Scottish Health Technical Memorandum 04-02

The control of *Legionella*, hygiene, 'safe' hot water, cold water and drinking water systems
Emerging technologies
Part A: Solar domestic hot water heating

July 2015

Contents

Health Facilities Scotland

SHTM 04-02: Part A Solar domestic hot water heating

NHS
National
Services
Scotland

Acknowledgements

Preface

About Scottish Health Technical Memoranda

Engineering Scottish Health Technical Memoranda (SHTMs) give comprehensive advice and guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare.

The focus of SHTM guidance remains on healthcare-specific elements of standards, policies and up-to-date established best practice. They are applicable to new and existing sites, and are for use at various stages during the whole building lifecycle: Healthcare providers have a duty of care to ensure that appropriate engineering governance arrangements are in place and are managed effectively. The Engineering Scottish Health Technical Memorandum series provides best practice engineering standards and policy to enable management of this duty of care.

It is not the intention within this suite of documents to repeat unnecessarily international or European standards, industry standards or UK Government legislation. Where appropriate, these will be referenced.

Healthcare-specific technical engineering guidance is a vital tool in the safe and efficient operation of healthcare facilities. Scottish Health Technical Memorandum guidance is the main source of specific healthcare-related guidance for estates and facilities professionals.

The core suite of eight subject areas provides access to guidance which:

- is more streamlined and accessible;

- encapsulates the latest standards and best practice in healthcare engineering;

- provides a structured reference for healthcare engineering.
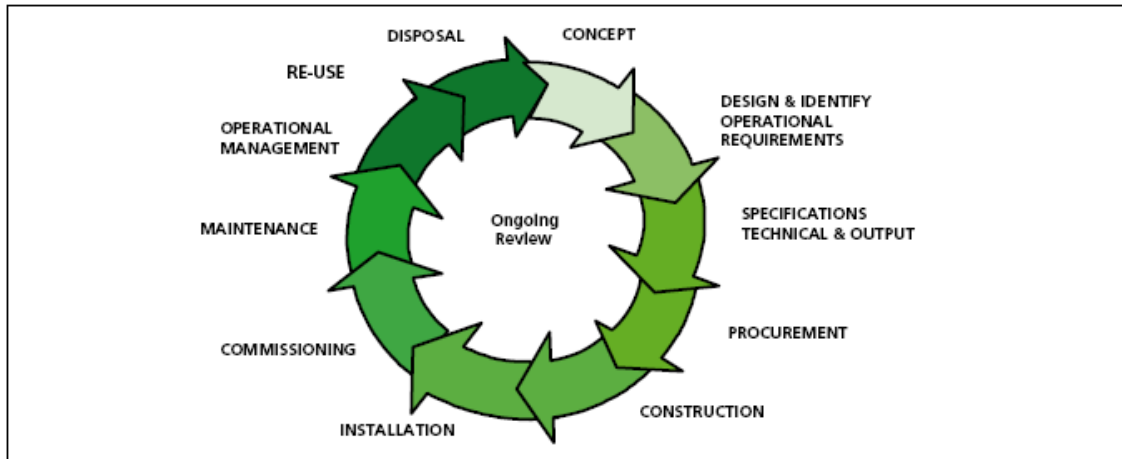
Healthcare building life-cycle

Structure of the Scottish Health Technical Memorandum suite

The series of engineering-specific guidance contains a suite of eight core subjects:

Scottish Health Technical Memorandum 00: Policies and principles (applicable to all Scottish Health Technical Memoranda in this series)

Scottish Health Technical Memorandum 01: Decontamination

Scottish Health Technical Memorandum 02: Medical gases

Scottish Health Technical Memorandum 03: Heating and ventilation systems

Scottish Health Technical Memorandum 04: Water systems

Scottish Health Technical Memorandum 05: Reserved for future use

Scottish Health Technical Memorandum 06: Electrical services

Scottish Health Technical Memorandum 07: Environment and sustainability

Scottish Health Technical Memorandum 08: Specialist services

Some subject areas have been further developed into topics shown as -01, -02 etc and further referenced into Parts A, B etc.

Example: Scottish Health Technical Memorandum 06-02 Part A represents: Electrical safety guidance for low voltage systems

In a similar way Scottish Health Technical Memorandum 07-02 simply represents: Environment and Sustainability – EnCO$_2$de.

All Scottish Health Technical Memoranda are supported by the initial document Scottish Health Technical Memorandum 00 which embraces the management

and operational policies from previous documents and explores risk management issues.

Some variation in style and structure is reflected by the topic and approach of the different review working groups.

Health Facilities Scotland wishes to acknowledge the contribution made by professional bodies, engineering consultants, healthcare specialists and NHS staff who have contributed to the review.
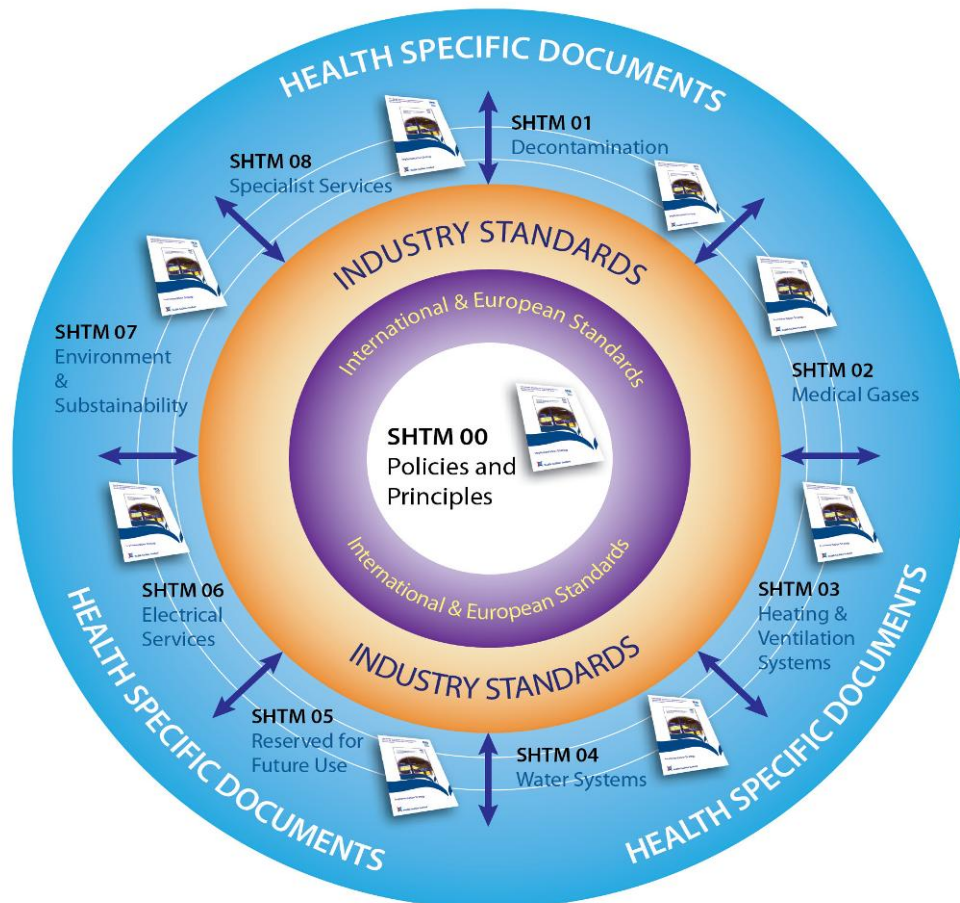
Engineering guidance structure

Health Facilities Scotland

SHTM 04-02: Part A Solar domestic hot water heating

NHS
National
Services
Scotland

Executive summary

Background information

The Building Research Establishment Environmental Assessment Method (BREEAM) rating of buildings awards credits which can be gained from reducing carbon emissions and, to that end, encourages incorporation of systems and controls making use of emerging technologies such as solar domestic hot water heating. To assess healthcare buildings a rating system has been created; entitled 'BREEAM Healthcare XB'. This is a credit-based self-assessment tool that substitutes and improves upon the former NHS Environmental Assessment Tool (NEAT) that was used previously for existing sites. BREEAM Healthcare XB has been endorsed by all health authorities within the UK, and can be used for both public and private health developments. It applies to all buildings that contain medical facilities.

There is, however, the temptation to seek credits awarded according to performance and incorporation of technologies seen to reduce carbon emissions yet having the potential to create other problems relating to control of infection. SHTM 04-01 Part A warns against taking such decisions without due consideration of the issues or the likely payback for the capital expenditure and revenue implications. This SHTM attempts to set out the relevant facts with exemplars to inform decisions on whether or not to pursue the incorporation of solar water heating into installations.

Note: The information contained in this SHTM is equally applicable to both new and existing sites.

