SOLAR WATER HEATING SYSTEMS STUDY

RELIABILITY, QUANTITATIVE SURVEY AND LIFE CYCLE COST METHOD

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Summary

This report tries to give an overview with the solar water heating status today. Chapters 1 is an overview of the systems used today, some new development systems and benefits of solar water heaters. Chapter 2 is concentrated with the type of solar collector's currently used, analysis of the material of frat plate collectors which at the moment they are extensively used around U.K. There is also a description of materials for heat management and storage as well as antifreeze solutions. Chapter 3 is referred to current market development in Europe and some countries around the world. Special attention is given in the market of U.K. Chapter 4 discusses the reliability and quantitative survey carried out compared data from U.K and Greek responders. Chapter 6 describes the procedure followed for the Life Cycle Costing, considering three major solar water heating systems. Finally Chapter 6 analyses the results and proposes some solutions for better market development.

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Objectives

Residential hot water use represents a large proportion of residential energy use. The residential energy use accounts for approximately one third of the total energy use. Utilities can use end-use pricing to target solar domestic hot water heating. This offers many benefits in terms of increased market share and reduced demand at the generation level in an increasingly competitive environment. The main objectives of this thesis are:

- To give a brief overview of the most commonly used SWH systems
- To investigate the current market development
- To carry out a reliability survey for problems identification
- Investigate what people believe about Solar water heating technology
- Life Cycle Cost analysis of the 3 most common systems currently used in U.K in order to compare with gas and electricity water heaters and investigate cost and economic benefits for a 30 year period.

Introduction

A great deal of research has been carried out on solar energy alternatives to heating by conventional means. The conclusion of a great part of this research is that solar energy is a viable, clean and sustainable source. Yet nearly 20 years after the energy scare of the early 1970s, solar energy's market share remains disappointing. In order to propose solutions that will increase the acceptance of solar energy technology, it is first necessary to understand the reason for the poor market penetration.

Primary between the obstacles that they noted are: lack of knowledge about solar, concerns about system reliability, concerns about the effect of weather on performance, concerns about dealer credibility and competence, high system cost and redundancy with other heating options. Essentially it seems that a customer would be more willing to consider solar if it were less expensive and there were someone to whom they could turn for maintenance issues and to be assured that the system was operating properly.

One proposed solution to both of these problems is to encourage the involvement of electric utilities. If a utility were to buy a large quantity of solar systems and rent them to homeowners there would be a number of benefits to all involved. The utility could buy systems at a volume discount rate, recuperating their cost through a leasing program. Furthermore, there are business tax incentives for solar options that are available to corporations, such as utilities, but are unavailable to individual consumers. The other benefit to the utility is that of avoided generation cost.

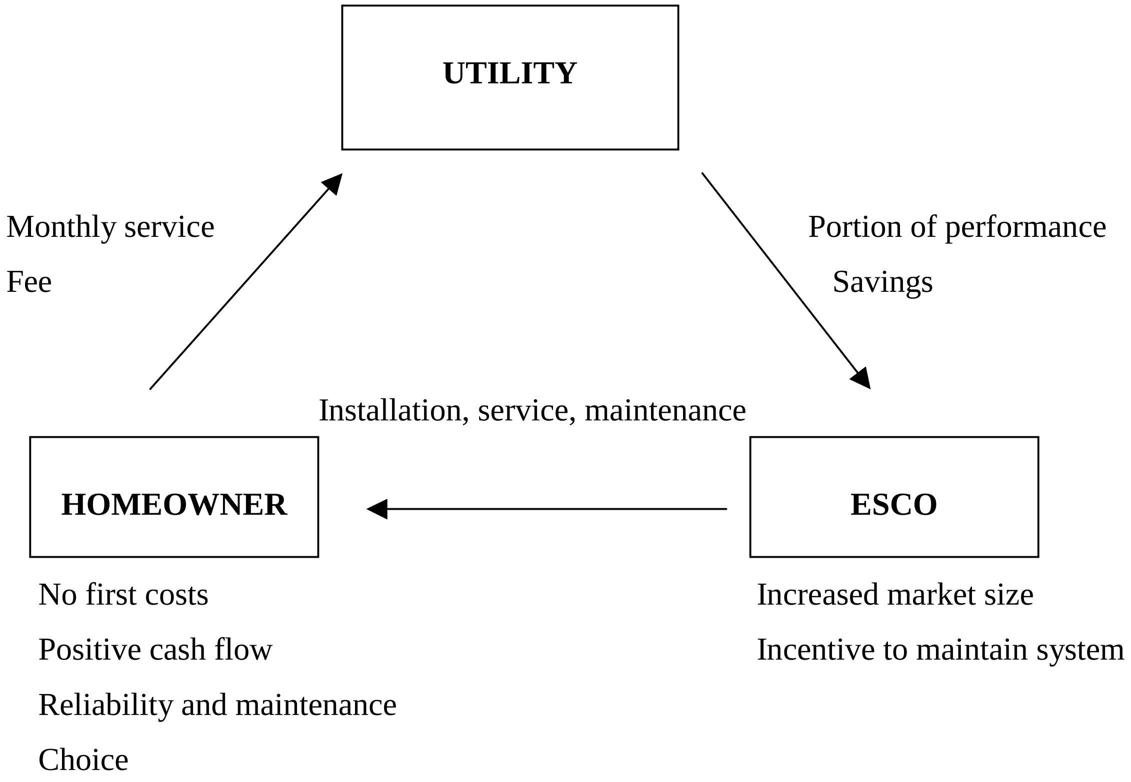
Most utilities are summer peaking meaning that the highest demand occurs during the summer when a large number of air conditioners are in operation. Because this is a problem for almost all utilities, simple rerouting of power from one utility district to another is not a sufficient solution. Many utilities maintain extra generating capacity year round so that they can meet their summertime load, a costly undertaking. If however, a large number of houses in the utility's service area heat water without creating an increased load on the utility, the utility's extra generating capacity could be reduced at great economic and environmental benefit. The benefit to the customer is that solar energy collection becomes much less expensive and that the utility would be in charge of maintenance. Furthermore, the customer would pay a fixed monthly lease on the collector, and would be charged a reduced electricity rate, hopefully decreasing the overall bill.

There are a number of barriers that have prevented the widespread acceptance of solar water heaters by both utilities and homeowners in the past. These have included high capital costs, a reputation for poor system reliability, an inadequate system infrastructure and limited public knowledge of the gains and benefits of current technology. With deregulation and new competition, utilities are seeking innovative new products and services that will add value and produce customer reliability. Utilities can experience demand reduction from solar water heating systems during peak times, typically morning and evenings when hot water draws tend to be the greatest.

The energy reduction eliminates the need for larger power plant generating capacities and pollution from power plants is reduced as loads decrease. Many electricity-providing utilities are losing customers who are switching to cheaper gas; solar hot water heating may provide a means of retaining customers. Many utilities are now employing Energy Service Companies (ESCOs). The concept presents the possibility of converting solar water heating from a subsidized Demand Side management program to a profitable business.

The ESCO is typically responsible for the installation, service and maintenance of the solar hot water system. In return for contributing to an increased market size, the ESCO receives a portion of performance savings from the utility. The Utility on the other hand receives a monthly service fee from the homeowner in return for the services the ESCO provides. The homeowner experiences no first costs and is assured reliability and maintenance of the system. The ESCO concept is demonstrated below. This end-use pricing, which involves the sale of solar heated water itself, rather than the sale or lease of equipment that makes it, is believed to increase market penetration. The increased demand will have a positive effect on the economics of solar water heating.

