



# Here comes the sun: a field trial of solar water heating systems

The Energy Saving Trust



energy saving trust®

**The Energy Saving Trust would like to thank our partners, who have made this field trial possible:**

**Government organisations**

The Department of Energy and Climate Change  
The North West Regional Development Agency  
The Scottish Government  
The Welsh Government  
Sustainable Energy Authority Ireland

**Manufacturers**

Worcester Bosch

**Energy suppliers**

British Gas  
EDF Energy  
E.ON  
Firmus Energy  
Good Energy  
Scottish & Southern Energy PLC  
ScottishPower Energy Retail Ltd

**Technical consultants**

EA Technology Ltd  
Energy Monitoring Company  
GASTEC at CRE Ltd  
Southampton University  
The National Energy Foundation

**Energy Saving Trust project team**

Jaryn Bradford, project director  
Frances Bean, project manager  
with Tom Chapman and Tom Byrne

# Contents

<b>Foreword</b>	<b>4</b>
<b>Executive summary</b>	<b>5</b>
Definitions	6
<b>The background</b>	<b>7</b>
<b>The field trial</b>	<b>7</b>
<b>What is a solar water heating system?</b>	<b>8</b>
<b>Undertaking the field trial</b>	<b>10</b>
Selecting participants	10
Developing our approach	11
Installing monitoring equipment	12
Householder feedback	13
<b>Findings of the field trial</b>	<b>14</b>
<b>Key findings</b>	<b>18</b>
<b>Conclusions</b>	<b>20</b>
<b>Advice for consumers</b>	<b>21</b>
Consumer checklist	21
<b>What's next?</b>	<b>23</b>

## Foreword

Boosting consumer confidence in green technologies is vital in driving the uptake of renewables in the UK. The UK lags behind its European neighbours, with just 1.3 per cent of energy generated from renewables compared with 8.5 per cent across Europe<sup>1</sup><sup>2</sup>. In order to meet the EU-wide target of 20 per cent by 2020 we need a step change in customer uptake of small-scale renewables, including solar water heating systems. According to a recent report, solar water heating could provide up to 6.3 per cent<sup>3</sup> of this EU-wide target, placing it as an important technology for the future.

The introduction of the Renewable Heat Premium Payment Scheme, Renewable Heat Incentive, the Feed-In Tariff and the Scottish loan scheme are important steps in helping to bridge the gap. Just as important will be ensuring that consumers can access in-depth advice and support founded on robust evidence. Yet for many renewable technologies there is little or no evidence to demonstrate the real-life performance of working systems. The Energy Saving Trust's trials of in-situ technologies have shown that understanding what works well, and what doesn't, is critical to building consumer confidence in low-carbon technologies. In some cases, it has even proven to be a driver for industry, creating a virtuous circle of understanding, trust and growth.

In this current study, we trialled solar water heating systems to provide evidence on how actual systems perform in real homes in the UK and the Republic of Ireland. This field trial, developed in 2008, follows our report on our field trial of domestic small-scale wind turbines, *Location, location, location*, and last year's report on our trial of domestic heat pumps, *Getting warmer*.

In line with the Energy Saving Trust's previous field trials, these results have been peer-reviewed by experts in the industry.

The Energy Saving Trust is committed to providing impartial and realistic advice to industry and to consumers, helping people to save energy and reduce carbon emissions. One of the key ways we do this is by providing expert insight and knowledge into low carbon/renewable energy technologies. Our activity in this area includes policy research, technical testing, and consumer advice.

The results of the trial have been integrated into our consumer advice network, continuing our role as impartial advisors in the field.

---

1 [http://ec.europa.eu/energy/publications/doc/2011\\_renewable\\_difference\\_en.pdf](http://ec.europa.eu/energy/publications/doc/2011_renewable_difference_en.pdf)

2 In Scotland 2.8 per cent of heat demand is currently met by renewables ([http://www.energysavingtrust.org.uk/Media/scotland\\_redesign/PDF-s/Renewable-Heat-in-Scotland](http://www.energysavingtrust.org.uk/Media/scotland_redesign/PDF-s/Renewable-Heat-in-Scotland))

3 [http://www.rhc-platform.org/cms/fileadmin/Documents/RHC\\_BROCHURE\\_140311\\_web.pdf](http://www.rhc-platform.org/cms/fileadmin/Documents/RHC_BROCHURE_140311_web.pdf)

## Executive summary

This study provides results from the largest independent trial of solar water heating systems so far carried out in the UK and the Republic of Ireland.

Its findings provide a valuable source of information about the real-life performance of solar water heating technology. This is important because the introduction of the Renewable Heat Incentive is likely to steer a wider variety of consumers to solar water heating installations.

The results of this study will help to inform policymakers as well as homeowners who are considering installing solar water heating technology.

The report is intended not as a detailed technical analysis or a side-by-side comparison of different solar water heating systems, but as an accessible overview of how solar water heating technology performs and the potential for savings on carbon and energy bills. The report is based on detailed work that has been conducted behind the scenes to collect monitoring data, understand customer perceptions of the technology and conduct detailed analysis of the results.

The findings are listed under the following headings:

- System performance
- System set-up and design
- Householders' behaviour and perceptions
- Economics
- Carbon impacts in use

These findings will help the Energy Saving Trust to provide detailed advice to policymakers, the industry and customers about the actual performance of solar water heating technology.

## Summary of key findings

1. Solar water heating systems have the potential to work well in the UK and the Republic of Ireland when installed properly and controlled adequately by the user.
2. From the properties we trialled, well-installed and properly used systems provided around 60 per cent of a household's hot water. The trial also found examples where systems were not properly configured or used, and where the contribution from solar was as low as 9 per cent. The median across all systems was 39 per cent.
3. Householders in the trial were happy with their solar water heating systems: 84 per cent were "satisfied" with their system, and over 50 per cent were "very satisfied".
4. In the field trial, there was little difference between the total solar energy yield of those installations that used flat-plate solar collectors and those that used evacuated-tube solar collectors.

5. The trial found that the way householders use their solar water heating system is critical in achieving the best results from solar water heating systems. Better advice to users on how to control their solar water heating systems (in terms of volume of hot water use, timing of back-up heating and hot water use, and temperatures required) is essential.
6. Where mains electricity provided power to the pumps and controllers of systems in the trial, the amount of energy used was generally small compared with the overall heat delivered.
7. We observed insufficient insulation installed on some hot water storage cylinders<sup>4</sup> and pipes. This significantly reduced the proportion of hot water their solar water heating systems provided.
8. Industry standards<sup>5</sup> should be reviewed to ensure they reflect the findings of the trial and the need for better advice to customers.
9. Solar water heating systems can achieve savings on energy bills. Based on the results of the trial, typical savings from a well-installed and properly used system are £55/year when replacing gas and £80/year when replacing electric immersion heating; however, savings will vary from user to user.
10. A well-installed and properly used solar water heating system is likely to provide carbon savings. The typical savings are 230kg/year when replacing gas and 510kg/year when replacing electric immersion heating.