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SHTM 04-02: Part A Solar domestic hot water heating

NHS
National
Services
Scotland

1. Introduction

Introduction

1.1   Climate change concerns are forcing countries worldwide to re-evaluate their energy policies. This in turn has led to governments reviewing their use of renewable energy sources in an attempt collectively to reduce the world's carbon footprint. The United Kingdom has taken steps to promote the use of renewable energy sources to help combat climate change through the introduction of new legislation and incentives. The 2008 Climate Change Act set a target of a 26% reduction in CO_2 emissions from 1990 levels by 2020, and 80% by 2050. This was then amended in 2009 to a reduction of 34% by 2020. In 2009, the Scottish Government set its own target to reduce CO_2 emissions by introducing The Climate Change (Scotland) Act 2009. This set out to reduce the amount of CO_2 emissions by at least 42% by the year 2020.

1.2   Energy consumption in the UK Health sector was reported at approximately 35,000 GJ in 2008, with just over 11% of this attributed to domestic water heating (DECC DUKES data 2010). Increasing the use of renewable technologies could assist in reducing the carbon demand resulting from this energy consumption. As a result, Health Facilities Scotland, in a bid to produce energy that is not only cost efficient but also less carbon intensive, set out to assess the use of renewable technologies in Scottish healthcare facilities.

1.3   One form of renewable technology considered by Health Facilities Scotland as a form of reducing carbon emissions has been the use of solar energy to heat domestic hot water. However, NHSScotland guidelines do not as yet allow the use of this technology in a healthcare setting (SHTM 04-01 Part A, paragraphs 14.6 & 14.9 refer) although a small number of pilot projects are being evaluated. The main reason for this is that it may provide additional risk to patients from *Legionella.* Inappropriately or incorrectly designed solar water heating systems can give rise to conditions which are favourable for multiplication and spread of water-based organisms such as *Legionella.* This can be particularly problematic in healthcare establishments due the increased likelihood of vulnerable patients being cared for, who could therefore be exposed to these organisms. However, solar energy has proved to be successful within healthcare settings elsewhere in the world (Hinotani *et al.*, 1979).

1.4   In 2008 there were 78,470 solar water heating installations in the UK (Utley and Shorrock, 2008), showing that the technology is feasible. None of these installations was in Scottish healthcare facilities. Since heat consumption in hospitals for the purpose of supplying domestic hot water is extremely stable throughout the year, and the majority of the demand is during the day (Bujak, 2010), it is theoretically possible to apply solar systems to produce domestic hot water in this type of facility.

1.5   For European hospitals, Werner-Verlag (1981) found the average per bed per day hot water consumption to be within the range 80 litres to 130 litres. A more recent study in the United States suggests 100 litres to 150 litres per bed per

day (Bourkas, 2005). The large range in consumption figures shows that site-specific surveys will be necessary to calculate accurately the demand and potential savings in primary fuel costs associated with generating domestic hot water.

1.6 Klingenberger *et al*. (2003) carried out a case study of a German hospital with a solar domestic hot water system (SDHW). It was found that 100m^2 of solar panel used could provide an average of approximately 7,000 litres of hot water per day over the course of a year, supplied at 60ºC at the point of use. The particular system used in this example had a total collector area of 276m^2 which equated to approximately 19,320 litres per day. The collector panels were sited with a southerly orientation at an inclination of 45 degrees. The solar fraction for the site ranged from 10% - 80%

1.7 The figures from the Klingenberger *et al* (2003) study suggest that the system studied can provide an annual average of 70 litres of hot water per m^2 of solar panel. The resulting primary fuel saving can be calculated by taking into account the percentage of hot water volume supplied by the DSHW system. Generalisations cannot be made from the Klingenberger *et al* (2003) study, due to site-specific considerations such as:

- available space for solar panels;

- type of system to be used, or;

- cost of installation.

1.8 It is important to note that the German hospital was in Baden Baden and further South than any point in the British Isles. It is also very far inland. As a result the solar irradiation, and therefore the useful energy, available in this location will be greater than anywhere in Scotland. The European Commission Joint Research Council's photovoltaic estimating tool (http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php) estimates average daily irradiation at the optimum angle as 3,290 Wh/m^2 in Baden Baden, compared with 2,760 Wh/m^2 for Edinburgh. This makes the solar irradiation in Edinburgh approximately 83% of that in Baden Baden. The estimates resulting from this tool are based on historical weather data from weather stations and climate satellites which take into account cloud cover.

1.9 In the United Kingdom, the Princess Alexandra Hospital in Harlow, near London, obtained a grant to fund the installation of a Solar Domestic Hot Water System. This system uses 38 solar panels split between two rooftops. The panels are estimated to provide a total of 74 MWh annually.

1.10 Installation cost will impact on feasibility of individual projects. The system installed in the Princess Alexandra Hospital was grant-funded, and cost £142,000 to install. Assuming a cost per kWh for gas of £0.03, and a Renewable Heat Incentive payment of £0.085 per kWh, an approximate saving of £7,560 is made per annum. This suggests a payback period of just under 19 years. The case study of the German hospital quoted a figure of €196,000 for retrofit of the system shown in Figure 1. Again, generalisations cannot be made

from this, due to specific site issues, and the change in the financial climate since 2003.

BREEAM Healthcare XB

1.11   As well as the carbon that may be saved and the fuel cost reductions from installing thermal solar panels for domestic hot water, the Building Research Establishment Environmental Assessment Method (BREEAM) rating of the building would also be improved as there are credits to be gained from using this technology. To assess healthcare buildings a rating system has been created; entitled 'BREEAM Healthcare XB'. This is a credit-based self-assessment tool that substitutes and improves upon the former NHS Environmental Assessment Tool (NEAT) that was used previously for existing sites.

1.12   BREEAM Healthcare XB has been endorsed by all health authorities within the UK, and can be used for both public and private health developments. It applies to all buildings that contain medical facilities. Credits are awarded according to performance. A set of environmental weightings then enables the credits to be added together to produce a single overall score. The building is then rated on a scale of: 'pass', 'good', 'very good', 'excellent' or 'outstanding', and a certificate awarded to the development. As energy accounts for the largest percentage of all the weighted factors (19%) the introduction of solar hot water panels may not make a substantial difference to the energy rating awarded for the building. The panels provide a low carbon alternative energy supply and reduce fuel related carbon emissions, but do not reduce the energy demand from buildings.

Aims of this SHTM

1.13   Ultimately the aims of this SHTM are as follows:

- to highlight the implications and benefits of using solar energy for the heating of domestic hot water;

- to determine its potential to reduce the carbon demand in Scottish hospitals;

- to assess its potential to reduce running costs and achieve a high BREEAM Healthcare XB rating.

1.14   Additionally, the SHTM will highlight:

- the limitations of using solar energy as a means of heating water; addressing issues such as achieving correct stored hot water temperatures in a Scottish climate;

- the concern that the temperatures produced through the use of solar energy could fall into the *Legionella* breeding range, thus creating significant health hazards for hospital patients.

2. Background

Use of Solar Collectors

2.1 Until recently Greece had the highest number of solar collectors per capita in the EU, with 25% of all households (850,000) having a solar domestic hot water system (SDHW). Their government offered incentives for the installation of solar systems and the Greek climate ensures that radiation from the sun during the summer months is sufficient for domestic hot water demands.

2.2 Such renewable energy has been slower to become established in the European Union (EU) where a target was set to achieve 12% of the total inland energy from renewable technologies by 2010. (Tsilingiridis and Martinopoulos, 2010). This has not been met despite solar energy having the potential to achieve this target on its own. A significant deterrent has been the high set-up cost of the technology (Belusko *et al.*, 2004).

Solar radiation

2.3 The sun radiates energy from its high temperature surface (approximately 6,000°C), which reaches the earth's surface either though direct or diffuse radiation (Boyle, 2004). In the UK, the total radiation from the sun consists of approximately 50% direct and 50% diffuse radiation and both can be used to heat domestic water (Boyle, 2004). The main consideration when assessing the viability of using solar energy as a means of heating domestic water is the amount of radiation that the solar panels will receive. This is dependent on a number of factors, including:

- whether a country is situated in the southern or northern hemisphere;
- the time of year;
- the positioning of panels.

2.4 Allen *et al* (2009), suggest that the amount of solar variability over different locations in the UK (Glasgow, Aberdeen and Plymouth) ranges from 3,200MJ/m^2 to 3,500MJ/m^2, and that solar panels are effective between the angles of 15° and 50° to the horizontal.

Maximising output

2.5 The amount of radiation reaching the Earth's surface varies throughout the year. June produces the highest amount and December the least. Another important factor to consider is the position or location of the solar panel. The position which receives the most radiation is required for optimal performance. In the northern hemisphere, a south-facing surface of a building receives the most radiation (CIBSE, 2006). The optimum positioning of a solar panel's surface is also dependent on the time of year. During the summer months a solar panel is required to sit more horizontally to receive the maximum radiation, yet during the winter months this position should be altered so as the panel sits

more vertically. Boyle (2004) asserts that the optimum angle of a non-articulated solar panel is 30º in the UK in order to provide continual radiation throughout the whole year. The solar panel ideally should face south. However, a solar collector orientation between south-east and south-west is acceptable for most solar heating applications, making these applications suitable for many buildings (Boyle 2004). CIBSE (2009) provides the diagram in Figure 2 to illustrate the effects angle and orientation of a fixed solar panel have on collection efficiency.