Considering all the above mentioned this report tries to give an overview with the solar water heating status today. Chapters 1 is an overview of the systems used today, some new development systems and benefits of solar water heaters. Chapter 2 is concentrated with the type of solar collector’s currently used, analysis of the material of frat plate collectors which at the moment they are extensively used around U.K. There is also a description of materials for heat management and storage as well as antifreeze solutions. Chapter 3 is referred to current market development in Europe and some countries around the world. Special attention is given in the market of U.K. Chapter 4 discusses the reliability and quantitative survey carried out compared data from U.K and Greek responders. Chapter 6 describes the procedure followed for the Life Cycle Costing, considering three major solar water heating systems. Finally Chapter 6 analyses the results and proposes some solutions for better market development.



CHAPTER 1: SOLAR WATER HEATERS BASICS

1.1 Introduction

This chapter provides basic information on the components and types of solar water heaters currently available around the world. Solar water heaters most of the time are called "domestic hot water systems". These systems use the sun to heat either water or a heat transfer fluid, such as water-glycol antifreeze mixture in collectors generally mounted on the roof. The heated water is then stored in a tank similar to a convectional gas or electric water tank. Some systems use an electric pump to circulate the fluid through the collectors [1,2].

Some water heaters can operate in any climates. Performance varies depending on how much energy is available and how cold the water is coming into the system. Aspreviously mentioned, this chapter provides basic information about the systems currently available. There is a description about the new developed systems of solar water heaters and their advantages and it concludes with the benefits of the solar water heaters.

1.2 Types of solar water heaters

1.2.1 Direct systems (open loop)

In direct systems the heat from the sun is transferred directly to the water in the collector. There is no anti-freeze solution used in this type of system. These systems, also known as "open loop" systems, are the most common systems in use in tropical and sub-tropical climates where temperatures do not often go below 0°C [3,8,9]. The basic components of an open loop system are listed below:

- Direct storage tank
- Circulating pump
- Differential control unit
- Temperature sensor
- Isolation valve
- Drain valve

A typical open loop system is shown in figure 1.1. A solar collector, typically mounted on the roof of the structure where the water is to be used, heats the water. The hot water is stored in a storage tank. The storage tank is typically installed in the basement, garage and is well insulated [3,10].

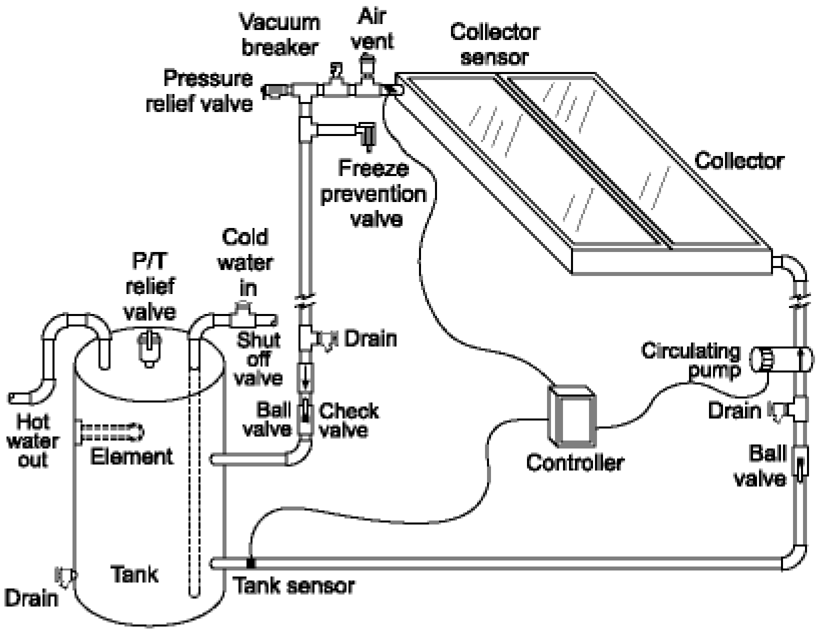


Figure 1.1: Open loop system (source: Florida Solar Energy Centre)

Sensors are used to monitor the temperatures of the water in the system. A differential control unit attached to the sensors is used to control a circulating pump. If the temperature at the collector is 5-7°C greater than the temperature at the bottom of the storage tank the water in the system is circulated. When the differential of the water temperature is 5°C the pump is turned off. In this way the water in the system is always being heated when the sun is shining. When required, a thermally operated valve, installed at the collector, is used to circulate the warm water into the collector as temperatures approach freezing. Closing the isolation valves and opening the drain valves instead of using a thermally operated valve can manually drain the system [3,11,12].

1.2.1.1 Photovoltaic operated systems

This type of solar water heaters is not much different to the ones discussed above. The main difference comes from the fact that the energy to power the pump is provided by a photovoltaic (PV) panel. The PV panel converts the sunlight into electricity, which then drives the pump. In this way water flows through the collector when the sun is shining [3,9].

The pump and the PV panel have to be suitable matched in order to ensure optimum performance of the system. The pump starts when there is sufficient solar radiation available to heat the solar collector. That system like the previous one, incorporates a thermally operated valve to provide freeze protection. Timers also used in order to control solar system operation. Most of them have a battery back up in case of power failure. The timers operate during the day when solar radiation is available to heat water. In order to avoid loss of energy from the tank during cloudy days, the collector lines are connected to the bottom of the storage tank with a special valve [3].

1.2.2 Indirect systems (closed loop)

Indirect systems are designed for use in climates where freezing weather can occur more frequently. These systems, also known as closed loop systems, are the most commonly used in cold climates where temperatures often go below 0°C. A solar collector, filled with an anti-freeze solution, is used to collect the thermal energy in sunlight. Typically a propylene glycol or ethylene glycol and water mixture is used [1]. A typical closed loop system is shown in figure 1.2. The basic components of a drain back system are listed below:

- Heat exchanger
- Circulating pump
- Differential control unit
- Temperature sensor
- Gate valve
- Drain valve
- Indirect storage tank

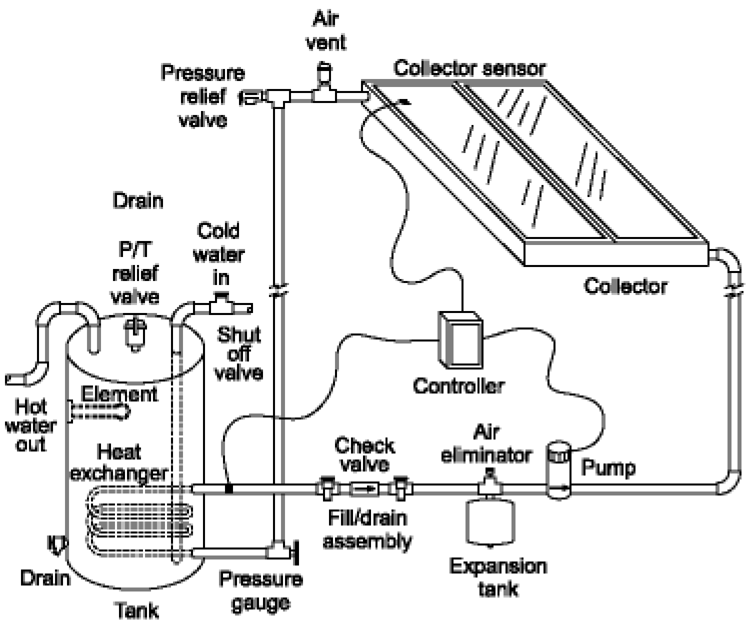


Figure 1.2: Closed loop system (source: Florida Solar Energy Centre)

A pump circulates the solution through the collector and into a storage tank where a heat exchanger is fitted. The heat exchanger transfers the heat into the water stored in the tank. The tank is designed to transfer the heat into the coldest water in the tank. The heat exchanger is a coil of tubing that wraps around inside the perimeter of the storage tank. The storage tank is typically installed in the basement, garage or utility room and is well insulated [1,12].