<sup>4</sup> This is a common issue with all types of water heating systems; a similar level of heat loss (as a result of lack of insulation) was observed in the EST's trial of condensing boilers. It is important that this is more thoroughly addressed by insulation standards across all heating systems.

<sup>5</sup> Industry standards to be reviewed include the British Standard 5918 Code of Practice for solar heating systems for domestic hot water and Microgeneration Installation Standard: MIS 3001 Solar Heating Microgeneration Systems.

## Definitions

### Solar output

A measurement of heat generated by the solar collector.

### Solar irradiation

The energy from the sun, which can be captured by solar water heating systems to heat water.

### Renewable Heat Incentive

A financial support scheme for customers installing renewable heat technologies.

### Microgeneration Certification Scheme (MCS)

An independent scheme for the certification of microgeneration products and installers. It provides reassurance to consumers through the assessment of microgeneration products and installers against quality, performance and safety criteria.

### Solar Keymark

The Solar Keymark is a quality label for solar thermal collectors and systems that fulfil minimum requirements according to specific European standards. It is recognised in the UK as equivalent to MCS.

### Clear Skies Programme

Clear Skies was both a grant scheme and a microgeneration products and installers certification scheme prior to LCBP for grants and MCS for certification. MCS is an industry led scheme and so is fundamentally different to Clear Skies certification and it is based on European wide norms & British standards.

### Low Carbon Buildings Programme (LCBP)

The Low Carbon Buildings Programme was a Government grant scheme to encourage installation of microgeneration technologies. It has been replaced by the Renewable Heat Incentive.

## The background

In 2010, the United Kingdom's solar water heating market for both small and large-scale installations grew by 18.1 per cent, to 73,640 kWth of installed capacity<sup>6</sup>. This is perhaps surprising given a 13.1 per cent decrease across the rest of Europe. An uncertain economic outlook, high fuel prices, and the proposed introduction of a Renewable Heat Incentive seem likely reasons for continued growth in the UK.

With any technology, the performance of products and installed systems can vary significantly. Advice can be inconsistent, which is often confusing to consumers. The Energy Saving Trust and its partners are committed to clarifying customer confusion by providing trusted advice and guidance to anyone who is considering investing in low-carbon technology.

The latest in a series of technology field tests, this trial of solar water heating installations provides insight on the in-situ performance of solar water heating systems in real homes. The trial was launched in 2008, and the Energy Saving Trust has worked with industry partners to carry out comprehensive trials, including technical monitoring of the technology, and speaking to those who had the systems installed, to gather feedback.

The resulting data<sup>7</sup> and analysis provides insight on solar water heating system installation and performance, consumers' interaction with their solar water heating systems, and consumers' attitudes towards their solar water heating systems. This insight feeds into advice for consumers, installers, manufacturers and the government.

By using the latest monitoring techniques, the trial collected live data over a full calendar year from solar water heating systems across the UK and the Republic of Ireland. Researchers also questioned occupants (all householders were sent online questionnaires, and eighteen in-depth interviews were carried out) to understand how systems have performed and to gather feedback about their experiences using the technology. Experts in the field have carried out detailed analysis. The headline results are shown in this report.

## The field trial

By trialling low-carbon technology, we can gain an insight into the actual performance and carbon savings of systems being used by real-life households. This information can help manufacturers, retailers, installers and others to understand how customers use new and innovative technologies, and to identify the potential future uptake of these technologies.

In delivering this latest trial we aimed to understand:

- The actual measured in-situ performance of solar water heating systems
- Customer behaviour and perceptions of the technology
- Potential for carbon savings
- Factors that affect the performance of solar water heating systems, including:
  - User behaviour
  - Installation practices

<sup>6</sup> [http://www.estif.org/fileadmin/estif/content/market\\_data/downloads/2010%20European%20Solar%20Thermal%20Markets.pdf](http://www.estif.org/fileadmin/estif/content/market_data/downloads/2010%20European%20Solar%20Thermal%20Markets.pdf)

<sup>7</sup> 123,931,181 data points were collected from the 88 sites over a 12-month period.



## What is a solar water heating system?

Solar water heating systems can be used to heat buildings, swimming pools or, most commonly, domestic hot water for use in the home. A solar collector absorbs solar irradiation and converts it into heat energy, which is then removed by a heat-transfer fluid such as water or antifreeze.

In most systems, a small pump circulates the heat-transfer fluid (usually anti-freeze or water) to a store from which it can be used later. In the case of solar water heating systems, this store is usually a hot-water cylinder. A back-up heat source is required to ensure that the water is heated to a sufficient temperature on days when light levels are limited.

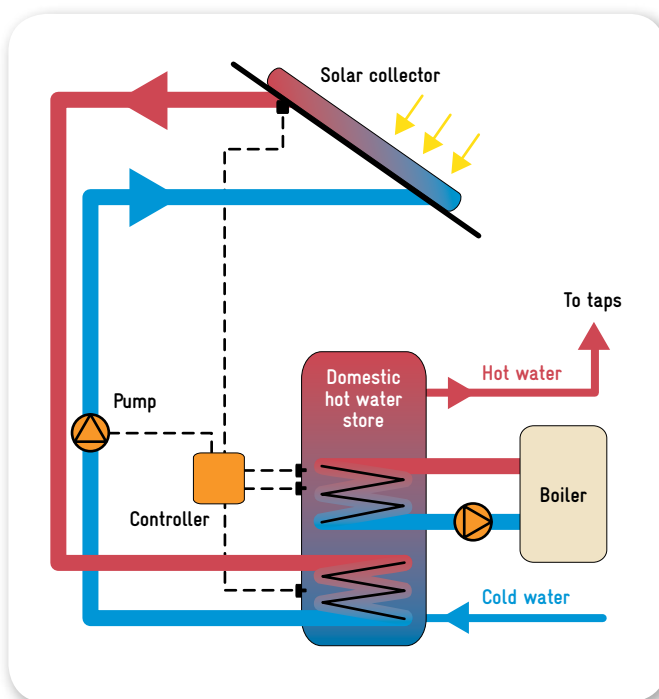


Figure 1. An example of a solar water heating system

Figure 1 shows one of the most common arrangements, although there are many possible configurations, including:

- System type – fully filled, drain-back, or thermosyphon
- Cylinder type – vented, unvented, or primary/thermal store
- Heat exchanger type – internal, external, or no heat exchanger
- Circulation operation type – main pump, PV pump or thermosyphon

## Types of solar water heating collector

There are three main types of collector that may be used in domestic solar water heating systems: unglazed, flat-plate and evacuated-tube. In this trial only flat-plate and evacuated-tube collectors were monitored.

### Flat-plate

Flat-plate collectors consist of dark-coloured absorber plates (made from metals such as copper or aluminium, polymers, or a combination of these) attached to tubes through which the heat-transfer fluid passes. The plates are enclosed within a glazed, insulated box that behaves like a mini-greenhouse to retain heat within the collector.