Tilt	Annual output as percentage of maximum for stated orientation (with respect to due south) and tilt / %												
	−90° West	−75°	−60°	−45° SW	−30°	−15°	0° South	15°	30°	45° SE	60°	75°	90° East
Vertical	56	60	64	67	69	71	71	71	71	69	65	62	58
80°	63	68	72	75	77	79	80	80	79	77	74	69	65
70°	69	74	78	82	85	86	87	87	86	84	80	76	70
60°	74	79	84	87	90	91	93	93	92	89	86	81	76
50°	78	84	88	92	95	96	97	97	96	93	89	85	80
40°	82	86	90	95	97	99	100	99	98	96	92	88	84
30°	86	89	93	96	97	99	100	100	98	96	94	90	86
20°	87	90	93	96	97	98	98	98	97	96	94	91	88
10°	89	91	92	94	97	95	96	95	95	94	93	91	90
Horizontal	90	90	90	90	90	90	90	90	90	90	90	90	90

Figure 1: Optimum positioning for solar collectors (Source: CIBSE 2009)

Solar Panels in the UK

2.6 When solar panel systems were first introduced into the UK market in the 1970s, the performance of the systems did not match the claims made by the manufacturers and installers (Brinkworth, 2001). For this reason, a British Standard was created: BS5918 (BSI, 1989), which was the first in the world to address the majority of design, construction, installation, commissioning and maintenance aspects of the solar panel systems.

2.7 It is recognised that the use of solar energy for heating domestic water in countries with moderate climates, such as the UK, still offers significant benefits in terms of reducing carbon emissions. Historically, excessive costs and, to some extent, the lack of confidence in the long-term durability of solar heating systems, have delayed their implementation in the UK (Lenel & Mudd 1984). However improvements in affordability, durability and efficiency, have increased the popularity of SDHW systems in more recent times.

2.8 The climate in the UK is a significant factor to consider when designing solar panel systems. The energy that can be provided through the use of these systems must be established at the earliest possible stage to ascertain if the cost saving over conventional fuels through the panel's installation will provide an acceptable pay-back period for the system cost.

2.9 Table 1 illustrates the percentage distribution of annual solar energy supplied to a solar panel system in London (BS5918, 1980).

Approximate percentage of the annual solar energy supplied each month			
January	2	July	13
February	5	August	13
March	6	September	12
April	10	October	8
May	12	November	4
June	13	December	2
NB: These values apply to systems located in the London area for south-facing collectors tilted at 30º.			

Table 1: Monthly distribution of annual solar energy (Source – BS5918)

2.10   For Edinburgh, the solar energy availability is approximately 10% less than for London, although the percentage of the annual total each month will be approximately the same (BS5918, 1980). A study by Garnier *et al.* (2009) showed that the solar radiance for Edinburgh is approximately 900 W/m^2 on a bright sunny day, but in winter a 400 W/m^2 is more representative.

Note: The internet provides access to many websites which allow estimates of photovoltaic performance to be carried out that are specific to a postcode area.

2.11   Garnier *et al.* (2009) found that with an Integrated Collector Storage Solar Water Heater (ICC-SWH) heated water temperatures were unlikely to exceed 70ºC. However, this is just one possible option and other systems may be able to reach higher temperatures.

2.12   In colder regions of Europe, including Scotland, these issues have to be managed:

- thermal losses from solar water heating systems are higher;

- solar irradiance is lower; and

- freezing of the fluid inside the solar collector.

2.13   This latter issue can be managed with in-built sensors and circulating pumps coupled with an antifreeze additive (if the system works by heat transfer). For these reasons, the design and optimisation of the system parameters is extremely important to achieve optimal.

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SHTM 04-02: Part A Solar domestic hot water heating

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National
Services
Scotland

3.   Types of Solar Panels

3.1   There are two main types of solar panel available on the UK market:

- the solar thermal energy collector (STE), heating panels which absorb solar energy and transfer that energy into heat;

- Photovoltaics (PV) panels which transform solar energy directly into electricity.

3.2   Both of these panels use different technology and offer different benefits to the end user. Currently, another type of solar panel is being developed, comprising a photovoltaic thermal system (PV/T). This is a hybrid system which contains both the STE and PV technologies in one unit.

3.3   For the purposes of this Report only Solar Thermal Energy collectors are further investigated. Photovoltaics are generally prohibitively costly and are not suitable for heating water. Hybrid technologies are relatively new and warrant further investigation once more is known about their performance and cost. A brief description of all these solar technologies is included here to show the range of solar options.

Solar Thermal Energy (STE) collectors

3.4   The solar thermal energy collector uses energy from the sun to heat water for domestic washing and cleaning requirements. The effectiveness depends on when the hot water supply is required. As the STE collectors are most effective during the day (as a result of the sun's radiation), these systems are most beneficial to environments where there is a high demand for hot water throughout the day and this would include a healthcare environment. However, due to the UK's climate, the water cannot be heated to the required temperature all year round, and for this reason the water has to be re-heated using another means such as a gas or oil-fired boiler or an electric emersion heater.

Note: Despite this, the Building Services Research and Information Association (BSRIA) (2008) states that a domestic installation with a $4m^2$ collection area can provide between 50 and 70% of the hot water requirement of a typical home in the UK.

Photovoltaics (PV) collectors

3.5   The solar photovoltaic (PV) industry is well established within the UK, and the systems themselves host some advantages; the most significant ones being their reliability and carbon saving properties. There are three types of photovoltaic cell available, with differing costs and efficiencies (CIBSE, 2009). These are summarised in Table 2 overleaf.
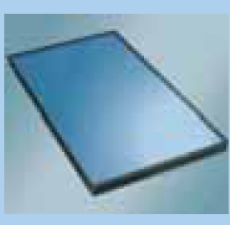
Property	PV cell type		
	Monocrystalline silicon	Polycrystalline silicon	Thin film amorphous silicon
Appearance			
Cell efficiency at standard test conditions[1]	15–17%	14–15%	8–12%
Module efficiency	13–15%	12–14%	5–7%
Area of modules required per kW$_p$[2]	7 m^2	8 m^2	16 m^2
Area per kW$_p$[2] of building materials incorporating PV cells	Glass–glass laminates: 8–30 m^2 (depends on cell spacing)	Glass–glass laminates: 10–30 m^2 (depends on cell spacing)	Solar metal roofing: 23.5 m^2 Glass–glass laminates 25 m^2
Advantages/disadvantages	Most efficient but highest cost	Cheaper than monocrystalline but slightly less efficient	Considerably cheaper but about half the efficiency of monocrystalline Offers the widest range of options for integration into building elements

Notes: [1] Standard test conditions (STC) are 25 °C, light intensity of 1000 W/m^2 and air mass (spectral power distribution) of 1.5 and a cell temperature of 25 °C; [2] kWp = peak output power (kilowatts) (solar PV products are rated by their output power at STC)

Table 2: Photovoltaic cell efficiency (Source – CIBSE 2009)

3.6   Drawbacks to installing and using this type of system include cost and the intermittent nature of the resource. In recent years, costs have dropped as the market for the systems has expanded, and it is predicted that these costs will drop further in the next few years. In order to support their market development, governments have been offering premium electricity tariffs and grants. In the UK, past grant schemes have been replaced by feed-in tariffs for photovoltaic systems. The tariff rate has recently been cut from 43.3p per kWh to 21p per kWh. Yet even with this payment, it is difficult to justify PV projects on cost grounds. As a result of their current high cost, the installation of photovoltaic systems to date has mainly occurred on small demonstration projects in order to

give engineering and maintenance staff experience with the technology, or where previous grant funding provided substantial financial aid.

3.7 CIBSE (2006) suggests that photovoltaic systems generally have a long pay-back period, which can extend beyond the expected lifespan of the system. A practical example of a PV system in the West of Scotland is given in the Appendix. The calculated payback time for this system was just over 60 years! It should be noted that a new Feed-in Tariff later became available post installation. At the original19p per kWh, this reduced the payback time to 27 years. As noted previously this level of tariff cannot always be guaranteed to be available in future.

Photovoltaic thermal hybrid solar (PV/T) collectors

3.8 When converting solar energy into electrical energy using only PV panels, a considerable amount of heat is produced (Vokas, 2006). Yet, coupled with this increase in temperature, the electrical efficiency of a PV panel is simultaneously reduced (Vokas, 2006). Through combining a PV panel with a STE panel (PV/T collector), both thermal and electrical energy can be produced. By collecting the thermal energy the panel cools and conversion of solar energy into electricity is improved. The PV/T collector has a thermal efficiency 9% lower than a conventional STE solar collector (Vokas, 2006). Despite this small drop in efficiency, it appears more resourceful to install the combined system so that both thermal and electric energy can be produced. This appears to be a technically viable option. However, more research would be required in this area before it would be considered for use in

4. Types of STE panels

4.1 For the sole purpose of heating domestic hot water there are three main STE panel designs:

- the glazed flat plate collector;

- the evacuated tube collector;

- the unglazed plastic (or low temperature collector).