Sensors are used to monitor the temperatures of the anti-freeze solution in the system. A differential control unit attached to the sensors determines when the circulating pump should be activated. If the temperature at the collector is about 5-7°C greater than the temperature at the bottom of the storage tank, the solution in the system is circulated in the closed loop. When the differential of the water temperature is 15°C, the pump is turned off. Indirect systems are closed loop systems. There is no contact between the anti-freeze solution and the potable water in the system [3].

1.2.2.1 Drainback systems

Drain back systems are indirect closed loop systems. There is no contact between the heat transfer liquid and the potable water in the system. Drain back systems are used in cold climates to reliably ensure that the collectors and the piping never freeze. This protection is achieved when the system is operated in drain mode. In drain mode all of the liquid in the system's collectors and piping is drained back into an insulated reservoir tank when the system is not producing heat. An indicator on the reservoir tank shows when the collector is completely drained. Each time the pump shuts off the solution in the collector is drained into the reservoir tank [1,3]. A typical closed loop system is shown in figure 1.3. The basic components of a drain back system are listed below:

- Indirect storage tank
- Reservoir tank
- Circulating pump
- Differential control unit
- Temperature sensor
- Gate valve
- Drain valve

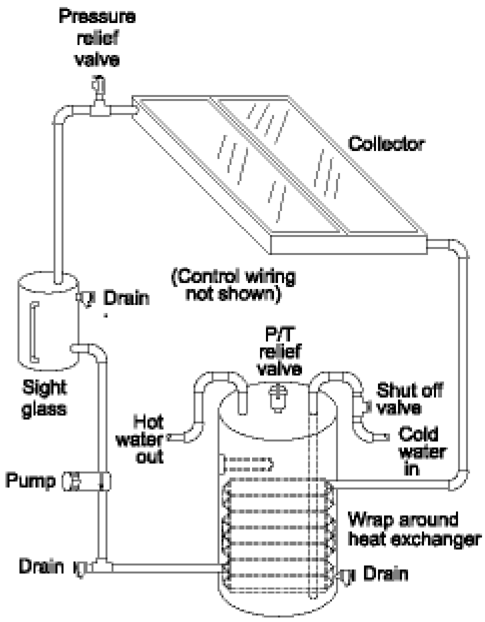
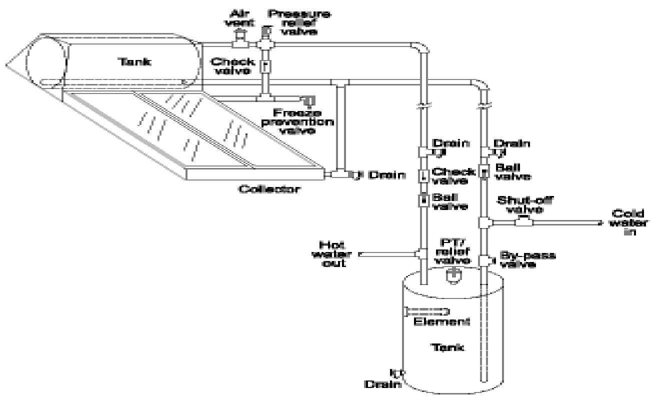


Figure 1.3: Drainback system (source: Florida Solar Energy Centre)

Drain back systems work like indirect systems. A solar collector, filled with distilled water or an anti-freeze solution, is used to collect the thermal energy. Typically distilled water or a propylene glycol and water mixture is used. A pump circulates the solution, through the collector and into a storage tank where a heat exchanger is fitted. The heat exchanger transfers the heat into the water stored in the tank. The tank is designed to transfer the heat into the coldest water in the tank. The heat exchanger is a coil of tubing that wraps around inside the perimeter of the storage tank. In this systems sensors are also used to monitor the temperature [1,12].

1.2.3 Thermosiphon systems

The use of thermosiphon systems is accepted world wide due to their simple and reliable characteristics [3]. A typical closed loop system is shown in figure 1.4. The basic components of a drain back system are listed below:



- Solar collectors
- Direct storage tank
- Isolation valve
- Drain valve
- Thermally operated valve

Figure 1.4: Thermosiphon system (source: Florida Solar Energy Centre)

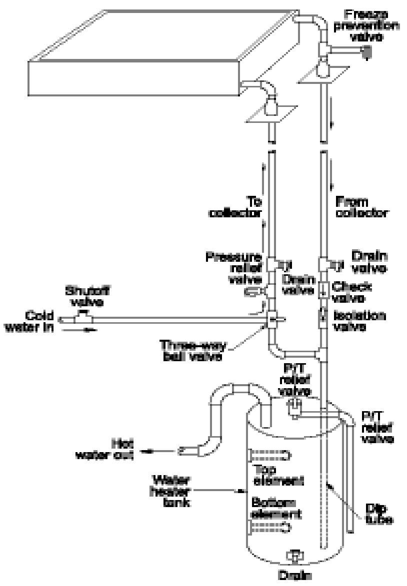
The collector absorbs the sun's energy and the water inside the collector flow-tubes is heated. As it heats, the water expands and becomes lighter than the cold water in the solar storage tank mounted above the collector. Gravity then pulls heavier, cold water down from the tank and into the collector inlet. The cold water pushes the heated water through the collector outlet and into the top of the tank, thus heating the water in the tank [3,16].

A thermosiphon system requires neither pump nor controller. Cold water flows directly to the tank on the roof. Solar heated water flows from the rooftop tank to the auxiliary tank installed at ground level.

This system features a thermally operated valve that protects the collector from freezing. It also includes isolation valves, which allow the solar system to be manually drained in case of freezing conditions, or to be bypassed completely [16].

1.2.4 Integral collectors storage systems (Batch heaters)

In the integral collector storage solar system, the hot water storage system is the collector. Cold water flows progressively through the collector where it is heated by the sun. Hot water is drawn from the top, which is the hottest, and replacement water flows into the bottom. This system is simple because pumps and controllers are not required. On demand, cold water from the house flows into the collector and hot water from the collector flows to a standard hot water auxiliary tank within the house [3,15].



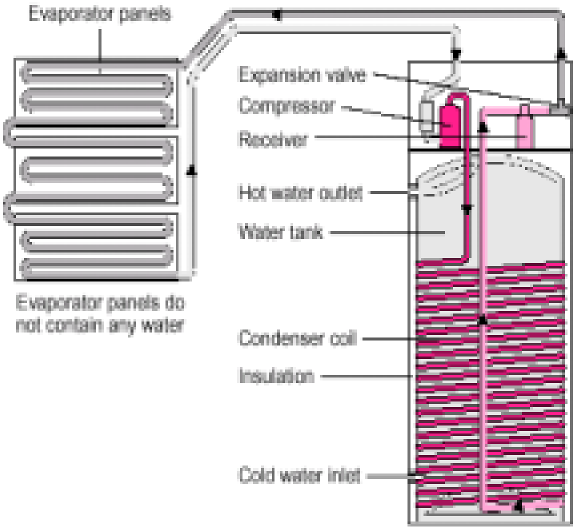
This system is simple because pumps and controllers are not required. On demand, cold water from the house flows into the collector and hot water from the collector flows to a standard hot water auxiliary tank within the house. A flush-type freeze protection valve is installed in the top plumbing near the collector. As temperatures near freezing, this valve opens to allow relatively warm water to flow through the collector to prevent freezing [1,14].

