmers surveyed said they had no use for any surplus hot water produced in summer, (though 20% said they could use it in the house, others citing supplies to tourist accommodation and cheese making). For the purposes of this case study it will be assumed that the aim is to just exceed the daily energy requirement on the hottest days in summer.

In the middle of summer a square metre of solar collector might be exposed to 4kWh of heat radiation per day (a conservative estimate), so the heat demand of 30kWh might be met by a collector area of seven or eight square metres if the collectors were 100% efficient, which they are not. The calculations below are based on T4's experience of installing solar hot water systems and the typical collector efficiencies that can be achieved.

	Flat plate	Evacuated tube
Efficiency	Decreases significantly with temperature rise - heat store temperatures above 75°C are seldom seen. Dairy water system temperatures are high so an efficiency of more than 45% is unlikely under these conditions.	Decreases relatively little with temperature rise. While initial rates of temperature rise may be a little slower than flat plate, rates of warming should be maintained well as heat store temperature rises. Efficiency of 65% may be achieved.
Likely size required	18m ² might be appropriate but this is likely to struggle to achieve the full temperature rise.	Less than 13m ² should be adequate and evacuated tubes should be able to reach the target temperature.
Size specified¹	16.5m ²	14.45m ²
Installation cost²	£8,900 (ex VAT)	£8,800 (ex VAT)
Forecast Annual Output (kWh)	8,250 kWh if well sited	9,390 kWh if well sited
Value of energy³	£618 per year	£704 per year
Payback time⁴	14.5 years	12.5 years

Notes:

- Sizes are specified based on the typical units available.
- Estimated installation costs are based on 2007 prices.
- Assuming an average electricity price of 7.5p per kWh – see Figure 46
- Larger systems may offer lower costs per installed capacity because some elements of the installation price, such as the control equipment and some elements of the plumbing, are fixed costs.
- Energy costs are likely to rise faster than installation costs.

7.2 System Financial Payback

The two systems have 'payback times' of around 13-15 years, with evacuated tubes being the lower of the two.

Enhanced Capital Allowances are available for certain solar hot water systems (see Section 12), enabling a business to offset 100% of the capital value against the first year's tax. If the above examples were fully eligible for ECAs the payback time would be reduced by between 2 and 3 years.

Fuel has increased in price rapidly over the last few years and this trend seem unlikely to abate in the long term¹⁰, due to both fuel scarcity and carbon taxes.

The UK is increasing its imports of natural gas, and it has been predicted that the rate of oil extraction world wide may be about to start its inevitable decline¹¹. At the same time demand from developing countries is growing significantly.

Non-domestic electricity prices for 'very small' users (below 20 MWh per year) monitored by the Department for Business, Enterprise and Regulatory

Reform (was Department for Trade and Industry)

www.berr.gov.uk/energy showed an average increase of 7.6% per quarter from late 2004 to late 2006. This is equivalent to an annual increase of 13.4% in 2004-5 and 28.5% in 2005-6 or 45.7% over the whole period (see Figure 46).

Table 6 shows the impact of various scenarios for annual price increases on payback period.

Ignoring inflation, even a very small ongoing increase of 3% per year would see both systems paying for themselves more than twice over during their anticipated lifetime of around 25 years, though paying for themselves three time over seems a quite plausible outcome.

Table 6: Energy price increase and payback (evacuated tube).

Annual increase	Payback (years)
3%	11
10%	9
17.5%	8
25%	6.5

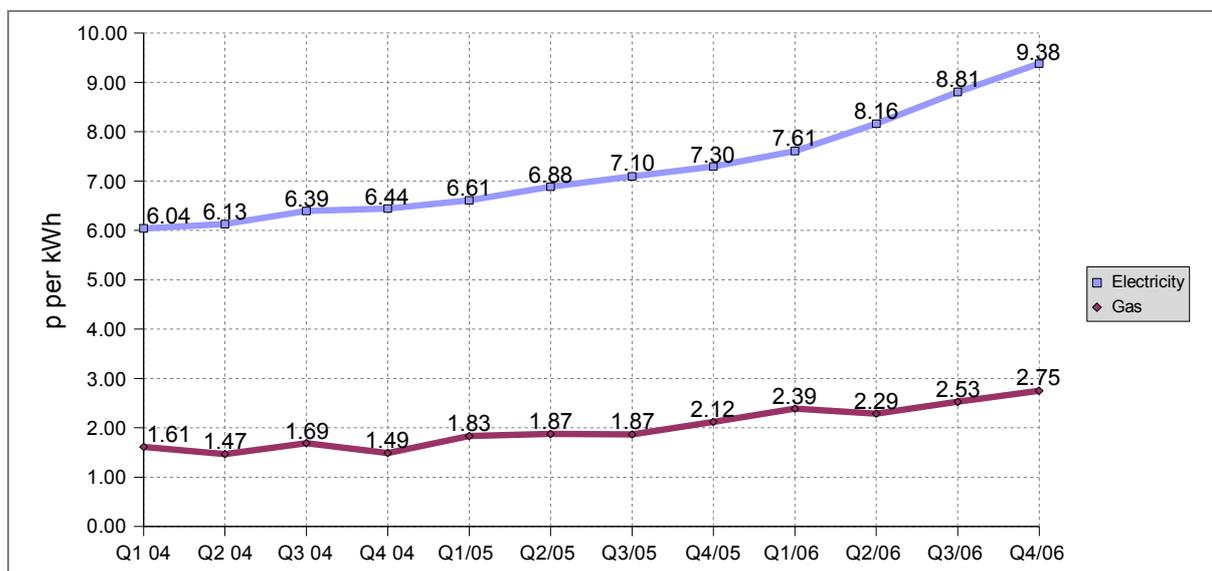


Figure 46: Non-domestic electricity and gas prices for "very small" users (BERR).

7.3 Farmers' Willingness to Pay

When asked what payback time would be acceptable for investments in energy saving or generating technology, farmers gave a range of figures from 2 to 10 years with an average value of 5. The farmers who already have solar heating also fall within this range.

As to reducing barriers to the uptake of solar water heating on dairy farms, it was clear that before farmers were willing to commit, that either energy price rises would make it more viable, or the cost of equipment would need to be reduced, (by waiting for the market to mature, or by grant, subsidy or interest-free loan).

Above all it was felt important to demonstrate that solar water heating was profitable in practice and that it is a robust, simple, appropriate technology that can be maintained as required if necessary, at moderate cost. It was felt that long term cash savings should be emphasized rather than environmental credentials, which might put off many potential users.

7.4 Displaced Fuels

On the basis of visits to farms in the Peak District National Park area, it seems most of the displaced fuel will be electricity, though LPG and oil are also widely used on remote farms.

From an environmental perspective the best emissions saving per pound invested in solar equipment, will be made where the existing installation makes inefficient use of primary fossil fuels. As electricity production and distribution are unlikely to deliver more

than around 40% of the energy available in their primary fuels to the consumer, the displacement of electrical energy use should be prioritised over the local combustion of oils and gas using modern efficient equipment.