Each system presents both advantages and disadvantages to the user, and all are classified under BS5918, as outlined in Table 3 below.

Solar Collector Specification		
Collector Class	**Range of collector characteristics** U/η_0 **(in W/m/K)**	**Typical collector technology for the class**
B	Less than 3	Advanced
C	3 to 6	Vacuum insulated
D	6 to 9	Single glazed with selective coating
E	9 to 13	Single glazed with matt black coating
F	Greater than 13	Unglazed

Table 3: Solar collector specifications (Source – BS: 5918)

The Glazed Flat Plate Collector

4.2 This type of collector comprises of an absorber (typically made from copper or aluminium) coated with a special black absorber coating, a transparent cover and insulation contained within a frame. The metal tubes can be used in two configurations:

- parallel;

- serpentine.

The Evacuated Tube Collectors

4.3 This is the most efficient form of solar collector and also the most expensive. This collector is formed from a number of vacuum tubes containing a finned metal collector tube. Each tube is filled with a heat transfer fluid. The vacuum reduces convection and conduction losses, enabling evacuated tubes to operate at higher temperatures than flat plate collectors. This technology may also be implemented through the use of a heat pipe, where a sealed copper pipe containing a fluid (either water or alcohol) undergoes an evaporating-condensing cycle. In this case, solar heat evaporates the liquid and the vapour travels to the heat pipe condenser - situated in the manifold. The fluid

condenses, transferring heat to the fluid in the manifold, and then returns to the heat pipe before repeating the process once again.

4.4 Evacuated tube collectors work efficiently with low radiation and with high absorber temperatures. Higher water temperatures may also be obtained from this type of collector. The heat pipe in the evacuated tube collectors also protects the collector from overheating or freezing. To work effectively, this type of water collector requires a minimum slope of 25° to allow the fluid to evaporate and rise to the top of the tube, and condense and fall back to the bottom. Evacuated tube collectors release very little heat and therefore snow can collect on them. However, they are also very delicate, meaning that removing any collected snow could cause damage.
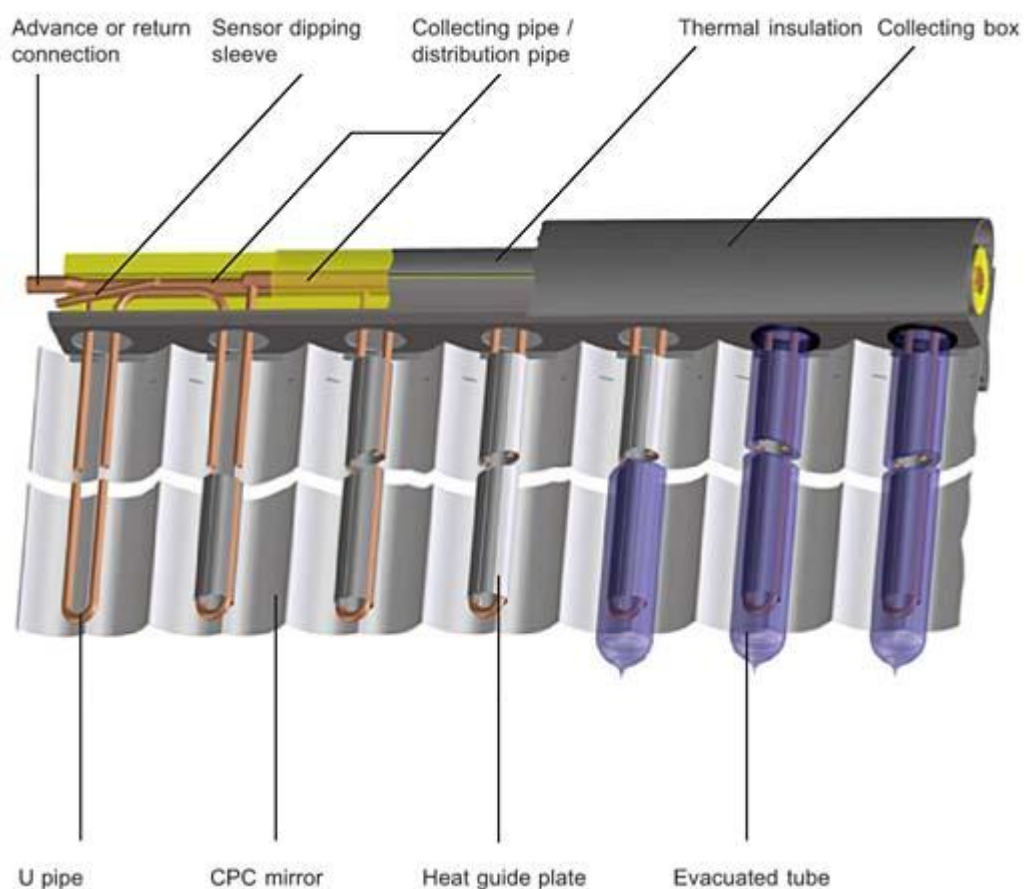
Figure 2: Evacuated tube collector cut-away illustration.
(Courtesy, Lochinvar Limited)

Unglazed Collector

4.5 The unglazed collector, which is predominantly used for heating swimming pools, is the cheapest and simplest solar collector and contains only an absorber tube. In this respect, it is less efficient than both the evacuated tube and the glazed flat plate collector, and has a lower operating temperature. This general arrangement is normally used in an open loop configuration and is fed directly back into the point of use.

Mounting of STE Panels

4.6 Although STE panels can be mounted on the ground or the façade of a building, the most common approach is to mount the panel on the roof (Juanico, 2008). One reason for this is that if the collectors are mounted on a building façade the radiance is far less than via roof or ground positions. STE panels can be incorporated into a roof's structure, where the solar panel replaces the roof and is fitted directly to the frame of the building; in this instance, a pitched roof is required for optimum solar radiation absorption. Another option is to mount the panels on a roof's surface. However, if the roof is pitched, the solar collector should be attached to the rafters, with a small gap between the roof and the panel.

4.7 The cost of the installation will depend on how easily the site lends itself to installation. Where a roof does not provide an easy installation, it may be preferable to install on the ground. However, this may come with extra costs for pumping the liquid from the collector to the heat transfer vessel and may be susceptible to vandalism. Figures for installation are difficult to estimate, however. As an example, the Princess Alexandra Hospital (PAH) in Harlow installed 38 evacuated glass tube panels, all pipework and storage vessels at a cost of £142,000. This included a bespoke frame for 20 panels to allow installation at the best possible angle on one roof. This system cost approximately £3,750 per panel. An example of another SHDW system is given in Appendix 2. This cost £11,500 to install a 3-panel system, or £3,800 per panel. These costs seem to agree well with the CIBSE estimate of between £3,000 and £5,000 per panel (CIBSE, 2009).

Note: When considering a rooftop installation, it must be ensured that the roof has sufficient strength to support the weight of the panels and all other roof-mounted materials.

Design Considerations

4.8 SDHW systems can be subject to extreme temperatures, ranging from –20°C to over 200°C for flat plate collectors, and 350°C for evacuated glass tube collectors. As a result of the potential for; high pressure steam, heat expansion, freezing of liquid in the collector and *Legionella* growth, the following factors need to be taken into consideration when designing a SDHW system:

- high temperatures;
- control of expansion and overpressure as a result of high temperatures;
- prevention of steam or scalding water reaching the taps;
- protection from freezing of fluid in the collector or other parts of the solar primary circuit;
- control of *Legionella* bacteria.

Estimating SDHW system sizing

4.9   Although design and installation should only be carried out by experienced personnel, making an estimate of the size of a SDHW system may be helpful in determining feasibility. CIBSE recommend the following steps for sizing different aspects of a system.

Item	Sizing Procedure
Collector	Calculate DHW load for building Calculate required DHW energy and allow for system losses Set a solar fraction for the total DHW energy Calculate energy to be solar collected Allow for orientation and shading of collector surface Choose collector performance and calculate collector area
Storage	Calculate daily DHW load for building Calculate stored DHW volume (if any) Calculate dedicated solar pre-heat volume Add DHW store and solar pre-heat volumes to obtain the combined store size
Heat exchanger	Calculate collector area Set circulation rate Calculate exchange area

Figure 2: SDHW system sizing procedure (Source: Adapted from CIBSE 2009)

Note: Where a SDHW provides more energy than can be used, the excess heat is wasted. This leads systems to be less efficient and have longer payback periods. The case study given in Appendix 2 is an example of this.

5. Types of Solar Domestic Hot Water Systems

5.1 This SHTM focuses on the use of solar domestic hot water (SDHW) systems which use STE collectors. A useful guide to SDWH systems is available from the Greenspec website (http://www.greenspec.co.uk/solar-collectors.php), which is summarised in the following paragraphs. These systems have several different components that provide a variety of options. They can be split into

- heat distribution;
- circulation;
- storage.