The addition of glazing slightly reduces the amount of light that reaches the absorber, but it reduces heat losses to the surroundings, allowing more heat energy to be captured and transferred to the store. Most collectors (whether flat-plate or evacuated-tube) also have a coating that reduces the amount of heat loss by radiation from the dark absorber plate.

There were 54 flat-plate systems in the trial.



Figure 2. A flat-plate system



### Evacuated-tube

Evacuated-tube collectors consist of rows of parallel glass tubes, each containing a metal or glass absorber surface with a dark coating. During manufacture, air is evacuated from the tubes. The resulting vacuum reduces conduction away from the collector, allowing it to potentially reach higher temperature at all light levels.



Figure 3. Evacuated-tube system

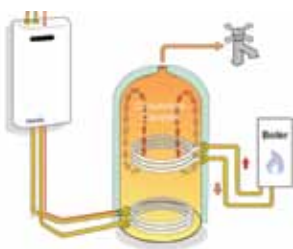
Evacuated-tubes can have either heat pipes (where each tube is connected into a manifold through which the heat transfer fluid passes externally) or a flow and return internal pipework configuration. Tubes with heat pipes can be easily replaced without draining the system; however, direct flow and return systems are more versatile in terms of their mounting position.

There were 34 evacuated-tube systems in the trial.

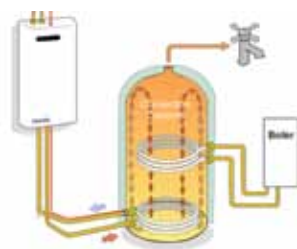
Due to their higher levels of insulation, evacuated-tube collectors can produce a higher energy output from an identical absorber surface area than flat-plate collectors. However, this did not translate into higher annual energy yields in the study because the geometry of flat plate solar panels generally gives a larger absorber surface.

### Back-up heating

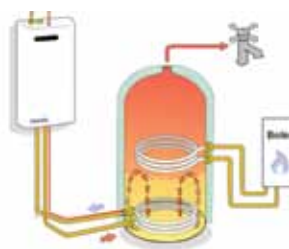
Solar water heating requires a back-up heat source to ensure that the water is warm enough when the solar collector cannot provide sufficient energy, because there was not enough sunshine. Systems in the trial used different ways of providing this, including gas, oil, biomass boilers, heat pumps or electric immersion heaters. The twin-coil cylinder was the most common heating arrangement in the study. Figure 4 explains how a twin-coil cylinder works.



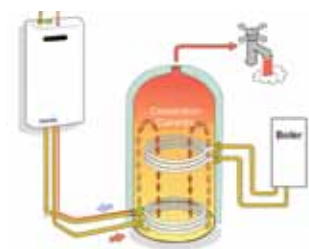
The back-up heater heats only the top part of the cylinder via an indirect heating coil.



The solar water heating system can heat the entire height of the cylinder from a coil at the base of the cylinder.



If the back-up heater has already heated the top part of the cylinder there is less capacity in the cylinder for solar heat.



If water has been used after back-up heating there is more capacity in the cylinder to accept solar heating.

Figure 4. How a Twin-Coil Cylinder Works

## Undertaking the field trial

### Selecting participants

In early 2009, the project team contacted more than 150 households across the UK and the Republic of Ireland and invited them to participate in a solar water heating trial. In order to have a robust and varied data set, we aimed to include a variety of systems and houses.

We worked with project partners and the wider solar water heating industry to identify suitable participants. In addition, we contacted people who had installed a solar water heating system using the Low Carbon Building Programme (LCBP)

and Scottish Communities and Householder Renewable Incentive (SCHRI) grants, inviting them to join the trial. Further sites were identified through energy suppliers.

As a result, 88 domestic sites were selected to participate in the study and had monitoring equipment installed. Of these sites, the study included:

- 54 flat-plate systems
- 34 evacuated-tube systems
- Products from different manufacturers
- Twin-coil or multiple cylinders
- Pressurised or open-vented systems
- Thermal stores
- Direct or indirect solar collectors
- Mains power and PV powered pumps
- Combined heat pump and solar water heating systems
- Retrofits to existing cylinders and new cylinders

It should be noted that manufacturers listed as partners in the field trial were not the sole suppliers of the solar water heating systems included in the study. While we have consulted with industry bodies and stakeholder groups, the Energy Saving Trust has ensured that the findings are robust and impartial.

It should also be noted that this field trial started before the Microgeneration Certification Scheme (MCS) was introduced. None of these solar water heating systems had been installed under that scheme; most of them were installed and accredited through MCS's predecessor, the Clear Skies programme. The field trial therefore monitored installations of products that were current as of 2008. The technology, standards, manufacturer and installer knowledge and practices continue to evolve and improve.

It was important to include a good geographic spread of sites in the trial, as annual solar irradiation across the UK and the Republic of Ireland varies quite considerably – from less than 900kWh/m<sup>2</sup>/annum in the Highlands of Scotland to over 1200kWh/m<sup>2</sup>/annum at the southernmost point. This can be seen from Figure 5, which shows the total average solar irradiation falling on a 1m<sup>2</sup> horizontal surface, measured in kilowatt hours (kWh). Figure 6 illustrates the geographic distribution of our trial sites across the UK and the Republic of Ireland.



**Figure 5. Map of UK and Republic of Ireland Solar Irradiation**  
(PVGIS © European Communities, 2001-2008)



**Figure 6. Map of locations of solar water heating systems across the UK and Republic of Ireland**

This variation means that the same solar water heating system installed in Scotland has less solar irradiation available to collect and convert into energy than the same system in Cornwall. In the trial we took account of this variation by measuring solar irradiation using pyranometers<sup>9</sup> (or making detailed estimates using modelling software) at the specific location of each solar water heating system we monitored. Collecting such data allows calculation of how system performance is affected by differences in solar radiation, and also to eliminate this difference when looking at other variables.

## Developing our approach

Monitoring of the 88 sites took place over twelve months from April 2010 to April 2011. The monitoring followed a specific and detailed technical specification, which set out the measurements to be gathered in order to establish system performance. This specification also set out the frequency and resolution of the measurements, the type of monitoring equipment to be used, where it should be installed, and the format in which the data should be recorded and presented for analysis. The specification was developed by the Energy Saving Trust and our partners with relevant stakeholders and members of industry. It is available on the Energy Saving Trust website<sup>9</sup>.

Three key measurements were required over the same period in order to establish the performance:

- The heat energy delivered by the collector to the water
- The electrical energy used to operate the pump and control system
- The heat energy delivered by the back-up heat source to the water

We also measured the conditions experienced by the system (solar irradiation and temperature near the collector), in order to investigate their effects and to eliminate them from investigations into the effect of other variables.

Taken together, these measurements created a structure in which to calculate the performance of the solar water heating system.