Figure 1.5: Integral collector storage system (source: Florida Solar Energy Centre)

1.3 New development systems

1.3.1 Solar boosting panel

An Australian team has introduced this new concept of solar water heating. It is called "solar boosting panel" and can achieve an energy reduction of up to 75%, compared to convectional solar water heating systems. The solar hot water system combines a heat pump with an evaporator (panels) exposed to atmosphere. The system uses a refrigeration circuit, drawing heat from one space and discharching to another. An analytical diagram of the system is presented in figure 1.6 below.



The major components of the solar boosted heat pump are:

- Two heat exchangers
- A compressor.

The solar evaporator panels absorb sun's energy and use it to vaporise the refrigerant (usually R-22). This vapour is then compressed raising its pressure and temperature [4].

Figure 1.6: Components of the solar boosted heat pump system (source: Australian National Team)

The high temperature vapour is passed to tubing, around the outside of the water storage tank (condenser). The refrigerant vapour condenses to liquid form giving off latent heat to the stored water. Then the condensed refrigerant liquid returns to the evaporator panels through an expansion device, becomes vaporised and the cycle is repeated. The main disadvantages of such systems are the cost compared to common solar water heaters and the possibility of the refrigerant to contaminate the water supply [4,5].

1.3.2 Low flow systems

During the last years pumped solar water heating systems use the low flow principle, introduced by many manufacturers around the world. These systems basically use solar tanks with high thermal stratification. The flow rates are also low between the ranges of 0.15-0.25 l/min per m^2 collector area. Such low flow rates always have been used in thermosiphon systems [6,7].

The low flow improves the system performance/cost ratio. First of all, using the low flow principle increases the thermal performance of the system. The thermal increase is influenced by the system design and by solar fraction of the system. The thermal design of the system increases with increasing thermal stratification in the solar tank. Low flow rates offer cost advantages. The smaller the flow rate, the less expensive is the system and the use of electricity. Investigations have shown that the solar collectors designed for low flow conditions can benefit from large material reduction making the total manufacturing cost less [7].

According to tests at Technical University of Denmark [6], the thermal performance of the system can be increased by improving the design of the system and that the solar tank is the most important component for the better thermal performance of the system. Investigations have also shown that the common solar collector systems in Denmark perform worse compared to laboratory tested ones. And the major reason is the solar tank [6].

1.4 Benefits of solar water heaters

It is a fact that most of the houses build today choose electric water heaters. The main reason is because they are easy to install and inexpensive. However, research has shown that in an average household with electric water heater spends about 25% of its home energy costs on heating water. According to the Florida Solar Energy Centre [3], it was found that U.S.A homes using solar water heaters can save as much as 50-85% annually on the utility bills over the cost of an electric water heater. Depending of the fuel sources the solar water heater can be more economically over the lifetime of the system than heating water with electricity, fuel oil, propane or natural gas [15,16].

Solar water heaters do not pollute because they avoid carbon dioxide, nitrogen oxides, sulphur dioxide and the other air pollution and wastes. When a solar water heater replaces an electric water heater, the electricity displaced over 20 years represents more than 50 tons of avoided carbon dioxide emissions [16].

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CHAPTER 2: COLLECTORS, MATERIALS & FREEZE PROTECTION

2.1 Introduction

Solar collectors are the heart of most solar systems. The main task of the collector is to absorb the energy of the sun and to convert it to heat energy. Solar collectors can be divided into two main categories:

a) Liquid collectors: these types of solar collectors are mainly used for water heating in houses and swimming pools. The most common liquid used is water or antifreeze solutions in cold climates. Antifreeze solutions are discussed in more detail in section 3.5 of this chapter.
b) Air collectors: They are basically used for indoor spaces and to regenerate drying material in a drying cooling system. In this chapter there is a brief description of air collectors for reference purposes [1,8].

The most common types of solar collectors are the flat plate, evacuated tube and concentrating collectors. This chapter deals with the different types of collectors in extensive format. It also provides analytical information about solar collector covers, insulation, gaskets and sealants. Finally, and most importantly it deals with antifreeze solutions.

2.2 Types of solar collectors

2.2.1 Flat plate collectors

Flat plate collectors (figure 2.1.) are the most common collectors for water heating (liquid type) and for space heating installations (air type). In simple words a flat plate collector is an insulated metal box with either glass or plastic cover, which is called “glazing”. The dark colour plate is called the “absorber plate” because it absorbs the sun radiation. The glazing can be “transparent” or “translucent” [8].

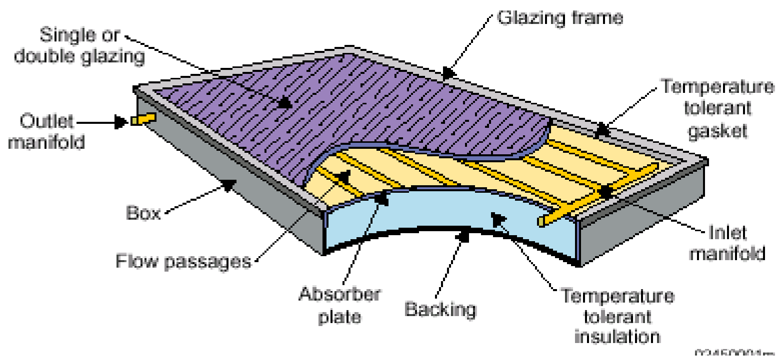

Figure 2.1: Flat plate solar collector (source: U.S.A Department of Energy)

Translucent (transmitting light only), low iron glass is a common glazing material for flat plate collectors because low iron glass transmits a high percentage of the available solar energy. The glazing allows the light to strike the absorber plate and reduces the escaped amount of heat. Usually the sides and the bottom of the plate are insulated to minimise the heat losses. The absorber plate is usually black. The reason is that dark colours absorb a higher percentage of sunlight than light colours [2,8,10].

It is very easy to explain how the flat plate collector works. The sunlight passes through the glazing and strikes the absorber plate. The absorber plate then starts to heat up concentrating solar radiation into heat energy. The heat then is transferred to the air or liquid passing through the flow tubes. Flat plate collectors are divided into two categories, a) liquid collectors and b) air collectors [11]. Both of them can be either glazed or unglazed. Detailed analysis of materials is presented in part 2

2.2.1.1 Liquid collectors

In a liquid collector solar energy heats the liquid as it flows through the tubes. The flow tubes are attached to absorber plate so the heat absorbed by the plate is transferred to the liquid. There are two types of liquid collectors

a) The “Z” array (figure 2.2) where the flow tubes are placed in parallel.
b) The “U” array (figure 2.3)

The most common is the “Z” array. However, the “U” array has an extra advantage. First of all it eliminates the possibility of leaks and ensures uniform flow. The disadvantage is that the system cannot be drained completely in order to avoid freezing [8,11,12].