Heat Distribution

5.2 The two main types of SDHW systems are direct and indirect heat distribution systems. Direct systems heat the water by passing it through the collector and passing it to a pre-heat cylinder (Greenspec, 2010). These systems are susceptible to freezing in cold temperatures and, as a result, are generally not used in the UK. Indirect systems use a 'heat transfer fluid circuit' to transfer heat from the solar collectors to the pre-heat vessel. This transfer fluid only flows between the solar collector and the heat exchanger. In the UK the transfer fluid is normally an antifreeze solution, to avoid problems with freezing during the winter.

Circulation

5.3 The method of heat circulation can be either passive or active.

- **Passive circulation** relies on gravity and the tendency of warmer fluid to rise in a system (generally referred to as a thermosiphon). These systems have fewer electrical components and are more reliable. However, they do not offer good control of heating output and can be slow to provide hot water.

- **Active systems** use a pump to control the flow of liquid around the solar collector. These systems use temperature differential controllers to allow the heat transfer fluid to be pumped from the collector only when the temperature in the collector is higher than that of the hot water cylinder. In Scotland, similar to the majority of Northern Europe, where freezing usually occurs in winter, conventional pumped systems are primarily used to prevent freezing in the pipes. Active pumped systems are similar to passive systems, the only significant difference being that a small pump is employed to circulate the water round the system. The installation of the pump increases the set up and running costs of a system, as electricity must be provided to keep the pump running constantly.

Note: For this type of pumped system to operate successfully in a healthcare environment, the controls for the thermal solar collector should be linked into the Building & Energy Management System (BEMS). In a BEMS system, the temperature of the water is constantly monitored and is only allowed to flow if the solar heated water temperature is higher than that of the hot water storage tank.

Storage

5.4   Storage of solar heated domestic water can be achieved in two ways.

5.5   One method is a separate pre-heat cylinder placed between the existing cold water feed and the normal hot water storage (also known as a thermal buffer.) Such a system is shown in Figure 3 below.
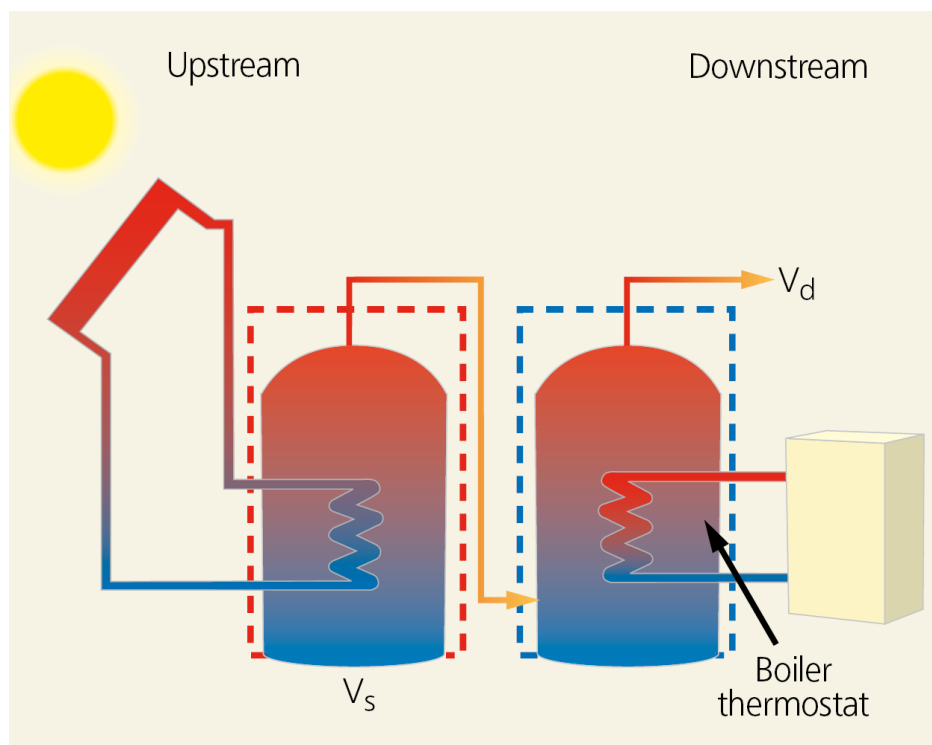
Figure 3: Separate pre-heat and storage system (Source: Energy Saving Trust 2006)

The second method is to replace the existing hot water storage cylinder with a larger double heat exchange coil cylinder, as shown below in Figure 4, overleaf.
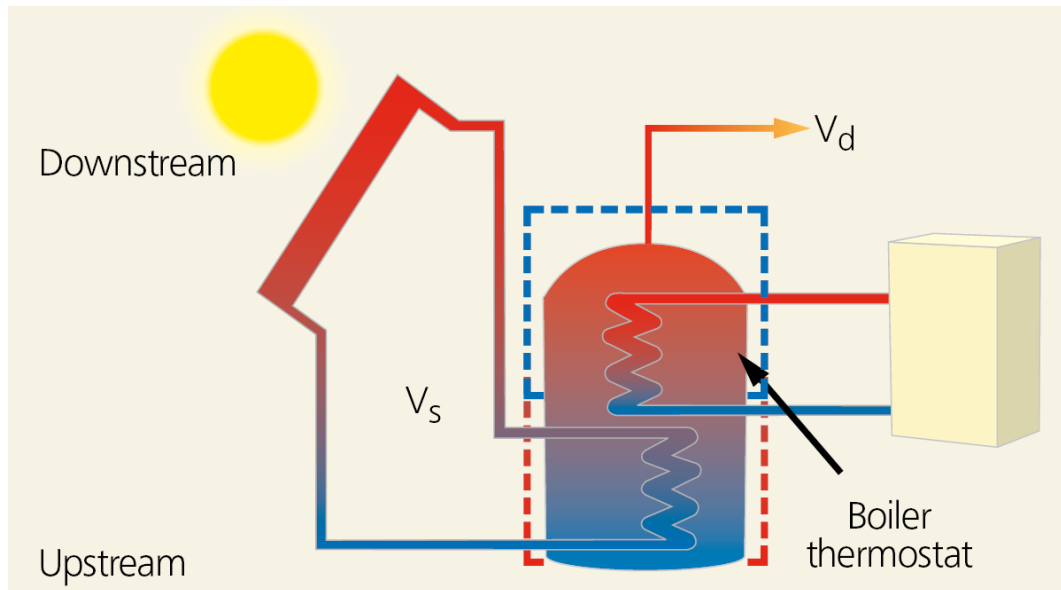
Figure 4: Combined pre-heat and storage system (Source: Energy Saving Trust 2006)

Note: 1. In both cases, a conventional water heating method is necessary to ensure that the water can be heated to the necessary temperature when the solar output from the collector is insufficient.

2. Dwell time is also important in removing *Legionella* risk. It must be ensured that the hot water has been held for long enough at a high enough temperature to kill all *Legionella* bacteria, before going to points of use.

IV = ISOLATION VALVE
PRV = PRESSURE REDUCING VALVE
NRV = NON-RETURN VALVE
EV = EXPANSION VALVE
TD = TUNDISH
LSV = LOCKSHIELD VALVE
EXV = EXPANSION VESSEL
TPRV = TEMPERATURE & PRESSURE RELIEF VALVE
DV = DRAIN VALVE
BRP = BUILDING RETURN PUMP
PCP = PRIMARY CIRCULATING PUMP
T = TEMPERATURE SENSOR

* = OPTIONAL EXPANSION VESSEL IF SYSTEM
    VOLUME REQUIRES

Figure 5: Typical gas-fired water heater / solar thermal schematic (Courtesy, Lochinvar Limited)
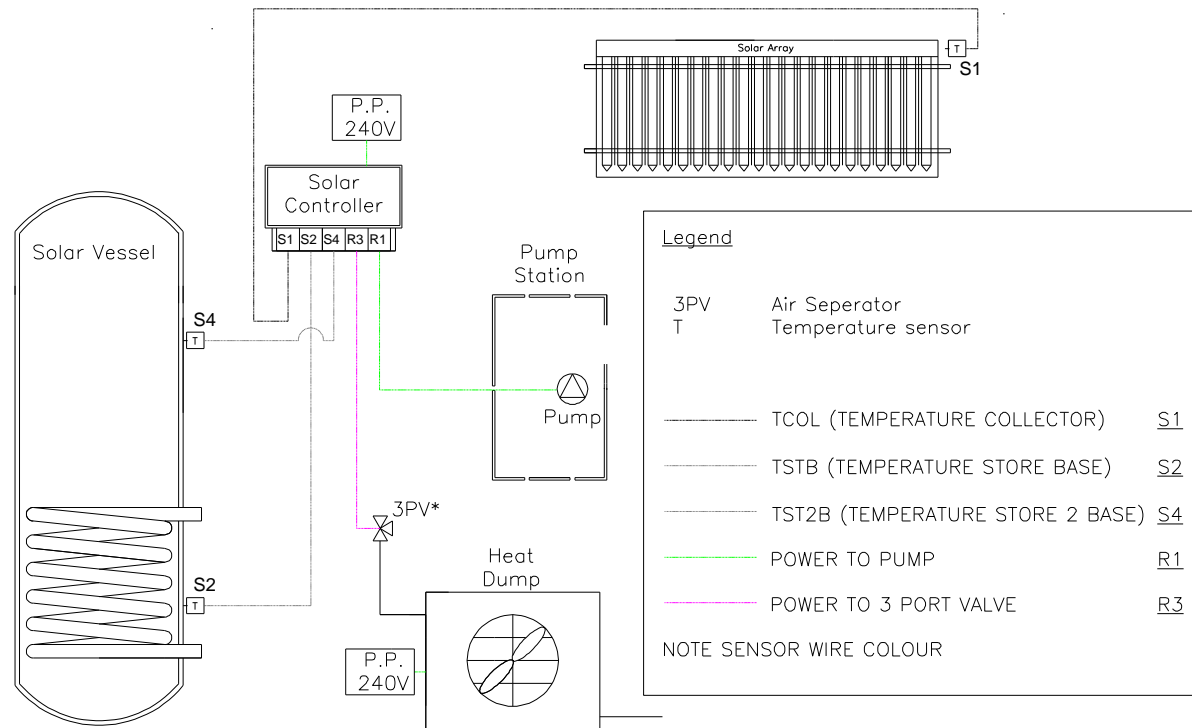
Figure 6: Typical Solar control functions (Courtesy, Lochinvar Limited)