While the displacement of any fossil fuel is desirable, coal and electric water heating should be given the highest priority, followed by oil and gas. There would be little advantage to displacing biofuels as these are nearly carbon neutral, though gas and oil boilers that are used to provide hot water in summer may be prone to 'dry cycle' as the thermal load is small, causing brief periods of combustion and inefficient fuel use. Under these conditions, the cost of gas or oil fuelling may be little better than electricity.

7.5 System Environmental Benefits

Electricity use is responsible for 430g of carbon dioxide per delivered kWh. On that basis, the evacuated tube system described above might prevent the release of over 4,038kg of carbon dioxide per year. As each installed system might reasonably be expected to have a working life of at least twenty five years, this would save the emission of in excess of 100 tonnes of carbon dioxide during its life, as well as other pollutants from the combustion of primary fuels, e.g. oxides of nitrogen.

8 Specifying Components and Standards

This section is not intended to replace the manufacturers instructions for any particular product, or guidance provided by any agency, but rather seeks to make some general but important points.

A system should be constructed in such a way that it can run for decades with only a minimum of simple maintenance, such as washing the collector surface annually. In particular it is worth making a good job of all work on the roof as the effort, risk and cost of gaining roof access may be significant compared to the effort required to make small but important repairs.

8.1 Flow Rates, Pipe Sizes and Pumps

The amount of heat to transfer dictates the primary circuit flow rates. A flow rate of about one litre per minute per square metre of panel is generally accepted as optimal. Unless the controller can modulate the pump speed electronically, the lowest possible speed that can move enough water around the primary circuit should be selected at the pump (this minimises the electricity used by the pump). The flow should then be adjusted down to the rate required, using the ball valve adjuster that is usually built into the flow gauge (Figure 47).

Except in systems that transfer heat by the convection of a fluid which require wide pipes, a low primary circuit thermal capacity is regarded as an advantage as this makes the system more responsive to brief periods of

sunshine. There is thus no advantage, and some cost penalty to fitting oversized pipes or pumps in a pumped system.



Figure 47: Flow gauge showing ball valve adjuster (to left).

8.2 Valves

Gate valves (typically a red hand wheel and brass bodied valve) are not very reliable if operated repeatedly over a number of years. In addition to increasing leakage from the gland over time, they may also seize, becoming impossible to open or close.

As an alternative, T4 suggests the use of good quality stainless steel ball valves which, while marginally more expensive, offer significant long term reliability and maintenance benefits, see Figure 48.



Figure 48: Gate valve and ball valve.

8.3 Insulation

Insulation of the entire solar water heating system is critical to performance, especially the panel, primary circuit pipe-work and heat store / cylinder. Insulation should be as thick as can be afforded, and will save money in the long run despite the higher initial cost.

In doors insulation can be secured with glass-reinforced plastic tape (see Figure 49). External insulation, however, must be weather-proof and resistant to ultraviolet radiation. Short runs of external insulation may be wrapped in aluminium tape for protection, Figure 50, (which may be anodised black for aesthetic considerations in sensitive areas). Longer runs should be wrapped securely in butyl rubber sheet, Figure 51.

Figure 52 illustrates insulation of the flow meter. Once the flow has been set the insulating foam is secured with a releasable cable tie to enable flow to be checked and adjusted in future if necessary.

Insulation of the pipe-work within at least two metres of the panel must withstand the stagnation temperature of the panel, i.e. the temperature it will reach in bright sunlight with no water flow. This may be several hundred degrees, and polymer foam products may melt and decompose at these temperatures. The use of glass fibre or mineral wool products is necessary despite the expense. These work well under the rood where they are kept dry, but where such insulation is used outside, precautions should be taken to stop it becoming wet in service, or much energy will be wasted by the evaporation of absorbed water.



Figure 49: Internal insulation, showing well insulated cylinder, foam insulation and glass-reinforced plastic tape.



Figure 50: Use of aluminium tape.



Figure 51: Butyl rubber sheet protecting Armaflex HT insulation from ultraviolet damage.



Figure 52: Flow meter wrapped in insulation to minimise losses.

8.4 Drain Points

When draining systems, standard drain cocks sold by many plumbers merchants only allow low rates of drainage and tend to leak from the valve thread as well as the hose tail. T4 normally recommends wide bore ball valves that allow quick draining of cylinders with a minimum of mess. The time saving is particularly significant on larger cylinders, or installation clogged by sludge.

8.5 Primary Pipe-work and Joints Close to Panel

In recent years plastic hot water pipe has been increasingly used in domestic hot water systems. Because of the extremes of temperatures that may arise during or after the stagnation of a solar water heating system, plastic pipes should not be used in primary circuits under any circumstances.

For the same reason, it is recommended that compression fittings are used within two metres of the panel to eliminate any risk of melting soldered joints.

8.6 Planning for a Quality Installation

The Clear Skies scheme (a DTI-funded renewable energy grant scheme, now replaced by the Low Carbon Buildings Programme) produced a check-list for solar thermal installations, covering the documentation to be left with the user as well as electrical, roof and operational checks.

This check-list has subsequently been incorporated into the Energy Saving Trust's "Solar water heating systems – guidance for professionals", covering conventional indirect systems (document CE131, available free from www.energysavingtrust.org.uk by navigating to the "publications" section under "housing and buildings" and searching for "solar hot water").

Even if work is not carried out under these schemes, it is instructive to examine this document for information. The original check-list is provided for information in Appendix 1, though subsequent documents that have superseded this should be checked.

Although these are aimed at the domestic sector, most of the points apply equally to systems on dairy farms. It will be much cheaper and easier in the long run to make a sound installation by good initial design, than to retrofit adaptations to make a poor system function reasonably well.

8.7 Bleed Valves

Bleed valves, manual or automatic, should be incorporated at all raised points in the pipework. Failure to do this may make filling the system difficult, flow erratic and commissioning time-consuming.

9 Making a Safe Installation

Farms have statutory duties under the Health and Safety At Work and other Acts, as well as building regulations. Whoever manages the installation of the system has a duty of care to consider both the process of installation and the safe use of the installed system, to protect the public, farm staff, and residents.

The list below is not intended as a substitute for a proper site specific risk assessment, but may be a useful starting point.

9.1 Access and Putting up the Panel

The bulk and weight of many flat plate collectors can make installation difficult where access is restricted, for example in the narrow gaps between buildings, or where a boundary, road, or path is close to a building. A winch or crane may be necessary to hoist heavy panels. Where manually handled, care must be taken to keep the centre of gravity well within the footprint of the scaffolding or tower used to gain access. Some panels may be carried up in component form as frame and insulation followed by collector surface and finally the glass front.

Most evacuated tube systems can be assembled on the roof tube by tube once the manifold is mounted. Manifolds and tubes can generally be lifted by one person and passed up to the roof by hand, but be aware of products, (such as the Nippon Electric Glass DP-4 and DP- 6 collectors), which are delivered with their tubes soldered into the manifold by the manufacturer, and which must be

mounted on a frame before being lifted onto the roof (see Figure 53 and 23).