As well as the performance of the system, it was necessary to measure householders' hot water use in terms of:

- Flow rate
- Total delivered hot-water energy
- Temperature of the cold water which enters the system
- Temperature of the hot water produced by the system

<sup>9</sup> [www.energysavingtrust.org.uk/Publications2/Housing-professionals/Microgeneration-Renewables/EST-solar-thermal-monitoring-specification-2008](http://www.energysavingtrust.org.uk/Publications2/Housing-professionals/Microgeneration-Renewables/EST-solar-thermal-monitoring-specification-2008)

## Installing monitoring equipment

Monitoring was set up to cover a variety of different system configurations, including:

- Twin-coil or multiple cylinders
- Pressurised or open-vented systems
- Thermal stores

- Direct or indirect solar collectors
- Mains power and PV powered pumps
- Combined heat pump and solar water heating systems

Figure 7 shows a generic schematic of a common system type – an open-vented hot-water cylinder with twin coils. Different systems were set up in different ways and therefore the monitoring equipment was adapted to different configurations.

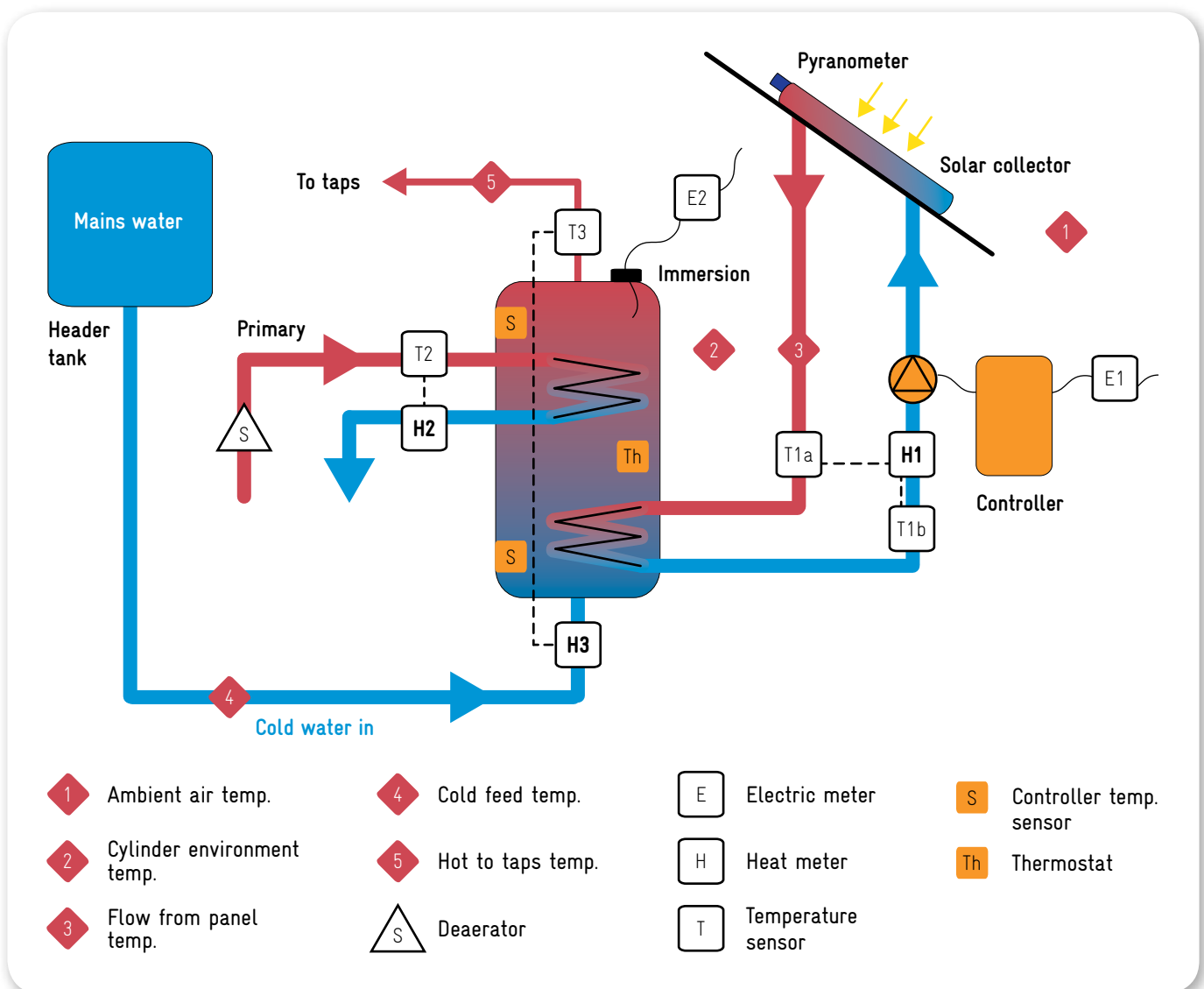


Figure 7. Generic monitoring schematic



**Figure 8. Two solar water heating systems showing good (left) and poor (right) levels of insulation**

While installing the monitoring equipment at some sites, we discovered a number of problems, including:

- Malfunctioning air vents on the solar collectors
- Glycol leaks from solar collector circuits
- Inadequate or absent insulation (shown in Figure 8)
- Pump flow rates set too high

Many of these issues should now be addressed by the Microgeneration Certification Scheme (MCS), which did not exist when these systems were installed. However, we believe that a thorough review of industry guidelines and standards should be undertaken to ensure that these issues are fully addressed. Most of the installers of these sites were registered with Clear Skies (a predecessor to MCS) – an indication that early standards were not sufficiently robust.

## Householder feedback

In addition to the technical monitoring, we also undertook research with the householders at our trial sites, collecting data on their behaviour and satisfaction levels. As well as providing insight into the impact of their behaviour on system performance, this has helped to inform the advice we should provide to customers.

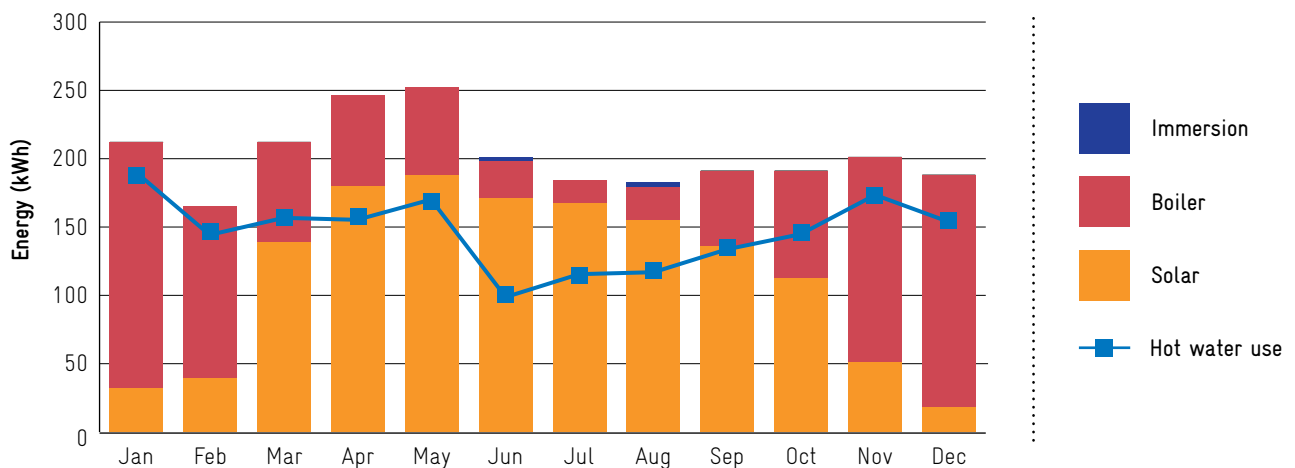
All householders in the trial were sent questionnaires on how they use their hot water, and on their experience and satisfaction with their solar water heating system. We also conducted eighteen face-to-face interviews to gain a deeper insight into householders' experiences.