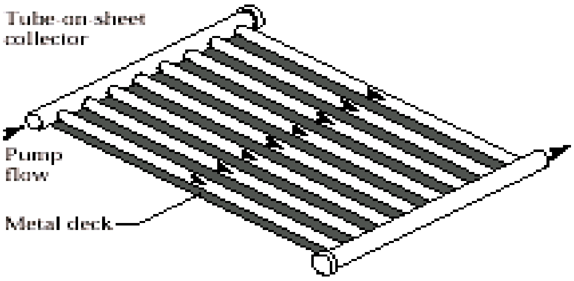

Figure 2.2: "Z" array liquid collector

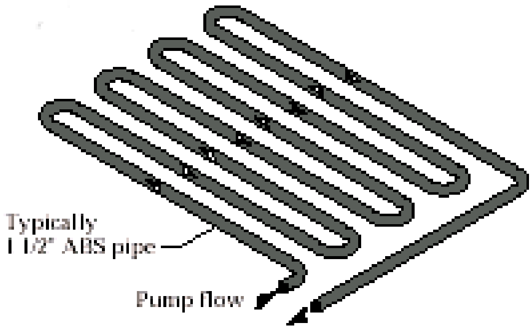

Figure 2.3: "U" array liquid collector

(source: U.S.A Department of Energy)

2.2.1.2 Air collectors

Air flat plate collectors (figure 2.4) are used mostly for space heating. The absorber plate can be metal sheet or non-metallic materials. The air flows past the absorber plate placed by natural convection or forced by a fan. A disadvantage of air collectors compared to liquid is that less heat is transferred between the air and the absorber plate [1,2].

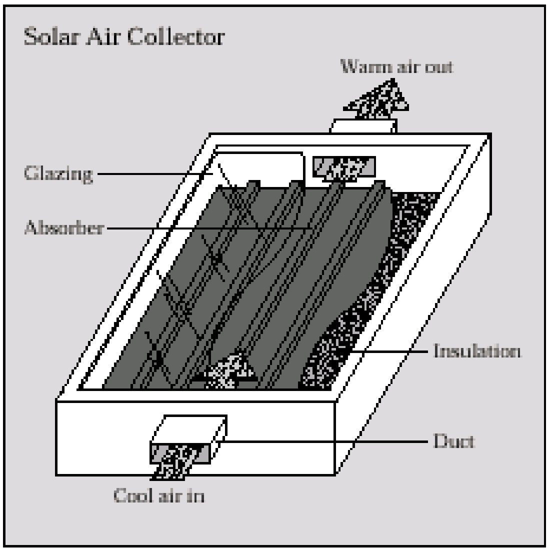

Figure 2.4: Solar air collector

(source: U.S.A Department of Energy)

In some air collectors, fins on the absorbers are used to heat transfer. The disadvantage of this configuration comes from the fact that it increases the power needed for circulating fans and thus increases the systems operating cost.

The advantage of air system is they eliminate the problems associated with liquid collectors (e.g. freezing). Leaks can cause less troubles compared to liquid systems. They also use less expensive materials such as plastic [2,8].

2.2.2 Evacuated tube collectors

Evacuated tube collectors are mostly used to heat water in residential applications that require higher temperatures. Sunlight enters through the outer glass tube and strikes the absorber tube(s) and changes to heat. The heat is transferred to the liquid flowing through the absorber tube. The collector consists of rows of parallel transparent glass (figure 3.5). Each tube contains an absorber tube with selective coating. In such type of solar collectors, tubes can be either added or removed [10].

The tubes are designed in such a way that air is evacuated from the space between the two tubes forming a vacuum. Conductive and convective heat losses are eliminated because there is no air to conduct heat nor to circulate and cause convective losses.

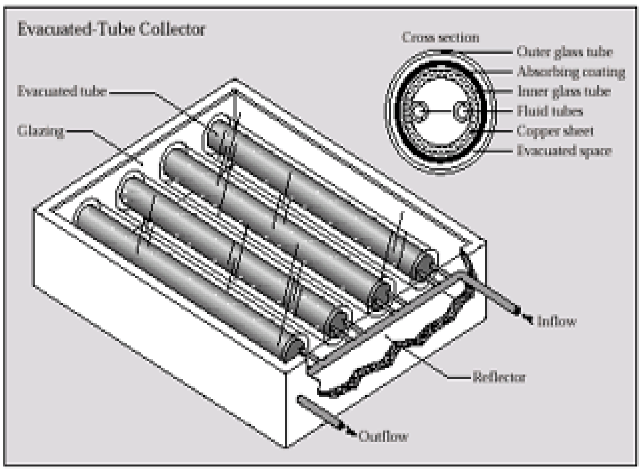

Figure 2.5: Evacuated tube collector (source: U.S.A Department of Energy)

Evacuated tube collectors are available in a number of designs. Some of them use a third glass tube inside the absorber tube or other configurations of heat transfer fins and fluid tubes. For additional sunlight it is possible to place reflectors behind the evacuated tubes. This makes the collector more efficient, offering the advantage of performing better in both diffuse and beam radiation, making the collectors useful in cold climate areas. Another positive fact is due to its shape. The circular shape absorbs the sunlight perpendicularly for most of the day. However the disadvantage of such collectors is that are more expensive compared to flat plate [8,10].

2.2.3 Concentrating collectors

Concentrating collectors use mirror surfaces to collect sunlight on an absorber called receiver. They can achieve high temperatures but like evacuated tube collectors, this happens when direct sunlight is available. The sun's energy is collected over a large area onto a smaller absorber area to achieve high temperatures. Concentrating collectors can be designed in two methods. In one, which is the most advantageous, the sun's energy is concentrated along a thin line called the "focal line" (figure 2.6). The second method is to concentrate the sun's energy onto a "focal point" [8,3].

As it was mentioned, the first method offers the advantage of the receiver to be located at the focal point or along the focal line. In this case a heat transferred fluid flows through the receiver and absorbs heat.

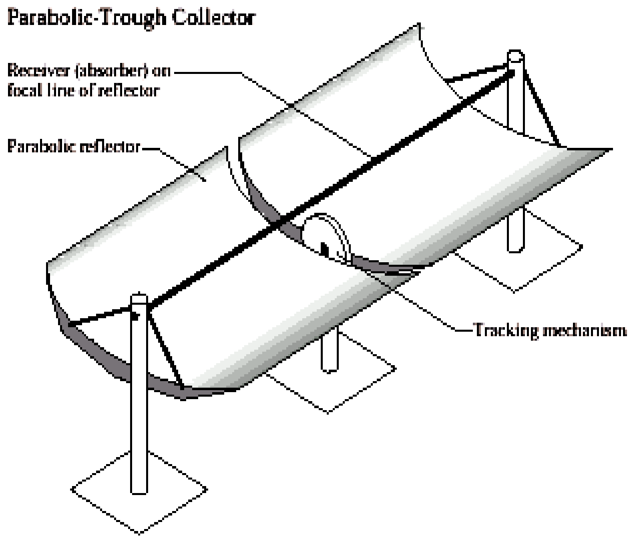

Figure 2.6: Concentrating collector (source: U.S.A Department of Energy)

Concentrating collectors can reach much higher temperatures compared to flat plate collectors. However they can only focus direct solar radiation, which affects the performance of the collectors especially in cloudy days. To improve the performance of the collectors, trucking mechanisms are used to keep them focused on the sun. There are single axis truckers moving from east to west, dual axis moving from north to south. There are also passive trackers using freon on supply the movement [3,4].

Concentrators are mostly used in commercial applications due to high cost and frequent maintenance of tracking mechanisms. For residential applications the most common type is the parabolic through collector (figure above) with simple tracking mechanisms, which are less expensive than dual axis, for either hot water or space heating [5].