Figure 53: NEG-DP-6 collectors mounted onto galvanised Dexion angle.

9.2 Working off the Ground

All work should be carried out in accordance with relevant legislation, currently the Work at Height Regulations (2005). For the purpose of the regulations, a place is 'at height' if a person could be injured falling from it.

A guidance note is available (INDG401 (Rev1)) from any Health and Safety Executive source or the HSE website (www.hse.gov.uk/pubns/indg401.pdf). The HSE website also contains a range of information at www.hse.gov.uk/falls.

9.3 Electrical Issues

All wiring should be carried out according to current wiring regulations by appropriately accredited persons. Most plumbers and heating engineers are not appropriately qualified to undertake electrical installations, so when work is carried out, it must be clear who is assuming responsibility for ensuring that all wiring associated with the work is safe, and complies with all

relevant regulations. In the words of a recent communication from the Health and Safety Executive:

“It will be taken for granted that the equipment conforms with relevant EN standards for electrical equipment. Because electrical connections are in a wet environment we would generally consider most farmers as not competent to carry out installation work...”.

9.4 Mechanical Explosion

While it can be convenient to use isolating cocks in some parts of solar water heating systems to facilitate easy maintenance without draining the system, care should be taken to avoid any risk of isolated parts of the system being heated when these are closed. Severe superheated steam burns and mechanical explosion might result if water is heated and released under pressure from enclosed vessels or pipes such as an isolated overheating pump or solar collector, see e.g. Figure 54.



Figure 54: Pump capable of being isolated. This should not be run while isolated.

9.5 Cylinder Installation Certification

Part L of Building Regulations requires water cylinders to be installed by competent persons and requires the

installer to certify the installation they have made. There appears, however, to be no clear definition of a competent person for unvented cylinders. It is T4's understanding that anyone with a plumbing qualification should be able to make this certification. While T4 understands that some people working as plumbers have not come into the profession by a path that accredits them, the requirement imposed by Part L remains.

The accreditation required for unvented cylinders is more stringent than that for gravity fed systems due to the greater intrinsic hazards of heating water at higher pressures in sealed vessels. These must be installed by an appropriately accredited person.

9.6 Temperature of Delivered Water

Dairy cleaning processes can require temperatures as high as 85 to 96°C, so except for tank washing, there should be little need to reduce peak solar water temperatures.

The temperature at which solar heated water is available depends on the amount of heat delivered to the water cylinder and the amount leaving it. If the insulation of the cylinder is good and no water is drawn off, the temperature may become very high with even a moderate amount of direct summer sunshine. Evacuated tube solar water heaters are notorious for bringing water up to boiling point, but flat plate collectors may also bring water up to boiling point, and reach temperatures that might cause discomfort or scald.

While these high temperatures are ideal for dairy cleaning applications, for hand washing it will be necessary to use a three port thermostatic mixing valve at

the sink or other point of use. These combine hot and cold water to give the desired output temperature and can be pre-set to meet the temperature requirements at each location.

9.7 Legionnaires' Disease (Legionellosis)

The legionella bacterial infection is a risk posed by all hot water storage and handling systems. As far as T4 is aware, stored potable water in domestic properties in the UK has not to date been responsible for any outbreaks of Legionnaires' Disease, occurrences being largely attributable to air conditioning systems where water remains warm and stagnant for very long periods.

Infection from contaminated water is by fine aerosol water droplets that are inhaled deep into the lungs. Attention has been directed towards minimising the number of bacteria in stored water. The legionella bacteria is present in all source water at sub-clinical levels, but growth of the bacteria depends on the time spent in store, the store temperature and nutrient availability.

Maximum growth rate occurs at about 42°C. At higher temperatures bacterial populations decline until at 60°C, sterilisation occurs within seconds. This has led to the recommendation from some quarters that all hot water stores be maintained at 60°C or above, and this is now regarded as normal and necessary practice. Although solar water heating system temperatures cannot be accurately controlled, all water used in the dairy should have been taken up to temperatures in excess of 60°C, so legionella should present no risk to dairy staff, cattle or the food chain.

In normal use a dairy hot water system is unlikely to remain stagnant for much more than twelve hours which reduces opportunity for bacterial populations to grow significantly, as does the use of a copper cylinder and pipe work, copper being toxic to the bacteria. The rising main cold water supply is also generally very low in nutrients and frequently contains traces of chlorine or other bactericides, though water collected from other local sources, such as local wells or bore holes, may have a higher nutrient content, especially if contaminated with agricultural run-off.

Should any hot water system be unused for any length of time, care should be taken to flush or sterilise it to eliminate all risk of infection.

The Water Research Centre (WRc) has revealed that its main concerns regarding legionella relate to shower units containing plastic or rubber water pipes. These materials may provide nutrients for growth, which may be significant if water remains warm and stagnant in them for some time. One of the greatest risks is that water might be delivered from a shower head in a form that could be inhaled. A similar issue might arise if droplets of warmed water can be inhaled when cleaning dairy equipment with water from any source that has not been heated sufficiently, though the disinfecting chemicals used are likely to kill legionella at normal working concentration.

9.8 Evacuated Tubes - Handling, Hazards and Disposal

9.8.1 Implosion

Rather like old television 'tubes' the primary risk associated with evacuated tubes is implosion. Although an implosion initially causes fragments of glass to move towards the centre of the tube, some material will pass through the collapsing structure or bounce out of it, and many fragments may fly outwards with enough energy to cause injury, especially to the eyes and any exposed skin.

To some extent this risk depends on the shape of the tube and the evacuated volume. It may be that smaller diameter double wall vacuum tube 'flask' designs pose less of a threat than other types of evacuated tube, especially single wall tubes of larger diameter, because of their lower evacuated volume.

This risk can be controlled by wearing full-face protection and robust clothing when tubes have to be handled, and also by wrapping the tubes when moving them to contain and restrain any broken glass.

Implosions are noisy. Even people of the most confident disposition may be startled into falling by a loud bang close to them, especially if accompanied by flying glass. This should be taken into account when working at height with evacuated tubes. T4 is aware of at least one worker being taken to casualty for treatment after a Nippon Electric glass tube imploded.

9.8.2 Getters

When evacuated tube collectors are fabricated, any gasses remaining after

most of the air has been pumped out are removed with a getter. A getter is a small, usually circular trough filled with a metal that, on heating, reacts quickly with the residual gas (Figure 55). Once the tube envelope is evacuated and sealed in manufacturing, the getter is heated to a high temperature by electrical induction causing the metal to evaporate. This adsorbs or reacts with any residual gas and deposits a dark metallic mirror like coating on the inside of the tube giving rise to secondary risks.



Figure 55: Getting ring and white residual getter chemical deposit (below central copper coloured heat-pipe).