The majority of the householders (95 per cent) stated in the questionnaires that they found their systems either very easy or fairly easy to operate. None of the householders found their system 'not at all easy' to operate. Most householders received some form of advice from their installer about their system (in terms of the effects of shading, roof orientation, and/or integration with their existing heating system type). However, only 36 per cent of the householders stated that their installer gave them information on how they might make best use of their solar water heating system. Of this advice, most related to advice on modifying the time of day they use hot water (have showers, baths or use appliances), and only a quarter to advice on hot water system settings and integration.

The householders, when interviewed, felt that the advice and information they received by installers was generally good or excellent. Reasons for it being deemed inadequate were due to potential confusion on the part of the installer due to complex/unfamiliar property type or the level of information being too basic.

Overall, householders showed a high level of satisfaction: 84 per cent were either fairly or very satisfied with their system, and over half of them were very satisfied. The main reasons for overall satisfaction were reducing CO<sub>2</sub> emissions, savings on energy bills, and system operation and performance. The main reasons for dissatisfaction were system operation and performance and product quality and performance. The analysis of customer responses with the monitored system performance data reveals that satisfaction is not strongly related to the actual contribution solar water heating systems make towards household hot water needs.

## Findings of the field trial



**Figure 9. Graph showing a typical energy profile for a well-installed and properly run solar water heating system.** The solar energy input to the hot water cylinder is at a maximum in summer, with back-up heating providing more energy in the winter months.

In general, the solar water heating systems in the trial performed well, producing a median output of 1,140kWh (of thermal energy) per year. This equates to around 39 per cent of a household's hot water demand. Overall, there was a wide range of results: one system provided 98 per cent of hot water demand, while another only provided 9 per cent. Extreme percentages are uncommon and could be due to many factors including under and oversizing, water use patterns and the absence of back-up heating. Well-installed and properly used systems provided around 60 per cent of a household's hot water. Detailed analysis was undertaken to identify the factors that influence how much energy can be provided and, therefore, how much a solar water heating system can save on energy bills.

There was found to be no difference in the amount of energy produced by flat-plate solar collector systems and evacuated-tube systems. The median for flat-plate collectors was 1,156kWh per year and the median for evacuated-tubes 1,140kWh per year. Although evacuated-tube systems have higher insulation, flat-plate solar collectors generally have a larger working area as a proportion of the collector size. This was supported by what we found in the trial.

The factors which were found to influence performance included:

- Volume of hot water used
- Interaction between the timing of water use and use of back-up heating system
- Heat lost from hot-water cylinders
- Hot water temperature

### Volume of hot water used

The amount of energy saved increased the more hot water was used. Generally, dwellings with more occupants used more hot water and so they achieved greater benefits from their solar water heating systems. In the trial, a number of householders used electric showers, which heat water themselves rather than using the solar-heated water, and so this reduced overall hot water use. Under these conditions, the maximum benefit of having a solar water heating system cannot be achieved.

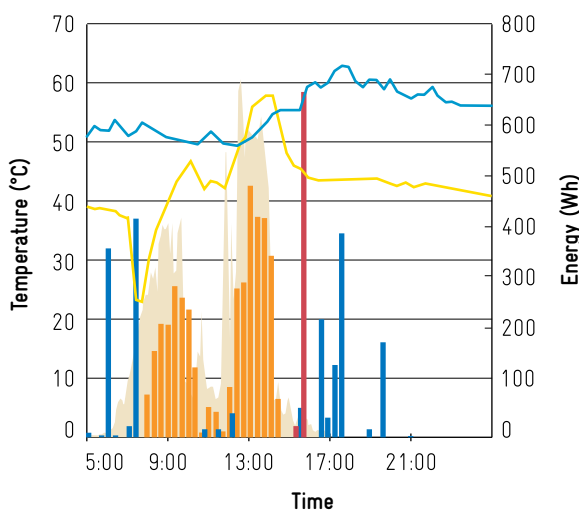
Higher hot water consumption in summer also increases the contribution the solar water heating system can make. However, most householders in the trial did not vary their hot water consumption over the course of a year.

### Interaction between the timing of water use and use of back-up heating system

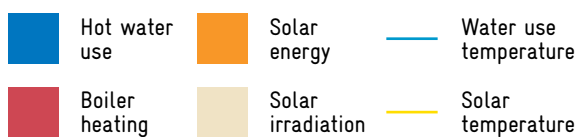
The timing of the back-up heating system and hot water use has been found to have an impact on how much energy a solar water heating system can provide. Systems that provided more energy were found to time the back-up heating to finish just before the period of higher hot water use and commonly (although not exclusively) at the end of the day. Subsequent use of hot water from the cylinder in the evening or in the

morning lets cold water into the base of the cylinder, which provides a volume of cool water for the solar collector to heat up the next day.

Many of the solar water heating systems where the back-up heating was found to be adding heat to the cylinder after hot water use had finished provided less energy overall, as there was less or no cool water for the system to heat.

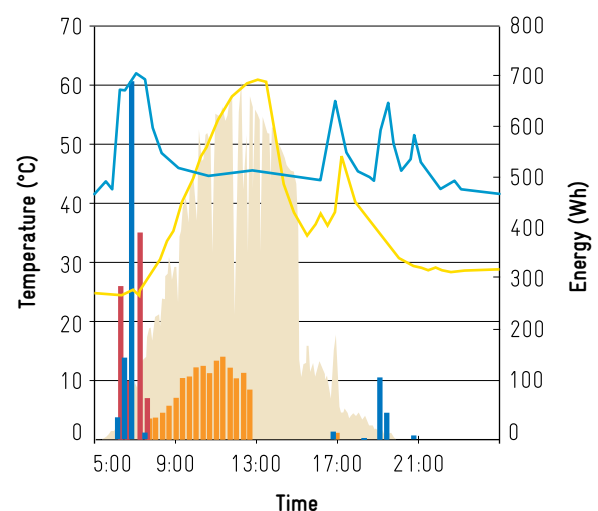


Peak solar irradiation 1,000 W/m<sup>2</sup>

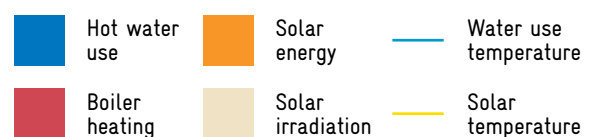


**Figure 10. Example of well-timed hot water and back up heating use**

The boiler fires at 15:30, raises the temperature of the hot water to 62°C for use that evening and the following morning. Although the household does not have a high water use this arrangement makes the maximum volume of cold water available the next day for the solar water heating system to heat. The solar water heating system started operation at 08:00 and had a cool cylinder temperature of 20°C at the bottom. It raised this to about 55°C over the course of the day.