Health Facilities Scotland

SHTM 04-02: Part A Solar domestic hot water heating

NHS
National
Services
Scotland

6. *Legionella*

Background information

6.1   *Legionella* is widespread in the environment and may grow in hot and cold water supplies. The bacteria can survive low temperatures and thrive at temperatures between 20 and 45ºC. It is clear that the temperature of hot water plays a vital role in contributing to the multiplication of *Legionella* (Mathys *et al*., 2008).

6.2   However, there are many ways to control *Legionella* within a hospital water system. If temperature is used as a means of 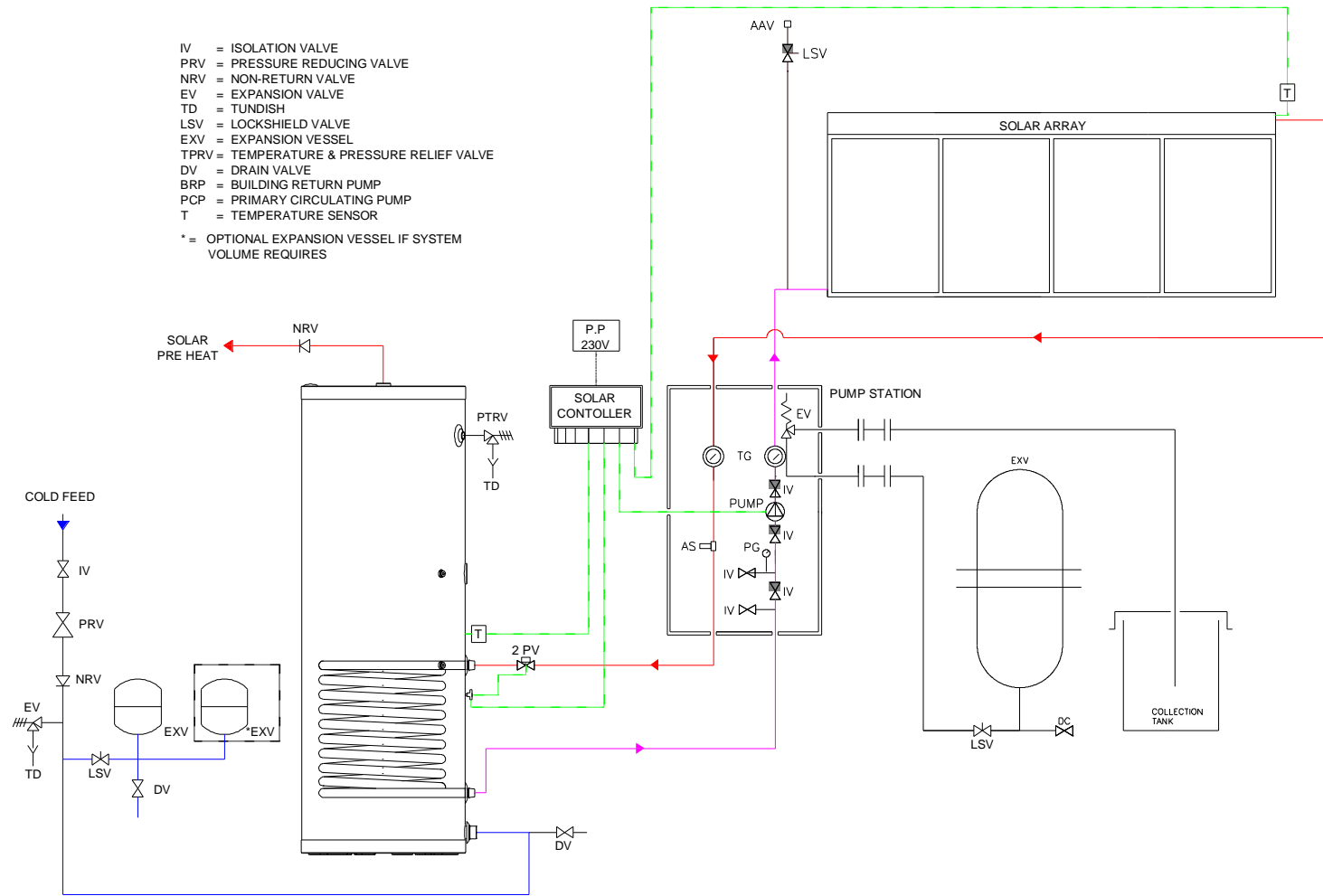preventing *Legionella,* the outgoing water from the calorifier should exceed 60ºC and the return temperature of the water should be at least 50ºC (L8, 2000). The various species of *Legionella* grow in different temperature ranges, varying between 20 to 50ºC (Rogers *et al*., 1994), with an optimal growth rate at 37ºC (Yee & Wadowsky *et al*., 1985). The reported doubling time of *Legionella* growth is 36 hours at 25ºC and 16.8 hours at 32ºC (Wadowsky *et al*., 1985). However, the organisms do not multiply below 20ºC and do not survive above temperatures of 60ºC.

> **Note:** In the UK there is insufficient irradiation for solar thermal systems to satisfy the entire hot-water energy demand all year round. It therefore becomes necessary to use another heat source to raise the temperature to the required level of 60ºC to prevent *Legionella* growth.

The Scottish situation

6.3   In Scotland, there are periods of time when there is insufficient sunlight to ensure that water entering a calorifier is of a sufficient temperature to be outwith the breeding range for *Legionella* and other bacteria.

6.4   A pumped closed loop system can remove this risk by ensuring that solar heated water does not mix with water circulated to outlets. Controls should be provided on this system where the fluid is only transferred when it is adding heat to the calorifier. To reduce further the risk of *Legionella* growth, the pumped system should feed directly into the calorifier and any additional heat, if required, would be provided via a conventional boiler. The entire calorifier temperature must be raised to 60ºC for one hour each day in order to disinfect the system.

6.5   In this design freezing the closed loop is prevented by employing an antifreeze solution that is pumped through the solar collector and exchanges heat in the calorifier.

6.6   Other forms of disinfection are available to eradicate *Legionella,* such as chemical or UV disinfection. For more details on *Legionella* and how an

outbreak can be treated, refer to the "Disinfection of Domestic Water Systems" document produced by Health Facilities Scotland SHTM 04-01 Part D, 2011).

7. Testing of SDHW systems

Preventing *Legionella* growth

7.1 Solar domestic hot water systems have the potential to promote *Legionella* growth. It is important to ensure that the performance of a system is accurately predicted to minimize the risk of colonisation. In practice, this will normally mean that the solar heating system will be paired with a conventional heating system to prevent the water from being stored or supplied at temperatures between 20 to 50ºC.

Predicting system performance

7.2 The performance and reliability of a SDHW system requires adequate sizing of components as well as the accurate prediction of the delivered useful energy and outlet water temperature. Different computational tools, such as Transient Systems Simulation Program (TRNSYS) and the ƒ chart Method, are used to evaluate the long term performance of solar energy systems and to study the effect of design parameters.

7.3 TRNSYS is an extensive software package and has been widely used to simulate solar energy systems (STE and PV) (Hobbi and Siddiqui, 2009) while the ƒ chart Method avoids lengthy calculations required with the TRNSYS package. (Abdel-Malek and Chu, 1985).

7.4 To predict the performance of a system, the water heating load is determined using various parameters including the annual or monthly average heating loads. In addition, the amount of energy produced by a solar collector and its upper temperature limits can be determined.

> **Note:** 1. It is essential that information provided for the designer's use is as accurate as possible and NHS Boards are best equipped to do so, particularly where there are records available.
>
> 2. It is important to ensure that only qualified and experienced practitioners are appointed to design such systems.

8. Feasibility of SDHWS

Funding Sources

8.1   The Energy Saving Trust (EST) provides a comprehensive list of grant schemes that are available in Scotland relating to energy efficiency. These can be seen on the EST web page, http://www.energysavingtrust.org.uk/business/Business/Local-Authorities/Funding/Funding-in-Scotland.