The getter continues to absorb any gas molecules that leak into the tube during its working life. If a tube develops a crack in the envelope, this deposit turns white on reaction with the atmosphere. It is thus easy to identify broken tubes.



Figure 56: Left: intact tube showing mirror-like coating.

Right: broken tube with white deposit.

The hazard lies in the possible toxicity of the getter material. As an example, one common getter metal is barium which is toxic¹², accumulating in muscle, lungs and bone, while having adverse effects on the nervous system, gastrointestinal tract, heart, respiratory system and other organs¹³. In general it should be assumed that the metals used in getters are esoteric, reactive and toxic, and that on entering the body via cuts from broken glass, or inhaled as dust, they may have high bioavailability. Seek medical advice if exposed to these materials, and keep a sample for analysis.

9.8.3 Heat-pipe Contents

Some evacuated tube collectors use a device called a heat-pipe (Figure 57) to move heat from the collector plate to a water filled manifold or heat store. These are generally fabricated in copper or steel to withstand significant internal pressure when in use. They are not as they may at first appear solid metal, and although some manufacturers use innocuous materials such as water under reduced pressure as the heat transfer medium in their products, others have used organic compounds such as hydrocarbons or other volatile or flammable organic materials.

While these products may not have high acute toxicity, the possibility exists that some manufacturers may have used less benign materials, and the manufacturers should be consulted to establish if any special disposal precautions are required.



Figure 57: Heat-pipe and heat conducting internal metal spring-loaded sleeve partially withdrawn from the collector.

9.8.4 Disposal

On no account should heat-pipes be disposed of on a fire. Apart from the risk of mechanical explosion due to the super-heating of the contents, the contents themselves may be flammable and some may produce toxic combustion products.

10 Commissioning, Testing and Handover

The Clear Skies and Energy Savings Trust information (Appendix 1 and Section 8.6) contains guidance on commissioning and handover of the system.

This includes:

- leaving sufficient documentation with the user to ensure that the system can be used safely and effectively,
- appropriate electrical safety certificates,
- roof integrity and mounting,
- checks on performance and operational standards, and
- general checks that the system has been installed to the required standard.

Among these checks, T4 has found the following steps to be important.

10.1 Flushing

When systems are commissioned, any residues of flux, wire wool, etc. should be flushed out of the pipes to minimise ongoing wear of mechanical parts. Many commercial installations T4 has seen have not been thorough in this respect, and as a result flow gauges can be hard to read and may give false readings making optimisation of the flow rate difficult. Systems will also be more prone to corrode if not flushed thoroughly prior to use.

10.2 Filling

If filled from the rising main, systems should be filled with care to prevent either over pressure or back-flow of antifreeze into the mains supply.

As an alternative, a hand-pump or electric pump (Figures 58 and 59) can be used, the electric pump being able to recirculate the fluid until all air has been removed from the system.



Figure 58: Hand pump.



Figure 59: Electric pump with pre-diluted antifreeze solution.

Good drain and fill points were shown in Figure 37. They can be used as demonstrated in Figure 60. It is important to drain the system and replace antifreeze every few years as the solutions have been reported to polymerise under sustained high temperatures, and can block small diameter pipework in some panels.

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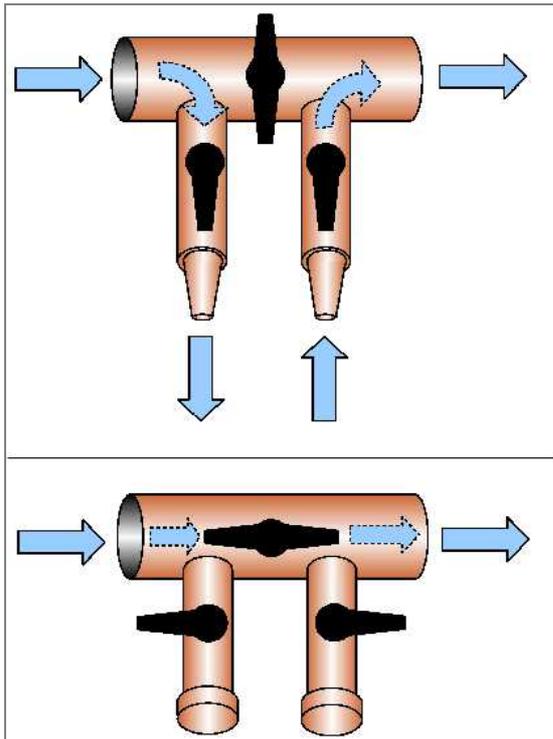


Figure 60: Above top: Upper valve closed and lower valves open for filling. Antifreeze solution is pumped into system and returns, carrying air out of the system.

Bottom: Lower valves closed and upper valve open in normal operation.

To reduce the probability of leaks developing in the system, it is good practice to pressure test the system up to the pressure at which the pressure relief valve opens. If this is done, there is virtually no scope for leaks to occur at normal working pressure unless the pipes are mechanically damaged.

Below, system components mounted on board, connected to an electric commissioning pump at a test pressure of a little over 4 bar, the PRV operating pressure. Components shown from bottom left to top left (the direction of water flow), pump, fill / flush valves, flow gauge, non return valve and pressure gauge



11 Performance Monitoring

There is great benefit to monitoring the performance of renewable energy systems and sharing information about them.

As fuel prices rise, information and experience collected by users will have increasing value in supporting decisions about the wider adoption of sustainable energy sources.

T4 will be pleased to suggest approaches to monitoring the performance of any equipment. Some of the techniques now available, especially for temperature recording, are simple, relatively low cost, and may also be applied to the monitoring of stored food, other agricultural processes and the wider environment.

A temperature data logger is shown in Figure 61. It has a programmable sample rate and is cheap, robust, waterproof, food-safe, and requires no external connections when in use. It has a wide temperature range and can be used for monitoring solar water temperatures. The device is programmed and data accessed when necessary using a standard PC.



Figure 61: Above centre, Thermachron® temperature data logger.

12 Funding Sources

At the present time T4 is not aware of any sources of grant funding for solar water heating projects specifically for dairy farming. For example, Carbon Trust zero interest loans and the Government's Low Carbon Buildings Programme (LCBP - 0800 915 0990 or www.lcbp.org.uk), whilst available to industry and domestic users, are specifically unavailable to agriculture.

If the farm has diversified to offer significant community access and the community is being made aware of environmental work on the farm, it may be possible to apply for funding under the LCBP, but the justification will have to stem primarily from community experience and learning.

Please contact T4 for up to date details of any schemes that may have emerged since the publication of this document.

Some schemes including the LCBP require systems to be commissioned by accredited installers. If you can carry out the work to the required standard and are willing to have it inspected, an accredited installer might be willing to commission it for you so that you will be eligible for a grant.

In some circumstances some solar thermal equipment may qualify for 0% Energy Efficiency Loans and Enhanced Capital Allowances (ECA). The Government website www.eca.gov.uk contains an "Energy Technology List" of allowable technologies and details of the process for making a claim (or call 0800 085 2005). Check to see if the products under consideration are approved before purchasing, or if appropriate alternatives are listed.