Peak solar irradiation 1,000 W/m<sup>2</sup>



**Figure 11. Example of poorly timed hot water and back-up heating use**

The household uses water predominantly in the morning, but the boiler fires between 06:00 and 08:00, during and after hot water use. This ensures that the boiler-heated zone in the cylinder is hot at the start of the day. Although it is a sunny day, solar energy can only be added to the solar dedicated section of the cylinder and the temperature of this smaller volume is rapidly driven up to 60°C by around 12:30. For the rest of the day, although high levels of solar energy remain available until 16:00, there is nowhere to put it and the solar hot water system switches off.



There are a number of ways to overcome this problem and improve the performance of a solar water heating system:

- Using boiler timers and/or solar controllers to ensure that water is only heated by the back-up heating sources after the water has been heated to the maximum extent possible by the sun.
- Having an adequately sized dedicated solar volume (that is, a portion that can only be heated by the solar water heating system). Where a dedicated solar volume is not used (for example in systems that do not require the existing cylinder to be changed), the timing of back-up heating has a particularly important impact on performance.

Insulation is a vital part of this, as systems with poorly insulated storage cylinders can suffer from inadequate hot water provision in the mornings.

The level of advice on back-up heating and timing of hot water use given to householders in the trial varied in quality and quantity. Improved advice on the interaction between the solar collector, back-up heating and hot water use would help to achieve the best results and therefore gain the best savings for consumers on energy bills. Under MCS, installers are required to communicate to householders the effect on system performance of the timing of back-up energy sources.

### Heat lost from hot-water cylinders

The heat lost from hot water cylinders in systems in the trial varied greatly, from 230kWh per year to 2,910kWh per year, as shown in figure 12.

Given that manufacturers' declared losses for a modern, well-insulated cylinder is typically between 500 and 800kWh per year (depending on size), this is a significant issue. It was also found that, unsurprisingly, solar water heating systems providing a high proportion of energy were those where heat-loss was lower due to sufficient insulation. Figure 8 shows examples of the levels of insulation found on two sites in the trial. However, this issue is not confined to solar water heating systems; in the Energy Saving Trust's field trial of condensing boilers, similar levels of heat losses were measured. This identifies a wider problem with hot water cylinders used in all types of heating systems.

In addition, inadequate pipe insulation can increase the amount of heat lost. Heat is conducted away from the cylinder along the pipes and is then lost to their surroundings.

The solution to this problem is to ensure that pipes and cylinders are sufficiently insulated, at least to current building regulations. The Microgeneration Certification Scheme, launched since the systems in this trial were

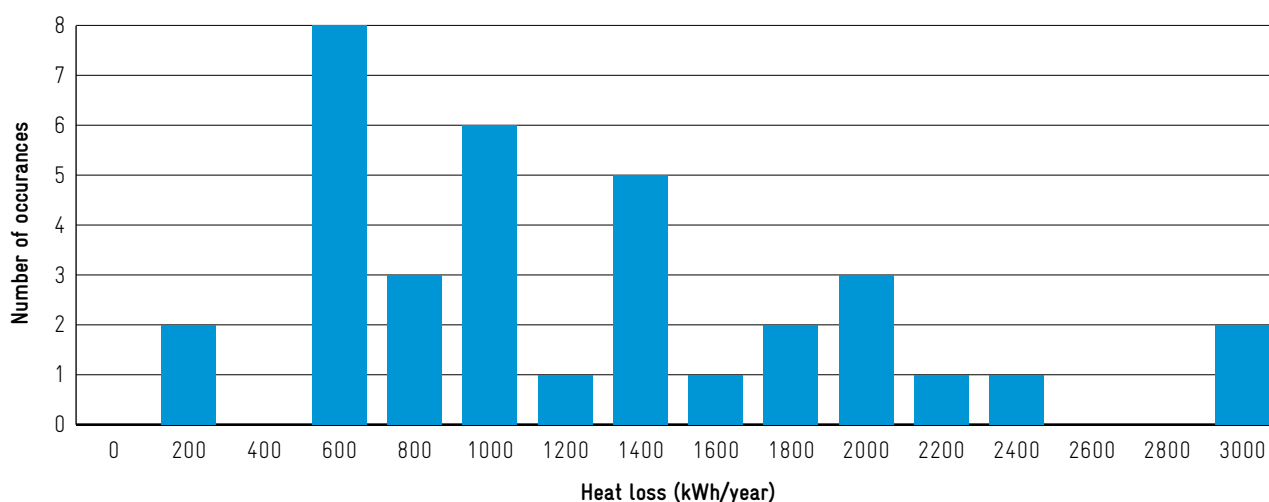


Figure 12. Heat loss from hot water storage cylinder

installed, includes a requirement for the installer of a solar water heating system to:

"Ensure that all pipes are lagged / insulated to protect against burns and unnecessary heat loss."<sup>10</sup>

Given that a lack of insulation was also observed with other types of hot-water systems, it is important that any work on heating systems includes a check of pipe and cylinder insulation. The Energy Saving Trust estimates that by installing a 75mm thick hot-water-cylinder jacket on a standard cylinder you will save around £40 per year; and adding insulation to pipes will save £15 per year (for a typical gas-fired water heating system).

#### Hot water temperature

Some households with solar water heating systems that provided the best results often allowed the hot water temperature to vary; nor did they require high temperatures at all times. This meant that less back-up heating was required to meet high temperatures when the solar collector could not provide sufficient energy, and it also reduced heat loss.

It is important to ensure that the hot water cylinder reaches high temperatures at times to undertake a pasteurisation cycle. Doing this after the solar water heating system has heated up the water as much as possible will reduce the amount of energy required by the back-up heater to reach high temperatures. This will improve performance.

#### Other impacts on savings:

##### Pumps and controllers

All systems in the trial used an electric pump to circulate the solar heat-transfer fluid to and from the solar collector. Some systems used a small solar PV panel to run the pump, but the majority used mains electricity to run the pump and controller.

Where mains electricity was used, generally only a small amount of energy was used in comparison to the total heat energy provided by the system (the median was about 5 per cent and 55kWh per year in total).