8.2   However, unless a solar domestic heating installation can in some way be seen to benefit the community directly, it is unlikely that such a project would attract funding from these sources. The only source of financial aid appears to be the Renewable Heat Incentive (RHI).

8.3   The Renewable Heat Incentive gives a payment of 8.5p per kWth useable heat generated by a solar collector (if the total energy generated is less than 200 kWth per day). This heat is metered and payments made quarterly.

Estimating Solar Irradiation Potential for Solar Thermal Panels in the UK

8.4   It is important to assess the amount of useful solar radiation available at a site before committing to an installation. Most installation companies are likely to offer a site assessment free of charge, but it is possible to estimate this independently using the **European Commission Joint Research Council's (ECJRC)** photovoltaic estimation tool (http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php).

8.5   This is an interactive tool using GIS mapping, climate satellite data, and historic weather station data to allow the estimation of solar irradiance values. A wide range of useful data can be retrieved by inputting a specific location. For example, reports can be produced that detail;

- the longitude, latitude and elevation of the location selected;
- the optimum fixed inclination angle for panels at that location;
- the average daily irradiation on a the horizontal plane;
- the average daily irradiation on the optimally inclined plane;
- the average daily irradiation at 90 degrees to the vertical plain;
- the optimum angle of inclination for each month;
- the average daily ratio of diffuse irradiation to irradiation at a horizontal surface.

8.6   These values can be used with manufacturer's stated panel efficiencies to estimate the amount of useful energy generated annually. A performance calculator is also available which has preset PV panel performance calculations.

Health Facilities Scotland

SHTM 04-02: Part A Solar domestic hot water heating

NHS
National
Services
Scotland

It is also possible to put specific manufacturer's data in the calculator to estimate the performance of specific panels.

8.7 The ECJRC tool is useful for estimation, but it should be noted that it does not take into account any site-specific details, such as shading from buildings or vegetation, although it does take into account prevailing weather conditions.

> **Note:** The PV performance calculator refers to the performance of photovoltaic panels generating electricity.

8.8 Performance of an evacuated tube collector cannot be directly estimated with this tool. However, the solar irradiation data will be necessary to make such a calculation. Evacuated tube collectors also draw their energy from diffuse irradiation. The ECJRC tool also has an option to include the ratio of diffuse radiation to that of global radiation (the radiation that reaches a horizontal surface).

8.9 The following two examples use the data from this tool, and show the difference in resource between two locations in Scotland.

Example 1 - Stranraer

8.10 Stranraer was located on the map in the ECJRC tool, and the monthly radiation tab selected. Data for the average daily irradiation on a horizontal plane (global irradiation), average daily irradiation at the optimum angle and the ratio between the global irradiation and diffuse radiation, were extracted from the report. The diffuse irradiation was calculated and added to the value for irradiation at the optimum angle, giving the estimated maximum useable irradiation for an evacuated tube type solar collector. This data is summarized in Table 3, overleaf.

Month	Avg. daily Global irradiation (Wh/m^2)	Avg. daily Optimum angle irradiation (Wh/m^2)	Ratio of diffuse to global irradiation	Avg. daily Total useable irradiation (Wh/m^2)
Jan	519	972	0.71	1340
Feb	1080	1700	0.66	2413
Mar	2050	2660	0.64	3972
Apr	3530	4060	0.56	6037
May	4680	4840	0.55	7414
Jun	4780	4680	0.59	7500
Jul	4590	4600	0.59	7308
Aug	3570	3830	0.63	6079
Sep	2450	3040	0.6	4510
Oct	1360	1970	0.64	2840
Nov	674	1210	0.68	1668
Dec	362	682	0.75	954
Year	2480	2860	0.6	4348

Table 4: Solar irradiation estimate for Stranraer

Example 2 - Lerwick

8.11   The same data has been extracted and presented for Lerwick in Table 5.below.

Month	Avg. daily Global irradiation (Wh/m^2)	Avg. daily Optimum angle irradiation (Wh/m^2)	Ratio of diffuse to global irradiation	Avg. daily Total useable irradiation (Wh/m^2)
Jan	244	512	0.78	702
Feb	762	1340	0.69	1866
Mar	1710	2420	0.63	3497
Apr	3130	3730	0.58	5545
May	4240	4430	0.58	6889
Jun	4660	4590	0.6	7386
Jul	4140	4160	0.63	6768
Aug	3310	3640	0.63	5725
Sep	2150	2850	0.6	4140
Oct	972	1550	0.66	2192
Nov	340	641	0.77	903
Dec	145	309	0.84	431
Year	2160	2520	0.62	3859

Table 5: Solar irradiation estimate for Lerwick

8.12   This data estimates that the average total solar resource available per day is 4.348 kWh/m^2 in Stranraer, and 3,859 kWh/m^2 in Lerwick. These figures can now be used with panel efficiency figures to determine the amount of energy any particular panel will supply.

8.13   CIBSE (2009) states that evacuated solar collector efficiencies range from approximately 80% to 45%, depending on the difference between the outside air temperature and the temperature inside the collector. This, and the efficiency of two other types of solar thermal collectors, is shown on the following graph.
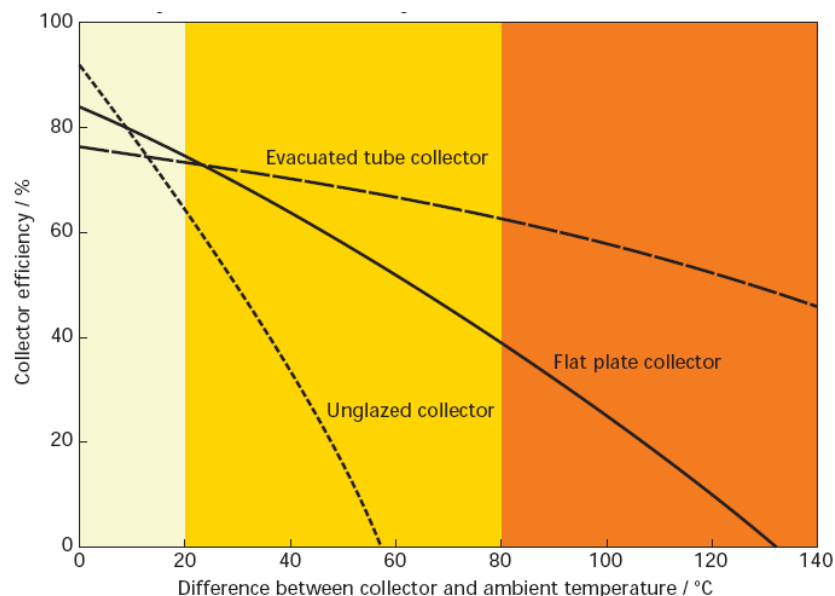

Figure 7: Solar thermal collector efficiency profiles (Source: CIBSE 2009)

Health Facilities Scotland

SHTM 04-02: Part A Solar domestic hot water heating

NHS
National
Services
Scotland

8.14   Therefore, the assumption would be that an evacuated tube panel would provide between 3.48 kWh and 1.96 kWh of energy per month per square metre of panel, if located in Stranraer and installed at the optimum angle. For comparison, such a panel installed in Lerwick would theoretically provide between 3.10 kWh and 1.74 kWh of energy per day per square metre of panel.

8.15   In practice it is difficult to state an efficiency figure for these collectors as it is dependent on the difference between the ambient temperature and the temperature inside the collector.

System Savings and Costs

8.16   System costs will vary by manufacturer and installer, and are rarely quoted without a site survey. Most companies will offer a survey and provide a free quotation. CIBSE (2009) states that for typically domestic properties, the useful energy supplied per year by a 3-4m^2 panel is between 1,000 and 1,500 kWh, and installations costs of between £3,000 and £5,000. CIBSE state that for non-domestic systems, costs will be similar, although savings will be made through economies of scale, and reduced heat losses from storing heat in larger units.

> **Note**: The CIBSE Guide suggests that economic payback times for these systems will be long, and in some cases longer than the lifetime of the system.

8.17   The only example of a solar water heating system installed at an NHS property is at the Princess Alexandra Hospital in Harlow referred to previously. This system cost £142,000 for 38 panels with 3.8m^2 absorber areas, which equates to approximately £3,750 per panel.

Case Study – Princess Alexandra Hospital, Harlow

8.18   The Princess Alexandra Hospital (PAH) received a grant of £400,000 from the Department of Health's Energy Fund in 2007 to fund a number of projects aimed at improving energy efficiency. £142,000 of this money was spent on replacing the existing gas-powered hot water system and installing an evacuated tube solar thermal domestic hot water system. To ensure that required temperatures can always be met, the solar thermal heating is backed up by traditional gas system. Two solar thermal arrays are located on two different buildings; the main hospital building and the Jenny Ackroyd Centre. These buildings have arrays with 20 and 18 solar collector panels respectively. Each panel has 30 tubes 1.8m in length. Generally 30 tube panels have a collector surface of 3.8m^2, and a physical size of 5.8m^2. Therefore the total physical area required is approximately 220m^2 and the effective panel area is 144m^2.