13 Robotic Dairies

In automatic milking (AM) systems (sometimes known as voluntary milking systems) milking is carried out entirely by machine (Figure 62). Continuous use throughout the day allows more cows to be milked per milking station. De-Laval, (Swedish supplies of AM systems), quote a rate of 55-60 cows per milking station, resulting in 150-200 milkings per day. Some cows are milked three times during this period, and manufacturers claim increased milking yields.



Figure 62: Cows entering an AM system.

Commercial systems became available from the 1990s, and by 2001 there were claimed to be over 1,100 systems worldwide. In 2005 The Times reported over 30 such systems in the UK¹⁴. Several of the UK farms have received a high level of publicity, for example the organic Manor Farm at Marcham in Oxfordshire and Kemble Farms in the

Cotswolds. Manor farm has approximately 100 cows, and Kemble 700. More locally, Nottingham University has an modern fully-automated farm used for teaching and research.

As AM system milking may take place at any time of the day, some European countries require each milking station to be cleaned three times a day instead of the standard two¹⁵.

Three types of cleaning occur:

- system cleaning – washing each milking station using hot water and flush to drain,
- unit flushes – flushing of a milking station, e.g. after contaminated milk or to stop milk solids drying during a gap in milking, generally using cold or lukewarm water, and
- cluster flushes – washing the milking cluster following contact with the cow, perhaps using disinfectants with a contact time of several minutes if cold water is used.

As AM systems aim to minimise 'down time', it is preferable to undertake system washes as quickly as possible which may require the use of hotter water. The above European study looked at 8 different AM systems. Referring to the washes specified in Section 2.1 the following use figures were reported.

'Circulation cleaning'

45-85°C
20-40 minutes
55-90 litres per milking station

'Boiling water cleaning'

Above 90°C
9-20 minutes
70-90 litres per milking station

To reduce the duration of the system washes, many units are set up to use the quicker 'boiling water' wash. See Figures 63 and 64 for a typical example heat store in an AM system.

It appears that AM systems may use less system cleaning hot water than conventional dairy plant.

In addition to equipment washes, automatic teat cleaning is carried out to remove dirt that could contaminate the milk. Whilst manual cleaning can take account of the amount of dirt actually on the teats, AM systems do not have sensors to monitor this, so cleaning has to be based on an assumed worst case level of contamination. AM systems will therefore generally use more warm teat washing water than manual cleaning, which is often carried out with disinfecting wipes in any case.

It is clear from the evidence above that the hot water use by AM systems could be significant in terms of volume and temperature, especially if boiling water system washes are chosen.

Given the typically greater total volumes of hot water used in AM systems, solar hot water systems could offer a better cost benefit and shorter payback periods for AM systems than conventional dairy plant, however backup heating may be needed on a more continual basis due to the temperatures required, and hot water consumption throughout the day, though ongoing consumption, reduces the need for solar heat storage.

As with traditional dairy plant, solar inputs can reduce costs and environmental impacts. The case for solar hot water is certainly worth exploring for AM systems.



Figure 63: Internal electrically heated AM hot water system with water level sensor in transparent tube.



Figure 64: Solenoid valve to control entry of water to the heater.

14 Ongoing Developments

14.1 Further Testing

Assessment of the various types of solar collectors will be improved by independent performance tests carried out to recognised national and international standards, particularly BS EN 12975-2:2001 and EN 12975-2:2001 (although these are generally aimed at domestic situations with lower operating temperatures than dairies require). The best sources of independent data appear to be testing facilities such as SPF www.solarenergy.ch.

It would be useful to perform comparative trials of flat plate and evacuated tube collectors in a dairy context, to demonstrate the contribution that solar water heating can make, and to determine the optimal configuration, given the particular water use patterns.

14.2 New Cleaning Procedures

Electrolysed oxidising (EO) water has been developed as a cleaning and disinfecting system in the USA over the past decade. It is manufactured by passing a current through a weak sodium chloride solution to produce alkaline and acid solutions, separated by a membrane, often referred to as alkaline and acid EO.

Research has been carried out by a number of universities into its performance. To date it has been tested for sanitising food products, including meat, fish and eggs and has been demonstrated to kill listeria, staphylococcus, campylobacter and E.Coli as well as other bacteria.

Tests on dairy equipment in 2005-6 demonstrated the ability of EO water to

remove bacterial cultures from milking and pipeline equipment, similar to those used in dairy systems. The latter tests were based on a 10 minute wash with alkaline, followed by 10 minutes with acidic EO water, both at 60°C.

One range of products (Primacide A, B & C) are marketed by Eau Technologies of the USA, and various approvals have been given by US agencies for use in food processing. One of the barriers to implementation has been the capital investment in the electrolytic generators, but the company claims to have developed affordable systems.

Should it be the case that this treatment also removes protein and fatty residues from the system at this temperature it may render traditional chemical treatments obsolete, and the manufacturer claims it to be just as effective as conventional cleaners.

Use of this process would reduce the hazards associated with the storage and handling of concentrated reactive chemicals that can cause serious burns to the skin and eyes if mishandled, and reduce chemical costs and environmental impacts as well as energy inputs.

Should this process be adopted in the UK it will alter the heating requirements for dairy cleaning, allowing the installation of smaller solar collectors, which would alter the assumptions of the case study in Section 7.

The Dairy Hygiene Inspectorate have been contacted for a response to the above research, but have not indicated that they consider the uptake of this technology likely in the UK.

15 Discussion

15.1 Funding

The research work for this report revealed deep concerns about energy issues among dairy farmers, particularly relating to cost. As the industry stands, it is not easy for many farmers to achieve much more than subsistence, given the income available from milk sales. This is particularly true for smaller farms, which make up a large proportion of those in the Peak District National Park.

With respect to investment in solar water heating, if energy prices do not rise enough to justify the investment, the payback time will be so long that the money is effectively lost. On the other hand, if energy prices rise enough, many farmers are likely to be driven out of business by direct and indirect energy costs, unless these can be passed on to consumers.

While the farming community may see investment in renewable energy as desirable and ethically satisfying, it would require a very significant proportion of their income, largely for the indirect benefit of protecting global resources.

The exclusion of farmers from key renewable energy funding streams or Carbon Trust interest free loans is particularly ironic as dairy farmers have a regular and predictable demand for hot water. Dairy solar water heating may offer a better outcome per unit spend than grants to the domestic sector. In addition to direct benefits of fuel and emission savings, the deployment of solar water heating on farms will give an opportunity to spread experiential learning about renewables into a new community.

There is evidence of chronic under investment on small dairy farms, which is as apparent in energy management as other elements of their activities.

To support the current structure of small, family farms financial assistance would need to be weighted towards farms with smaller annual turnover. To enable payback in within 5 years (the average figure quoted) would require subsidy of up to 65% of the total cost. There are already international examples of this magnitude (Table 2).