2.3 Materials for collector components

The materials selected for one component will affect the possible choices of other components of the system. Therefore, it is important to consider all components whether they play a major role in the system or not. Thus the selection of the optimum materials and manufacturing processes is of vital importance of solar collectors and more specifically solar systems. As the project deals with a flat plate solar collector and as flat plate collectors are most used around U.K., this part gives an analytical overview of the appropriate materials and their specifications

2.3.1 Absorber materials

The absorber is the central component of the solar collector. Metals such as copper, aluminium steel and stainless steel are commonly used for absorber materials. Since these are not strongly absorbing a coating is provided which absorbs the solar radiation. As it was mentioned in section 2.1, this can be produced in a transparent or translucent form.

Heat transfer to the fluid depends on the thermal conductivity of the plate material and on the distance between fluid passageways. Thermal conductivities of absorber materials are given in Table 2a. High thermal conductivities such as copper and aluminium can be economically used in plate and tubes, where heat conduction takes place along the plate. The passageways are most of the time closed spaces with medium conductivity materials, such as steel or stainless steel or copper and aluminium. Novel forming techniques such as superplastic forming and integral rolling are used to provide good mechanical bond between the absorber plate and the passageways.

Material	Thermal Conductivity ($Wm^{-1}K^{-1}$)
Copper	376
Aluminium	205
Mild Steel	50
Stainless Steel	24
Acrylic	0.20
Polyethylene	0.30-0.44

Polypropylene	0.20
PVC (Polyvinyl Formal)	0.16

Table 2a: Thermal conductivities of absorber materials

Certain polymeric materials are resistant to water and other fluids are suitable for use in solar absorbers. Another important material is polypropylene, which can be used as absorbing material [13].

2.3.1.1 Absorber coating

In current solar collector constructions, the absorber is generally made from a material with poor absorbing properties (e.g. copper, aluminium, steel). A coating, which is highly absorbent of solar radiation, is generally applied to the upper surface. Two basic types of coatings are available. These are non-selective and selective coatings. Non-selective coatings have a high absorptance of solar radiation and a high emmitance of thermal radiation, at high operating temperatures. Selective coatings have high absorptance of solar radiation but the emmitance is low [13].

The materials used for non-selective surfaces include matt-black paint based on polyester acrylic and epoxy resins. Common pigments are carbon black iron oxide, amorphous graphite, bone black and asphalt bases. Aluminium black paints can be used in concentrating collectors. For selective surfaces black chrome coatings have been investigated and show that there is a little change in optical properties after long time at high temperatures. Black nickel coatings are less stable and degrade with exposure to temperature and to humidity. Copper cobalt and zinc oxide show significant deterioration with exposure and stain less steel conversion coatings show a little decrease in absorptivity [13].

2.3.2 Glazing

As previously mentioned, the role of glazing in a solar collector is to reduce heat losses. The glazing also protects the absorber from the environment and may reduce radiative heat losses by reflective thermal radiation emitted by the absorber. But the most important property is the higher amount of transmittance of solar radiation. Any loss of transmittance will have direct effect of the collector's efficiency [13,14].

The important properties are transmission of solar radiation (up to 2μm), which must be as high as possible, and transmission of thermal radiation (greater than 2μm), which is more preferably should to be low. Glass, acrylic, polycarbonate and glass-reinforced polyester all have good optical properties. PVF and FEP (Fluorinated Ethylene Propylene) have better transmission of solar radiation but low transmission of thermal radiation. Metal oxide semi-conducting films such as such as tin oxide and indium oxide are applied increasing the reflectance of thermal radiation to 75-80% [14].

Glass is highly resistant to weathering compared to some polymers, which are susceptible to solar radiation. Acrylic has also good resistance to weathering. PVT's are also resistable and are used to protect the less durable glassing. Other polymers such as GRP and polycarbonate are deteriorated by ultra violet radiation but can be stabilised by addition of fillers. The main disadvantage in this case is the high cost of fillers [14].

2.3.3 Casing

The majority of solar collectors in U.K use aluminium as the major casing material. Other materials commonly used are GRP and galvanised mild steel. Occasionally polypropylene, PVC and stainless steel are also used. Many materials with adequate properties are available. The choice of the material for casing is largely one of cost. Of the metallic materials, stainless steel and aluminium have good mechanical and weather properties. Coated mild steel has also good mechanical properties is cheaper but the weathering properties are poor. Mild steel has the advantage of little maintenance of solar collectors for at least 20 years, except in dry environments [13].

Cheaper casings are produced using polymeric materials. GRP is suitable for the outdoor environment although it cost nearly as much as aluminium or stainless steel. Other useful materials are extruded polypropylene or PVC moulded thermoplastics and vacuum formed thermoplastic such as polypropylene or ABS. Filled polypropylene appears to be the lowest cost option. Some potential properties with polymeric casings are UV degradation, high thermal expansion coefficients and fire properties. Wood is also cheaper than plastics, but it is not used so often because it requires maintenance[13].

2.3.4 Seals

Sealing materials are applied to ensure the solar collector is not affected from weather conditions. The most common materials used are EPDM and silicone rubbers. Neoprene and butyl rubbers are sometimes used. The sealing material is applied in solid form. In this case it is known as a seal. Also it can be applied in a butyl form [13]. The important properties of sealing materials are their temperature resistance, mechanical properties and weathering resistance. Some properties of the most appropriate materials are presented in Table 2b below.

Materials	Working temp. range (°C) Min.	Max.	Elongation to failure (%)	Resistance to compression set	Resistance to creep	Resistance to weathering	Resistance to water
Acrylic	-40	130	400	3	2	4	1
Butyl	-50	125	800	2-3	2	4	2-4
Chloroprene (neoprene)	-20	130	600	3-4	2-3	4	3
Chlorosulphonated polyethylene	-40	120	500	1-2	2	4	3-4
EPDM	-40	150	600	3-4	2	4	4
Fluroelastomers	-40	230	300	3-4	3	4	4
Silicone	-60	230	700	2-4	3	4	3-4
Urethanes	-50	100	700	1-4	3	4	1-2

(4=excellent, 3=good, 2=fair, 1=poor) ***Table 2b: Properties of sealing materials***

An important consideration is that sealing materials must withstand low ambient temperatures, which especially in the U.K may be as low as -15°C. Seals must also withstand the high temperatures encountered under stagnation conditions, which can be in excess of 100°C [13,14].

Acrylics, EPDM and have lower maximum service temperatures and fluroelastomers and silicones but their temperature performance is likely to be adequate [13]. All of these materials can withstand sub-zero temperatures. Acrylic rubbers are known to have a poor resistance to water and relative poor creep properties and therefore they are unsuitable. The performance of EPDM, fluroelastomers, neoprene and silicones seem to be quite satisfactory.

2.3.5 Absorber insulation

A layer of insulating material can reduce heat losses from the back of an absorber. Insulation materials are commonly cellular, fibrous or granular [13]. Some properties of insulation materials are presented in Table 2c. The common insulating materials such as glass fibre, mineral fibre, polystyrene foam, polyisocyanurate foam and polyethene foam, all have compatible thermal conductivities.