8.19   The installation company quotes a figure of 2,000 kWh of useful energy being generated per year, per panel. Thus equates to total of 76MWh per annum for 38 panels. At a £142,000 installation cost, this works out as approximately £1,870 per MWh. A simple annual cost saving on natural gas can be calculated by multiplying the unit cost of natural gas by the annual energy saving figure attributable to the solar collectors. Assuming a gas price of £0.03/kWh, the savings can be estimated as;

£2,280 per annum

8.20   This results in an approximate payback period of *72 years*. However, if this system qualifies for the Governments Renewable Heat Incentive (RHI), it may also be possible to claim £0.085/kWh. This equates to further savings of;

£6,460 per annum

8.21   Assuming these prices, and that the RHI is available, the total saving achieved for the PAH hospital is £7,560 per annum. This equates to a payback period of just under19 years.

8.22   Using the solar irradiation data given by the EU JRC web tool, it is possible to estimate the annual efficiency of this system. The data gives a total daily solar irradiation value of 5.080kWh/m^2 for Harlow. This equates to a resource of 1.85 MWh/m^2 per annum, or 268 MWh per annum of useable energy impinging on the 38 collectors. This gives an approximate efficiency of 30% throughout the year.

Stranraer estimated solar resource

8.23   Using the data provided by the EU Joint Research Council Photovoltaic tool, energy cost savings per m^2 can also be estimated for the Stranraer example given above. A figure for average panel efficiency throughout the year will be required. For a best case scenario, 80% can be used, but recognition should be given the estimated 30% efficiency of the solar collector used at the PAH in Harlow. For Stranraer, the cost savings for 80% and 30% efficiency would work out as follows;

80 % efficiency

For a standard 30 tube panel with a collector area of 3.2m^2 working at 80% efficiency, the useful solar energy can be calculated as;

Useful solar energy   = 0.8 x 4.348kW/m^2/day x 3.8m^2

= 13.218 kWh per panel per day

= 4,824.54 kWh per panel per year

Primary fuel cost saving per annum per m^2 is then calculated by multiplying the unit energy price by the annual available energy. Assuming £0.03 per unit for gas;

(£0.03 x 4,824.54 kWh) / 3.8m^2 = £38.09 per m^2

Additional savings through the Renewable Heat Incentive (if applicable) can be calculated by multiplying the RHI unit energy payment by the annual available energy. Assuming £0.085 per kWh;

(£0.085 x 4,824.54 kWh) / 3.8m^2 = £128.15 per m^2

Therefore, as a best case scenario, the savings resulting from an evacuated glass tube collector system, installed at the optimum angle in Stranraer, can be estimated at £166.24 per m^2.

If a system of similar size and cost as the PAH case study were to be installed in Stranraer, the annual saving would be £24,005.06. The payback period would be 5.9 years (assuming the system qualifies for the Renewable Heat Incentive payment).

30% efficiency

For a standard 30 tube panel with a collector area of 3.2m^2 working at 30% efficiency, the useful solar energy can be calculated as;

Useful solar energy = 0.3 x 4.348kW/m^2/day x 3.8m^2

= 4.957 kWh per panel per day

= 1,809.20 kWh per panel per year

Primary fuel cost saving per annum per m^2 is then calculated by multiplying the unit energy price by the annual available energy. Assuming £0.03 per unit for gas;

(£0.03 x 1,809.20 kWh) / 3.8m^2 = £14.28 per m^2

Additional savings through the Renewable Heat Incentive (if applicable) can be calculated by multiplying the RHI unit energy payment by the annual available energy. Assuming £0.085 per kWh;

(£0.085 x 1,809.20 kWh) / 3.8m^2 = £40.47 per m^2

Therefore, as a more realistic scenario, the savings resulting from an evacuated glass tube collector system, installed at the optimum angle in Stranraer, can be estimated at £54.75 per m^2.

If a system of similar size and cost as the PAH case study were to be installed in Stranraer, the annual saving would be £7,905.90. The payback period would be 18 years (assuming the system qualifies for the Renewable Heat Incentive payment).

Panel efficiency

8.24   Panel efficiencies can be calculated for individual panels if required. Calculations are given in Appendix 1 which can be used along with manufacturer's data to determine; the power absorbed into a collector, the power loss from a collector, and the useful power supplied by a collector. It is difficult to predict how a panel will perform in practice, as the power loss increases as the temperature difference inside and outside of the collector increases. Theoretically, if the temperature differential can be maintained, efficiency can be calculated. However, practically the actual collector efficiency

Health Facilities Scotland

SHTM 04-02: Part A Solar domestic hot water heating

NHS
National
Services
Scotland

will not be known until it is functioning, and will vary with the prevailing weather conditions.

9. Conclusion and recommendations

9.1   Solar energy has the potential to be cost efficient and help towards reducing a country's carbon footprint as has been demonstrated in Mediterranean countries such as Greece and Cyprus where such systems are used extensively.

9.2   The SHTM has established that the primary benefit of using solar power systems in the UK is to reduce its carbon footprint in an attempt to help combat climate change. However, in a healthcare setting, strict guidelines are in place to prevent contamination of domestic water systems, especially where immunocompromised patients may come into contact with this contaminated water. Since a SDHW system has the potential for cultivating an environment that could promote *Legionella* growth, a system would have to be designed to ensure sufficient dwell time in a high temperature store to ensure the destruction of *Legionella* bacterium.

9.3   The Health and Safety Executive (ACOP L8) suggests that a hot water tank should be heated to at least 60ºC for one hour each day. One design that minimizes the risk of *Legionella* is the closed looped system with an immersed or external heat exchanger to extract the heat from the solar panel.

9.4   This SHTM has highlighted other design considerations which must also be considered in the UK climate. **Any solar energy system employed should incorporate the following:**

- a pumped system containing antifreeze to prevent freezing of the pipes in the closed circuit;

- a draining system could also be included for this purpose, draining the fluid in the collector when solar irradiance is too low to provide heat;

- controls must also be included in a system's design;

- the fluid from the SDHW system must only pass to the heat store or through the exchangers if it is adding heat, otherwise this could be detrimental to its efficiency and reduce the temperature of the water.

9.5   **Once design parameters have been established, modelling would have to be undertaken prior to any solar energy system installation to ascertain the heat load and the pay back period of the system.** Initial estimates using the European Commission Joint Research Committee Photovoltaic estimation tool suggest that annual savings would be in the region of £54.75 per m^2 of collector area in the south of Scotland (assuming an average annual efficiency of 30% and that the system qualifies for the RHI payment of £0.085 per kWh).

> **Note:** At current energy prices, and dependent on the installation costs, this is likely to mean a substantial payback period.

Appendix 1

Solar collector efficiency calculation

The power absorbed into the collector (Qp) is given by:

$$Qp = GA(tc + ap)$$

Qp = absorbed power (W)

G = total irradiance (W/m^2)

A = area of solar collector (m^2)

tc = transmission factor of cover (0 for evacuated tube)

ap = absorptance factor of collector plate

The power loss from the collector (QL) is given by:

$$QL = UA(Tc - Ta)$$

QL = power loss from collector (W)

U = collector U value (W/m^{2}K)

A = area of solar collector (m^2)

Tc = temperature of collector plate (K)

TA = ambient air temperature (K)

Useful power supplied by collector (W)

$$Qs = GA(tc + ap) - UA(Tc - TA)$$

(http://www.esru.strath.ac.uk/EandE/Web_sites/01-02/RE_info/active_solar.htm)

Appendix 2

Case Studies

Case Study – Evacuated Solar Tube Collector

Organisation – Public Sector

Location – West Central Scotland

Size of system – 3 panels with a total area of 9.9m^2

Total installation cost - £11,500

Estimated annual energy used* - 1,423** kWh

Estimated annual gas cost savings - £41.54

Estimated annual RHI payment - £120.96

Total annual financial benefit – £162.50

Estimated payback period – 70.8 years

*System has only been in place since August 2010, so May, June and July 2011 energy use has been assumed as being equal to August, September, October 2010 use.

** These figures are for energy used from the SDHW system, not energy generated. The building has a low hot water demand, and may not always use the total energy available from the panel.

Case Study – Solar PV Installation

Organisation – Public Sector

Location – West Central Scotland

Size of System – Two 48 kWp arrays, active area 698m^2

Total installation cost - £485,645 (£125,135 cover by a grant)

Recorded average annual yield – 64,600kWh

Estimated annual electricity cost saving* - £5,168

Estimated annual ROC** payment - £2,907

Total annual financial benefit - £8,075

Estimated payback period for total installation cost – 60.4 years

* Assuming an electricity cost of 8p per kWh

** This system is covered by the Renewable Obligation Certificate (ROC) which pays 4.5p per kWh. As has been seen the Feed-in Tariff offered for solar PV systems has been subject to fluctuation making it difficult to calculate payback periods with any degree of certainty.   Although this will reduce, it is unlikely to be less than the anticipated life-span of the installation.

Health Facilities Scotland

SHTM 04-02: Part A Solar domestic hot water heating

NHS
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