15.2 Decision-making

While solar water heating can be demonstrated to reduce farm costs, it is important to optimise returns on investments. For the foreseeable future, energy conservation may yield more benefit per pound spent than the installation of renewables.

The recommendation for solar water heating to be implemented on a dairy farm should be subject to the following criteria.

- The farm should be aware of all the options for conserving and generating energy,
- all basic cost effective energy conservation measures should have been taken,
- it should be understood that the time to recover the investment may be long and dependent on energy price fluctuations,
- the initial investment must not compromise the farm's ability to trade, and
- it must be likely that dairy activities will continue on the site for at least fifteen years (to provide the right conditions for the farm business to

receive a net benefit from the initial investment, even without significant energy price increases).

Despite the medium term problem of investing in equipment, solar water heating should play an important part in the provision of low cost heat to dairy farms in the future.

15.3 Social Benefits

Dairy solar water heating systems are not a quick fix for rural poverty, but can make a contribution to rural sustainability. It is foreseeable that rural jobs and enterprises may be created to install and maintain the equipment, which may make a pool of installers available who will provide services beyond the agricultural sector, and may undertake more lucrative private work in the sustainable energy sector.

Supporting small, family farms will also help to sustain the pattern of landscape and social characteristics which make the Peak District National Park so famous.

15.4 Other Renewable Energy Technologies

The main renewable energy sources applicable to farms in the Peak District National Park are those relating to solar, wind, varying forms of biomass and other biofuels.

Solar photovoltaics have been discussed earlier, and identified as currently too expensive in this agricultural context.

It is possible to achieve refrigeration from solar heat using adsorption chillers. Whilst these are available on a domestic and industrial scale there is not currently a well-developed market

for farm-scale equipment. This should be explored further.

Wind turbines are probably the most common renewable energy technology on remote farms, particularly those without electricity grid connections. The main issues surround the siting of a turbine in relation to dwellings, non-turbulent and consistent wind availability, and planning constraints. Again, the Peak District Supplementary Planning Guidance is relevant. One of the three farmers with solar hot water systems referred to in Section 4 also has a prototype 5kW wind turbine on the farm, though this is just outside the Peak District National Park.

Various biomass systems are available and the two of the farmers with solar hot water systems used short rotation willow coppice or mixed deciduous wood as energy crops (heating fuel).

Biogas (methane) can be generated by anaerobic digestion of cattle slurry. This is used extensively in the US and EU, and some grants are issued for this technology. However, in the Peak District National Park, most of the farms are not of a sufficient scale to make this technology economic, although a cooperative approach may work.

Because of the desire to conserve visual amenity, it may be easier to gain support for schemes including ground-source heat pumps or micro-hydro, than those involving large wind turbines or large areas of photovoltaic panels.

15.5 DIY or Professional Installation?

DIY solar hot water installations are increasingly common and effective systems can be installed by end users who have some hands on engineering or plumbing experience, given appropriate training and support.

Several farmers surveyed said they would be keen to try to install their own 'DIY' systems, as long as expert help was available to help with any problems.

'Shine 21' is a nationally recognised course, resulting in accreditation and is one source of practical and regulatory information. Commercial trainers are increasingly running courses too. More information and further contact details are given in Appendix 2. It must be noted however, that most grant schemes (e.g. Low Carbon Buildings Programme) do not apply to DIY installations unless they are commissioned by an accredited installer.

Information on DIY installation can be obtained from a number of charities, educational bodies and industry associations.

15.6 Encouraging Take-up

A number of suggestions were made by the farmers about routes to disseminate messages about solar water heating to the wider farming community. These included the free farming press and certain internet forums¹⁶.

Another suggestion was for developers to install the equipment at their own cost and charge farmers for the hot water used. This may become viable as energy prices rise, but raises interesting questions about metering the energy delivered.

16 Conclusion

As fuel prices increase, solar water heating is likely to become more competitive, possibly paying for itself two or three times over during its anticipated life, on sites with high hot water demand such as dairies.

Even without subsidy, dairy solar water heating offers an opportunity to benefit from, and gain experience of, the deployment of renewable energy systems. In the long term these are likely to give significant benefits to the farmer, in financial and environmental terms as well as by demonstrating corporate social responsibility. It also offer a broader benefit to society as a whole, to everybody on the planet, by the protection of global resources and the reduction of carbon emissions.

Unfortunately these benefits cannot be realised unless the end user is willing to commit invest in them, and as there is significant global benefit, it seems reasonable to asked if the farmer should be asked carry this cost alone.

Most farmers contacted take the view that the capital cost is a very significant proportion of their annual profits and that such investment cannot be a priority in the current agricultural economic climate. Consideration might be given to setting up funding schemes so that the benefits of this opportunity to use renewable energy can be delivered.

As long as the more cost effective energy conservation measures are already in place, the increased deployment of renewable energy among small to medium sized enterprises such as farms should be supported to encourage wider uptake of renewable energy sources in industry, and complement the increase in uptake in the domestic sector.

To date, central government and many local authorities have recognised the benefits of promoting solar water heating in the domestic sector through various funding schemes. By contrast, little has been done in the agricultural sector, despite the fact that the larger and more consistent hot water demand should offer greater financial and environmental benefits per unit investment. With the right financial incentives, dairy schemes have been a success in other countries including in North America, Australasia and northern Europe.

Sustainability requires the use of more localised, renewable energy sources, and there is a growing need to start building a culture of renewable energy production at a local and regional level. Solar water heating on dairy farms is one way to integrate such a culture into the traditional practices of the Peak District National Park, whilst protecting an important element of the rural economy.

T4 would be pleased to discuss the practical details of solar and other renewable energy schemes, along with policy issues as they arise. Please fell free to contact us.