However, there were a small number of sites that used a high amount of electricity (up to 180kWh per year in total). Investigation of the monitoring data has shown that the excessive electricity consumption was due to faults causing pumps to run at times when there is no solar energy. This can have a significant impact on the savings associated with installing a solar water heating system and could increase the cost of running the pumps and controllers from about £8 for a typical system to £26 per year.

<sup>10</sup> MCS Installer Standard 3001 <http://www.microgenerationcertification.org/admin/documents/MIS%203001%20Issue%202.0%20Solar%20Heating%202010.08.26.pdf>

## Key findings

Our analysis of performance data from 88 solar water heating sites gives the clearest picture we have had of how solar water heating systems perform in real life, when installed in homes across the UK and the Republic of Ireland. In addition to the monitoring equipment, we asked householders at trial sites about their experience of using their system, to improve our understanding of how customer behaviour affects system performance.

Overall, the results illustrate that solar water heating systems, if installed and used correctly, can perform well.

The following section outlines the field trial's key findings along with our headline recommendations.

### System performance

1. From the properties we trialled, well-installed and properly used systems could provide around 60 per cent of a household's hot water and produce around 1,500kWh of energy a year.
2. The trial also found examples where systems were not properly configured or used properly, and therefore these systems had significantly reduced benefits. Across the whole trial, the proportion of domestic hot water energy provided by solar power ranged between 9 per cent and 98 per cent (with a median of 39 per cent).
3. There was no difference in the annual solar energy yield observed between solar installations using flat-plate solar collectors and those using evacuated-tube solar collectors. This may be because although evacuated-tube collectors have higher insulation, flat-plate solar collectors generally have a larger working area as a proportion of the collector size.

### System set-up and usage

4. The way a solar water heating system is installed, set up and used strongly influences how well it works. The factors that impact performance include:
  - Volume of hot water used. Generally, houses with high occupancy can expect more from their solar water heating system.
  - Timing of back-up heating and hot water use. Systems provided more energy when the back-up heating was used just before the main hot water use or at the end of the day. This provides a better opportunity for the solar collector to heat the water rather than using the back-up.
  - Temperature settings. High temperature settings for hot water require significant back-up heating and increase standing losses from the cylinder.
  - Level of insulation. Poor insulation of hot-water storage cylinders and pipes contributed significantly to heat loss and low performance. This is a common issue with all water-heating systems (not just solar water heating systems).

5. Where mains electricity was used to power pumps and controllers, the amount of electricity used was generally small compared with the overall heat delivered. However, the amount ranged from 1–23 per cent (10kWh to 180kWh per year in total), showing that in some cases a large amount of electricity was used. The high figures were due to faults causing pumps to run at times when there is no solar energy. This could increase running costs from about £8 for a typical system to £26.

#### Householders' behaviour and perceptions

6. The way in which householders use their system and their controls is crucial, so comprehensive and easy-to-understand advice for users on how to control solar water heating systems could improve the way in which the systems are used and how they perform overall. The level of advice provided to householders in the trial varied greatly.
7. 84 per cent of householders in the trial were either "fairly satisfied" or "very satisfied" with their system, with over 50 per cent very satisfied. So, overall, householders were happy with their systems.

#### Economics

8. Solar water heating systems can achieve savings on bills. Properly installed/controlled systems can save from £30 to over £100 per year, but poorly installed/controlled systems could actually increase fuel costs. The savings depend on the type of system and fuel the solar water heating system has replaced and vary from user to user. The typical savings are £55/year when replacing gas and £80/year when replacing electric immersion heating. However, the Renewable Heat Incentive (see text box on page 23) may increase this saving.

#### Carbon savings

9. A solar water heating system is likely to provide carbon savings, depending on the heating system being replaced. Properly installed/controlled systems can save 50 to 500 kilogrammes of CO<sub>2</sub> per year, but poorly installed/controlled systems could lead to an increase in overall household emissions. The typical savings are 230kg/year when replacing gas and 510kg/year when replacing electric immersion heating. This is the roughly the same carbon saving you would get from draught-proofing round all the doors, windows and skirting boards in a gas heated or electrically heated home.

## Conclusions

Our analysis of performance data from 88 in-situ solar water heating systems has shown how solar water heating systems can perform in real-life conditions when installed in homes across the UK and the Republic of Ireland.

Overall, the results are positive, and they illustrate that if the system is designed, installed and used correctly, solar water heating systems can be an efficient way of providing domestic hot water. Customer behaviour can also make a significant difference to how effectively the generated heat is used. A number of systems, which demonstrated lower levels of performance than anticipated, did not fulfil these criteria.

We found that set-up and installation can significantly hamper the performance of solar water heating systems. In particular, systems should be designed to provide adequate storage, and they should have sufficient insulation and suitable pump settings. This will prevent unnecessary heat loss, ensure that the heat generated is stored effectively and reduce unnecessary electricity consumption. In general, as the demand for hot water and the supply of hot water by the solar water heating system tend to occur at different times of day, effective hot-water storage is the key to making the most of the heat generated.

The way in which people use the energy produced by their solar water heating system plays an equally important part in its overall performance. Simple and clear advice from installers is important to ensure the householders' understanding of the effective use of controls and the optimum heating pattern (especially around timing of hot water use and back-up heating). It is clear that customers can make cost savings and reduce their carbon emissions; and that they can do simple things to maximise both of these.

The findings from this trial will be of importance to those who provide, sell and install solar water heating systems, and also to consumers, and those who advise them. The Energy Saving Trust's advice on solar water heating has been updated to ensure that consumers have access to the latest information, and we will also incorporate this into the work we do through our advice network.

## Advice for consumers

The Energy Saving Trust provides support through our trained advisers, websites and consumer guides, to help you decide whether investing in solar water heating system is the right choice for you, and how to get the most out of your system.

To help you to get started, the Energy Saving Trust has compiled a simple consumer checklist. However, more detailed advice can be found in the Energy Saving Trust's buyers' guide on solar water heating systems, available at [www.energysavingtrust.org.uk/Publications2/Generate-your-own-energy/A-buyer-s-guide-to-solar-water-heating](http://www.energysavingtrust.org.uk/Publications2/Generate-your-own-energy/A-buyer-s-guide-to-solar-water-heating).

When considering a solar hot water system, it is essential that you first consider what energy-efficiency measures can be implemented, such as draught proofing, loft and cavity wall insulation. These simple measures will provide long-term financial and carbon savings, as well as improving the overall thermal comfort of your property.