Materials	Thermal conductivity @ 24°C ($Wm^{-1}K^{-1}$)	Maximum service temperature (°C)
Glass fibre (board)	0.032	343
Mineral fibre	0.036-0.055	649-1037
Calcium silicate	0.055 (@90°C)	649
Perlite	0.048 (@90°C)	816
Foamed glass	0.058	
Polystyrene foam	0.029-0.039	74
Polyurethane foam	0.023	104
Isocyanurate foam	0.025	121
Phenolic foam	0.033	135
Cellular plastic	0.040	100

Table 2c: Properties of insulation materials

The insulation material in a solar collector is generally in contact with the absorber. Therefore, it should be able to withstand the collector stagnation temperatures. Inorganic materials such as glass, fibre, mineral fibre, calcium silicate and perlite can withstand high temperatures.

One of the main problems that occur at high temperatures is the outgassing (i.e. vaporisation of the chemical components of the insulation material) [13]. Polymeric foams may outgas at ambient temperatures as the cell walls break down. Insulation materials are generally high surface area materials and therefore constitute fire hazards. Glass or mineral fibre insulants present no fire hazards compared to other polymeric foams.

2.4 Materials for heat management and storage

The heat management and storage system consists of the pipework, the storage vessel (i.e. as the project deals with hot water system) and the control system. It is necessary that the particular conditions to considered for a solar water heating system. The materials aspects of these components are considered in this.

2.4.1 Pipes and connection.

The pipework in a solar system must be able to withstand circulating fluid at temperatures up to 100°C without corroding. The most commonly material used is copper. Copper has good corrosion resistance. Stainless steel also has also excellent corrosion resistance but it is more expensive than copper. It has several advantages like lower thermal conductivity (leading to lower heat losses) lower thermal expansion coefficient and higher strength to mass ratio allowing the use of thinner sections. Some other metals are cheaper than mild steel and copper but the oxidisation rate is higher [13].

2.4.2 Storage vessels

The primary task of the storage vessels is to contain the hot heat transfer fluid without corroding, and must withstand the pressures involved. Copper is the most commonly used material used for storage vessels because of its high thermal conductivity. The corrosion resistance of the copper is good but its disadvantage lies in its high thermal conductivity leading to heat losses.

Stainless steel and galvanised steel are used as storage vessel materials. Stainless steel has much the better corrosion resistance but is more expensive. The thermal conductivity of steel is lower than copper and therefore less insulation material is required.

Polymerics such as polypropylene and GRP can be used for storage vessels. Corrosion and degradation resistance are adequate and the polymerics have the major advantage of thermal conductivity values reducing the need for insulation. The price for GRP is close to copper [13].

2.4.3 Control system

The control circuit contains several components and depending on the system design it may include a central control unit, temperature and pressure sensors, pumps flow meters.

The temperature and pressure sensors and the wiring in the collector box must be able to withstand the temperatures reached during stagnation conditions. The cable insulation is mostly from a material PTFE (Polytetrafluoroethylene), which have good high temperature properties compared to the commonly used PVC.

Pump components, valves are generally made from cast iron, brass, bronze, and stainless steel and for certain components polymerics such as acetal and nylon [13].

2.5 Freeze protection

The types of heat transfer fluids may be divided into two categories: non-aqueous and aqueous. Silicon fluids and hydrocarbons are included in non-aqueous group. Inhibited distilled water and inhibited glycol water mixtures (e.g. ethylene glycol, propylene glycol). The potable tap water and inhibited distilled water don’t offer freeze protection compared to glycol solutions which are most preferred in cold climates.

2.5.1 Non-aqueous solutions

2.5.1.1 Silicon fluids

Silicon fluids have many properties, which make them one of the major preferable collector fluids. Basically they do not freeze, boil or degrade. Most importantly they do not corrode the metals used in solar collectors, including aluminium. According to investigations, silicon fluids are non-toxic with a high flash point. Silicon fluids can last the life of a closed loop water-heating system under 180-200°C. However, the most common silicon fluids are used in systems with maximum temperature around 180°C or less. An extra advantage of silicon fluids is that they do not form sludge or scale so the performance of the system does not decrease with time [12].

The main disadvantage of silicon fluids is the cost. As a typical example, the price of 100 ml is around £60. As it was mentioned before, they have the advantage of lasting the life of the system, but also require less maintenance. This helps to minimise the operating expenses. However the initial cost of silicon fluids is higher than that of other available heat transfer fluids. Their use allows absorbers with aluminium fluid passages to be used without corroding them [12].

2.5.1.2 Hydrocarbon oils

Hydrocarbon oils give long life to the systems and additionally they cost less. They are relatively non-corrosive, non-volatile, environmentally safe and most important non-toxic. They are for use in systems with lower operating temperatures. Typically flash points run from 150-220°C, but the fluids with higher flash points have a higher viscosity [12].

Newer hydrocarbons have been developed which do not harm rubber or materials of construction, which has been a problem with hydrocarbons. They cannot be used with copper as it serves as a catalyst to fluid decomposition. The thermal conductivity of hydrocarbons is as low as water, although the performance of some is better [12].

2.5.2 Aqueous solutions

2.5.2.1 Glycol –water antifreeze

Non-freezing liquids can be used to provide freezing protection. These liquids are circulated in a closed loop with a double wall heat exchanger between the collector loop and the storage tank. In this part there is only a description of the antifreeze solutions and their properties. Glycol water antifreeze solutions are the most commonly used because their cost is less compared to silicon fluids. Ethylene and propylene glycol are the two most common antifreeze solutions. A concentration of 50% ethylene or propylene glycol and 50% water solution provides freeze protection to about -20°C. The boiling point also rises to about 120°C [12,14].

The use of glycol-water solutions has the disadvantage of corrosion. Glycol-water solutions corrode galvanised pipes and at high temperatures glycols may break down to form glycolic acid. This break down usually occurs at 85°C and accelerates as the temperature reaches 95°C. This glycolic acid corrodes almost all the metals used in solar collectors including copper aluminium and steel. The decomposition rate of glycol varies according to the degree of exposure to air and the service life of the solution.

Most glycol-water solutions require periodic monitoring of the pH level and the corrosion inhibitors. The appropriate value of pH is between 6.5-8.0. Also the replacement of the solution is done every 12-24 months or even sooner in high temperature systems [12,14].

2.5.2.2 Distilled water

Distilled water has been suggested for use in solar collectors since it avoids some of the problems of untreated potable water. Since the distillation process removes contaminants such as chlorides and heavy metal ions the problem of galvanic corrosion should be eliminated. However, distilled water is still subject to freezing and boiling. For this reason glycol-water concentrations are most preferable [12].

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CHAPTER 3: THE MARKET OF SWH

3.1 Introduction

The aim of this part of the report is to give an overview of the solar water heating systems market in U.K, some European countries and some countries around the world. It also presents some statistical data from various researches. Attention will be concentrated mainly in the U.K. market. The purpose of the data is the best approximation of how popular solar water heating systems are. The use of different types of systems and variants of these systems in different countries is often due to variations in local conditions.

The world market for solar water heaters has expanded significantly during the 1990's and, as a result there has been a substantial increase in range and quality of products now available. Solar water heating production is now a major industry in countries such as China, Israel, Japan, Netherlands, Germany, Australia and Greece. The self-building industry has also expanded significantly in Europe. On the other hand there are still countries (U.S.A) that solar water heating industry is nearly invisible throughout the supply and distribution chain.

The current situation of the solar thermal market can be summarised as follows:

- Installed surface in the EU through 1999: 9,000,000
- In the past 20 years growth rates of the EU collector market varied considerably per year, varying from -20% (1987) to +50% (1999) with an average growth rate of 13% since 1990.
- Collector sales 1999: 900,000 m^2 (90% flat plate, 10% evacuated tube collector)
- EU market growth in 1999 is approx. 10% per year. It is expected that the market growth will accelerate in the near future
- Sales in Germany represent 50% of the annual EU collector sales at the moment
- Market growths per country in 1999 vary from 0% to > 20% [3].