Appendix 1: Clear Skies Inspection Check-list for Solar Thermal

Documentation

- 1) Documentation left with building occupier.
- 2) Solar system commissioning certificate completed and signed.
- 3) Cylinder/store commissioning certificate completed and signed (if store replaced).
- 4) Signatory on solar commission certificate to be noted.
- 5) User instructions left and indicate safe operation instructions.
- 6) Transfer fluid type fluid level tolerance and circulation rate tolerance indicated. Method and frequency of checking is stated.
- 7) DHW solar temperature adjustment, DHW drain location and DHW isolation points recorded.
- 8) System schematic drawing (mechanical and electric).
- 9) Specialist maintenance tasks, schedule and parts list.
- 10) User actions to prevent overheating are stated (if required).
- 11) Manual DHW drain-off method to prevent over-heating is prescribed and safe (if required).
- 12) Schedule and method of testing safety valves (where fitted).
- 13) User actions to prevent freeze damage to be stated (if required).
- 14) De-commissioning method including any hazardous substances to be stated.
- 15) Confirm previous site visit and that risk assessment was carried out before giving a quote.
- 16) Evidence of limescale assessment by installer/householder.
- 17) Expected thermal performance in kWh per year to be stated.
- 18) Freeze damage protection measures used and lowest safe ambient temperature is stated.
- 19) Written warning if expansion tank is insufficient and under which conditions.
- 20) Evidence of legionella risk assessment and suggested method of control.
- 21) Written warning if there is potential for airlocks or component failure during or after stagnation.
- 22) All end-user and manufacturer's instructions for all installed solar water heating equipment shown and explained to end-user. Document storage location to be explained.
- 23) Where required by the Pressure Equipment Directive (pressure has potential to exceed 0.5 bar and temperature over 110 Celsius), evidence left on site of compliance with essential safety requirements with CE mark.
- 24) Manufacturer's written installation requirements to be left on-site for any fitted electrical and mechanical equipment.
- 25) Product list labelling criteria for store (copy of label provided in documentation): manufacturer, serial no, year of production, country of production, maximum operating secondary pressure, total water volume, weight, dimensions, number of exchangers, maximum operating exchanger pressure, dedicated solar preheat volume, volume of each heat exchanger, area of each heat exchanger, label informing if the system is a direct system, heat exchanger position for solar system.
- 26) Product store listed as approved by Clear Skies Labelling and type of replacement store to building regulations.

- 27) Product list labelling criteria for collector (copy of the label provided in documentation), manufacturer, serial no, year of production, country of production, glazing format, absorber insulation, area, stagnation temperature, maximum operating pressure, volume, weight when empty.

Electrical

- 1) Low voltage (LV - including 240 VAC) electrics to BS7671.
- 2) LV isolation switch and fuse protection fitted.
- 3) Existing equipotential bonding is refitted. Equipotential bonding fitted in locations of increased shock risk referred to in BS7671.
- 4) Class 1 equipment such as pumps etc. is earthed.
- 5) All wiring supported and routed reasonably and of correct length.
- 6) Cable to pump is heat resisting flex.
- 7) All cabling correct current rating, type and suitable for purpose.
- 8) Cable sheaths taken into enclosures and glands.
- 9) All connections are enclosed.
- 10) Extra low voltage (ELV) if fitted to BS 7671
- 11) Sensor and ELV wiring dissimilar in appearance to higher (LV) voltage wiring
- 12) Sensor and ELV wiring of Band I sufficiently separated from higher voltage (Band II) wiring.
- 13) PV installation (greater than 36 volts) if fitted has isolator and labelling that complies with DTI/Pub URN02/788 (publication can be attained tel. 01235-432450).

Roof

- 1) Collector glazing seals are weather-tight and sound.
- 2) Collector temperature sensors clamped & insulated from ambient.
- 3) External pipes insulation to be UV and HT standard.
- 4) No significant shading across collector.
- 5) Collector orientation checked with that on application.
- 6) Any auto air vent if fitted must have an isolation valve.
- 7) Roof fixings robust and weather tight. Roof penetrations i.e. sarking felt made good.
- 8) Collector mountings fit for purpose.

Operation

- 1) Indicator of circulation evident for end-user.
- 2) Electrical controls and sensors are operating sensibly.
- 3) Cistern, gauges or other fluid indicators at the commissioned settings.
- 4) Reverse flow protection identifiable from schematic.
- 5) If a hot water store does not have an open vent then a combination of thermostatic control device, energy cut-off device and heat dissipation method should be present, (i.e. unvented stores and sealed thermal stores).
- 6) If a hot water store has an open vent it must have at least a thermostatic control or a temperature relief valve.
- 7) Is there potential for airlocks or equipment failure after stagnation.
- 8) All safety devices to operate correctly.

- 9) Check for excessive pump noise.
- 10) Check provision of key system functions (circulation, temperatures).
- 11) Condensation prevention in unheated areas.
- 12) Store temperature sensor capable of 100°C.
- 13) New boilers fully pumped with interlock. Existing cylinders to have interlock with thermostat on fully pumped systems.
- 14) Solar system not to preheat combination boilers or instantaneous water heaters unless the appliance is suitable (confirmation in writing from a manufacturer).
- 15) Sufficient expansion capability in cisterns and vessels.

General

- 1) Prevention of water backflow into potable rising main by check valve. Filling loop is disconnected.
- 2) Sufficient drain points to enable all pipes to be drained.
- 3) Materials are rated and Water Regulations Advisory Scheme listed at stagnation temperature and pressure.
- 4) Open vent termination over correct cistern
- 5) No obstruction before safety valves or vents. Vents and discharge pipes to be correctly graded and exhaust locations are safe – no scald risk to people.
- 6) Sound engineering practice to be used or evidence left on site of higher conformity according to the Pressure Equipment Directive. All pressure components to be labelled and identifiable.
- 7) Pipe clips and insulation to be sufficient for stagnation temperatures.
- 8) All indoor components in unheated areas to be sufficiently protected from freeze damage.
- 9) Anti scald measures are in place e.g. controller can be set or auto blend valve is fitted.
- 10) Pressure relief measures will operate before failure risk of most vulnerable component.
- 11) Appropriate lime scale reduction measures employed for collector loop.
- 12) Solar control present to be capable of limiting store below 60°C in high hardness area or exchanger cleaning facility to be provided.
- 13) If replaced, DHW back-up heat source to have time switch.
- 14) If replaced, DHW back-up heat source to have correctly located thermostat and interlock.
- 15) On replacement cylinders, all connected pipes to be insulated where practicable.
- 16) Product list store sufficient and dedicated pre-heat volume for user requirements.
- 17) Product list store sensor pockets or digital readout.
- 18) Check auxiliary heat source is capable of heating store to at least 55°C to prevent legionella.
- 19) All unions, and glands are free from leaks; no leaking evident elsewhere e.g. from pipework joints etc.
- 20) All pipework is adequately clipped, insulated and components are adequately supported.
- 21) Pipe insulation to be firmly in place and secured at junctions and corners.
- 22) Penetrations in building made good. Debris removed.

Appendix 2: Project Support, Training and Accreditation

For farmers wishing to explore the issues discussed, or to undertake installation work themselves, there are a number of local organisations providing training and support. Please contact T4 for up to date details, see Appendix 3.

One nationally recognised course is 'Shine 21'17 which also results in a recognised accreditation, seen as an indication of competence. T4 endorses the use of this course and its materials, both for initial training and reference.

Installers have also been accredited under Government-funded schemes, Clear Skies and the Low Carbon Buildings Programme. Such accreditation is an indicator of demonstrated competence and experience.

An increasing number of commercial trainers are now offering solar courses.

Project advice and less formal training may also be available from some national and local groups. The Centre for Alternative Technology runs courses on solar water heating, as have a number of other organisations. More locally the Derbyshire Alternative Technology Association has advised farmers to help them assess which systems are most appropriate to their needs.