### Consumer checklist:

#### When you are considering installing a system you should:

- Consider **roof orientation and any potential shading issues**. Unobstructed south-east to south-west facing roofs are ideal, although systems facing east and west still provide a significant benefit. Shading from objects such as trees, chimney stacks and other buildings will reduce the performance of your solar water heating system. It is not recommended to install a system on a north-east, north or north-west facing roof. An MCS certified installer will be able to advise you on this.
- Consider your **existing heating system**. Solar water heating systems are designed to be compatible with most existing heating systems. However, not all combination boilers will work effectively with a solar water heating system. If you do have a combination boiler, a Gas Safe installer, OFTEC installer or MCS certificated installer should be able to advise you on any compatibility issues.
- Check **building control and planning regulations** in your area. An MCS certificated installer can advise further. If you are in doubt check with your local authority.
- Consider how much you spend on your **current fuel source**. If you switch to a new solar water heating system, then the amount of money and carbon you save will depend on how much you are spending now.
- Consider **how you currently heat your hot water**. If you rely heavily on appliances that heat water at the point of entry (for example, electric showers), you may not be taking full advantage of the hot water generated through your solar collectors. Again, your installer should be able to advise you on how to get the most out of your system.
- Consider **availability of space**. You need room for a suitably sized hot-water cylinder, and sufficient space – normally on the roof – to fit the collector. Roof space: typical hot water panels vary in size from around two to four square metres, although some systems may be even larger depending on hot water demand. Again, an MCS certificated installer should be able to advise you on this.
- Select a **Microgeneration Certification Scheme (MCS)** certificated installer, who uses **MCS** or **Solar Keymark** accredited products. This will ensure that your installation satisfies the necessary Government backed and industry approved installation standards. The Energy Saving Trust can help you find an MCS approved installer by calling 0800 512 012, or by visiting [www.energysavingtrust.org.uk](http://www.energysavingtrust.org.uk) in order to obtain a minimum of **3 quotes** from certificated installers.

#### What to expect from your installer:

- All MCS installers should be able to provide a detailed breakdown of the specification and costs of their proposed system. They should:
  - Complete a technical survey.
  - Explain how they calculated the size of the system to be appropriate for your hot water usage.
  - Provide an estimate of how much heat will be produced by any proposed system.
  - Supply clear, easy-to-understand and detailed information and advice on how best to use the system and operating instructions.

- Explain how the system will be installed and if there will be any disruption to your property.
- Install and set controls and settings to ensure you get the most out of your solar water heating system.
- Provide clear and easy-to-understand information on product and workmanship warranties.

**Once you have your system installed, you should:**

- **Make the most of your solar-heated hot water** by:
  - Using your water-heating timer to ensure that water is only heated by the back-up heating sources immediately before hot water use or at the end of the day.
  - Fitting a mixer shower, with an eco showerhead (and pump, if necessary) instead of an electric shower. This will be just as efficient in water use, but will be able to use solar-heated water instead of electric heating.

An MCS installer should provide information on how to make the most of your system.

- Ensure that your hot-water **storage cylinder and pipes are adequately insulated**<sup>11</sup> to minimise any heat loss. An MCS-approved installer should have notified you if any work needs to be done.
- Ensure that your system is properly maintained. Your installer should advise you on how to **look after your system**.
- **Be careful not to waste water** just because it is heated for free. Even before the water reaches your home it requires energy to clean and transport it.

## Renewable Heat Incentive

In March 2011, the UK Government announced the details of their Renewable Heat Incentive (RHI) and the Renewable Heat Premium Payment.

### Renewable Heat Premium Payment

The Renewable Heat Premium Payment scheme has now been announced and you can now make an application. It will reduce the initial installation cost of a solar water heating system by £300. There is around £12m available to householders in Scotland, England and Wales who install from 1 August 2011. The scheme runs from 1 August 2011 to 31 March 2012.

The Energy Saving Trust will be administering the Renewable Heat Premium Payment (RHPP).

### Apply now for the Renewable Heat Premium Payment scheme at:

<http://www.energysavingtrust.org.uk/Generate-your-own-energy/Sell-your-own-energy/Renewable-Heat-Incentive>

### Renewable Heat Incentive

The Renewable Heat Incentive is designed to provide financial support that encourages individuals, communities and businesses to switch from using fossil fuel for heating, to renewables such as solar water heating. People in receipt of the Renewable Heat Premium Payments will be able to apply for the full Renewable Heat Initiative tariff support once the scheme is introduced in Autumn 2012, as will anybody who has installed an eligible technology since 15th July 2009.

However, the Government has not yet published its proposals for how the Renewable Heat Incentive will work in the domestic sector, so there is no guarantee at this stage that those of you who are eligible for a Renewable Heat Premium Payment grant will also be eligible for the Renewable Heat Incentive.

These payments will start alongside the Green Deal from Autumn 2012 to allow for a more whole-house approach to heat production and energy saving.

### Full details are available on the Department of Energy and Climate Change's website at:

[http://www.decc.gov.uk/en/content/cms/meeting\\_energy/renewable\\_ener/incentive/incentive.aspx](http://www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/incentive/incentive.aspx)



## What's next?

### What to expect from your solar water heating system:

- On average, you should expect a solar water heating system to provide roughly **half of your hot water** requirements across the year, with highest output in the summer months.
- The **financial payback** of the system will depend on many things including:
  - What fuel is being displaced
  - How much hot water is used in the home and when it is used
  - How much the system cost to install

Properly installed/controlled systems can save from £30 to over £100 per year, but poorly installed/controlled systems could actually increase fuel bills. Typical savings are £55/year when replacing gas and £80/year when replacing electric immersion heating.

As fuel prices increase so will the savings earned from using a solar water heating system. By generating your own clean energy, you will be future-proofing your energy supply.

The Renewable Heat Premium Payment Scheme (RHPP) will reduce the initial installation cost of a solar water heating system by £300. However, the RHPP runs only until 31st March 2012 or when the funds run out, whichever is sooner. More information is given on p.22. The UK government intends to introduce a domestic element to the Renewable Heat Incentive (RHI), which is currently available for industrial, commercial and public sectors. Details of how the RHI will apply to RHPP participants will be published alongside details of the Government's 'Green Deal'.

This solar water heating field trial of real-life, in-situ performance shows that the efficiency of solar water heating systems is strongly affected by how they are controlled and used. Additional research into the impact of installing controls and/or smart home energy management and educating householders on system performance would provide a greater understanding of their potential performance within real homes.

A review of standards and guidance, including British Standards, MCS and the Energy Saving Trust's Solar thermal guidance for installers (CE131) guide, is also critical to ensure that installations are meeting best practice requirements. This review should consider whether advice to householders should be included within the handover requirement and strengthen existing requirements for insulation and controls.

11 Part L of UK building regulations requires that all pipes leaving a hot water cylinder should be insulated.



**energy saving trust®**

Prepared by the Energy Saving Trust  
September 2011

C0326 © Energy Saving Trust, 2011

Energy Saving Trust  
21 Dartmouth Street  
London SW1H 9BP  
Tel 020 7222 0101 Fax 0845 120 779  
[www.energysavingtrust.org.uk](http://www.energysavingtrust.org.uk)

The Energy Saving Trust would like to thank Stuart Elmes (Solar Trade Association), Steve Harris, David Matthews, Chris Laughton, Dave Sowden (Micropower Council), and Roger Webb (HHIC) for their help and advice in writing this report.