Centre for Alternative Technology,
Machynlleth,
Powys.
SY20 9AZ

www.cat.org.uk/
01654 702782

Derbyshire Alternative Technology Association,
c/o 181 Belper Road,
Stanley Common,
Ilkeston,
Derbyshire.
DE7 6FT

0115 9448911
Info@DerbyshireAta.org.uk

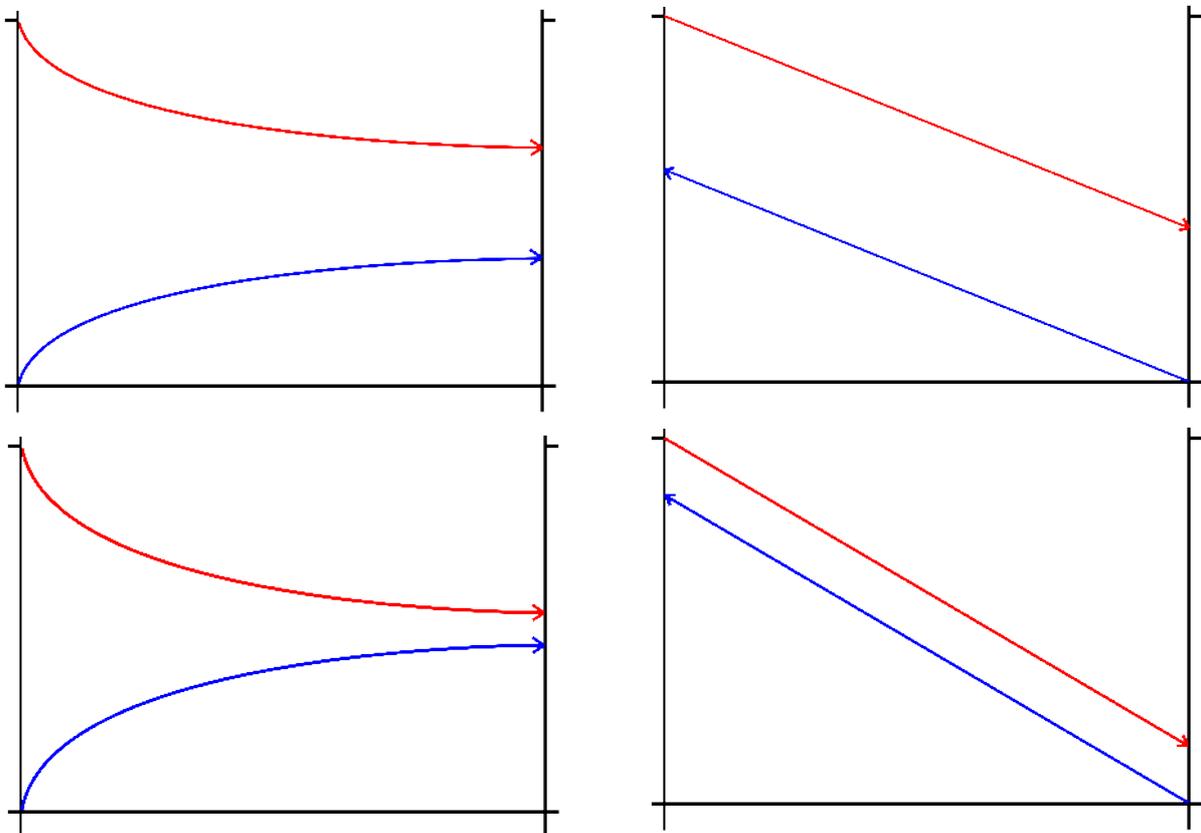
Appendix 3: The Use Of Plate Heat Exchangers For Milk Cooling

Measurements on site during visits to farms indicated that the flow of cooling water in plate heat exchangers is not always sufficient to reduce milk temperature as much as it might. The cost of using more cooling water is likely to be much less than the cost of using more energy for refrigeration, especially if the water, warmed by the milk can be put to good use. Farmers should check this as it is a low cost adjustment that can be made in minutes, and has a relatively quick payback time.

Checks should also be made that heat exchangers used to cool milk are plumbed in a 'contraflow' configuration, i.e. the milk and cooling water pass in opposing directions. This is much more efficient, as the milk which has been cooled can attain a lower temperature than the cooling water leaving the heat exchanger. At least one farm visited did not have a contraflow heat exchanger configuration.

The graphs below indicate the relative performance of better (bottom row), and worse (top row) heat exchangers, used in parallel flow (left column), and contraflow (right column) configurations. The y axis indicates temperature range between the incoming milk and the inlet cooling water temperature. The x axis indicates location within the heat exchanger, and the arrows on the lines indicate the direction of flow.

While it is important to use a good quality and adequately sized heat exchanger, parallel flow, (milk and water passing the same way), will greatly limit the performance that can be attained.



Appendix 4: Project Contacts

The Peak District National Park Authority

Contact: Richard Godley.

Address: Peak District National Park Authority,
Aldern House,
Baslow Road,
Bakewell,
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DE45 1AE

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Web site: <http://www.T4sLtd.co.uk>

End notes

- [1] Farm Energy Centre, NAC Stoneleigh, Dairy Energy Efficiency fact sheet TN27.
- [2] www.bitc.org.uk/take_action/in_the_community/rural_action/the_peak_district.html
- [3] www.ddc-wales.co.uk/
- [4] www.farmenergy.com
- [5] Love, John F. (October 2005), "New York State Hydrogen Energy Roadmap", The New York State Energy Research and Development Authority. And, Pûngao, Te Tari Tiaki (May 2001), "Solar Energy Use and Potential in New Zealand", Energy Efficiency and Conservation Authority.
- [6] Dunham, Chris (July 2005, "In Praise of Solar", Resurgence Issue 231. Available from www.resurgence.org
- [7] See <http://www.brookes.ac.uk/other/uk-ises/facts.htm> UK ISES, "SOLAR ENERGY - BASIC FACTS".
- [8] See <http://www.met-office.gov.uk/climate/uk/location/england/sunshine.html> to get an idea of the energy availability distribution throughout the year.
- [9] Tedlar® polyvinyl fluoride (PVF) is part of the DuPont fluoropolymer family. See <http://www.dupont.com/tedlar/> for details.
- [10] The book Hubberts Peak: The Impending World Oil Shortage, written by a petroleum geologist, has an interesting and accessible analysis of this issue. Author, Kenneth S. Deffeyes, 2001, Princeton University Press. TN 870 .D37 2001.
- [11] ibid
- [12] See <http://physchem.ox.ac.uk/MSDS/BA/barium.html> and <http://www.acialloys.com/msds/ba.html>
- [13] See <http://www.rense.com/general21/tox.htm>
- [14] <http://www.timesonline.co.uk/tol/news/uk/article581764.ece>
- [15] See www.automaticmilking.nl/ for more details. Results from a variety of studies are detailed in outcome reports.
- [16] Suggestions included: Farmers Weekly, Farmers Guardian, Dairy Farmer, The Farmer, or events, including The Dairy Event.
- [17] See <http://www.dti.gov.uk/renewables/publications/pdfs/sp300272.pdf> and <http://www.dti.gov.uk/NewReview/nr42/html/training.html>