The varying collector sales growth rate per year and per country demonstrates that the market development of solar systems depends strongly on external factors like the existence of financial support and information campaigns.

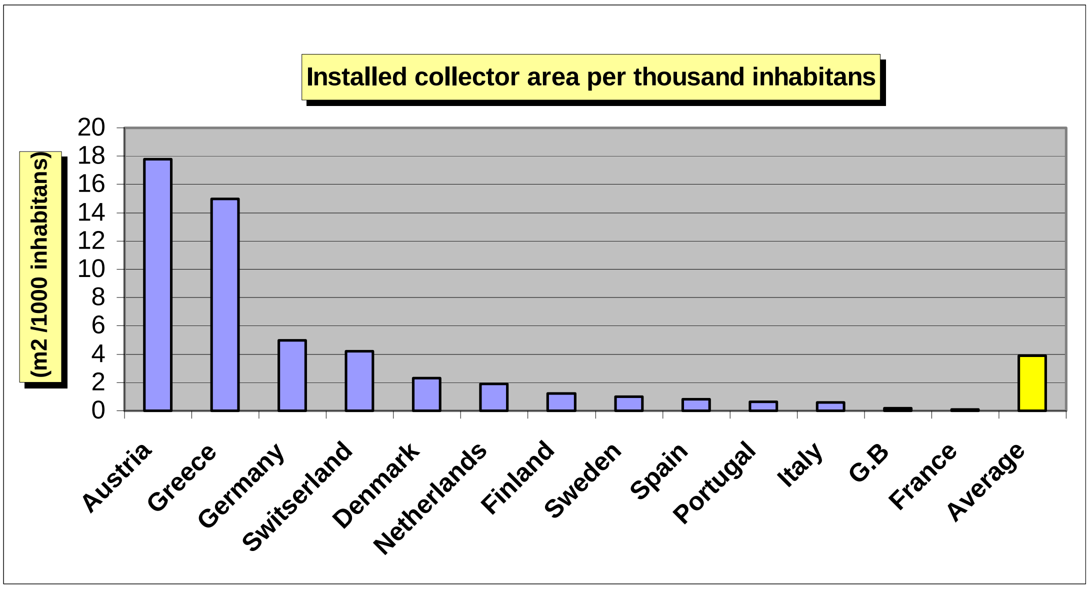

Figure 3.1: Installed collector area per thousand inhabitants in Europe (1999)

According to data, the sales figures of the European countries show that the annually installed collector areas vary between countries. It is clear that Austria, Greece, Germany and Switzerland lead the market. Countries with similar climates show very low m^2 figures.

3.2 U.K market

The history of the solar water heater market in U.K starts back in 1973 during the oil crisis and formation of OPEC. It can be characterised by three phases since 1974.

a) Initially, when the government showed a potential interest for research and development of solar water heaters, the market started to expand rapidly. The government's interest push the imports from southern Europe and the market started to grow till the early 1980.
b) The market collapsed with the installation rates reduced to half in the early years. This was mainly due to the price of fossil fuels, which surprisingly had not risen during the period of the oil crisis. Another important reason was poor installations. The panels provided were not appropriate for U.K weather conditions (i.e. low temperatures during the winter).
c) Since 1991 there has been a big concern about the advantages offered by solar water heaters and especially the environmental protection they offer [1,7].

3.2.1 System types and data

Most of the solar water heating systems used for domestic households. It has been calculated that the annual savings using a solar water heater are 40-50% [8]. In the summer a solar water system may provide all the hot water needs of a typical family and the savings in winter can be significant. The most common systems currently used are:

- Evacuated tube collectors
- Flat plate collectors with selective surface
- Flat plate collectors without selective surface
- Freeze tolerant flat plate single pass flat plates with selective and part unselective surfaces
- Unglazed polypropylene collectors (for outdoor swimming pools) [7].

There are two designs widely systems used:

- Single water storage cylinder incorporating the solar heat exchanger at the bottom of the cylinder and a convectional back up source at the top of the cylinder. These types of systems are considered for the analysis in chapter 5.
- A preheat cylinder incorporating the solar heat exchanger which feeds water directly into the main hot water cylinder [7].

An estimated 169256m^2 of domestic water heating collector area and 106884 m^2 of swimming pool collector area was installed in 1997. This is equivalent to approximately 47650 systems in the U.K. Of this total installed, 50770m^2 was installed between 1992 and 1997 [2].

3.2.2 U.K SWH industry

The U.K solar industry, as it was mentioned before, was first established in the early 1970's. It can be divided into five major areas of activity:

- Collector manufacturers
- Collector importers
- Collector installers
- Service providers

Over 80% of the solar thermal technology manufactured in U.K is exported to over 40 countries. The majority of the exports are carried out by Thermomax Ltd and are to Germany [9]. Evacuated tube collectors are the largest amount of production and exportation. The currently flat plate collectors manufactured in U.K use several variations:

- Glazed selective-surface aluminium absorbers
- Glazed stainless steel absorbers
- Glazed copper absorbers [7]

3.2.3 Range of costs for SWH

The cost of a complete solar water heating system varies due to the different types and sizes of systems. The following table shows the range of costs in the U.K. Based on these costs data from different companies [9,10,11,12] a "Life Cycle Costing" is described in full detail in chapter 5.

Input data	Output data
Typical system area	2-7m^2
Typical system price ➢ Complete installed system ➢ DIY including VAT or new built	 £2000-£4000 £1000-£2500
Annual pump running cost	£6
Installation time	1-2 days
Assumed lifetime	25-30 years
Annual output	1500-2000 kWh

Table 3a: Cost and performance data for a typical SWH system

Selective coated flat plate collector panels cost in the range of £140-£250/m^2 and evacuated tube collectors cost approximately£550/m^2. The additional cost is for the hardware and for the fittings of the installation. The range in prices is basically due to the different companies and house specifications. However, there are significant cost savings available if solar water heaters are included into a new building

3.2.4 Potential for SWH

The accessible resource for solar hot water systems by 2025 is estimated to be 12 TWh/year, based on 50% of the housing stock being suitable for a solar water heating system . A survey carried in 1995 indicated that 96% of solar water heaters were in homes that were owner occupied [13].

The greatest potential in the U.K would be the uptake of solar water heaters on all new build developments orientated in a suitable direction. Planned new buildings in U.K are estimated as 150000 a year [2]. If it were assumed that 5% of the new houses install a solar water heater it would increase the growth of solar water heater market furthermore.

3.3 The European market

This part is a brief description about the status of the solar water heater market in some major European countries. There is just a summary of some statistical data obtained. For each country there is the total installed collector areas as well as the systems used in each one.

3.3.1 France

Until 1998 an estimated 268 000 m² of collector surface was installed in metropolitan France. There was no growth rate in the French market, but a drop rate. The installed collector surfaces decreased from 57,000 m^2 in 1982 to 1800 m^2 in 1998 [6].

The market survey shows the predominance of the classical pump split design (68%), followed by the mono-block SWH systems (21%), and some thermosiphon split units (9%). Integrated SWH are marginal (2%) [6].

3.3.2 Greece

Greece with 2,493,000 m^2 installed solar collectors has risen to second place in Europe.
About 95% of the installed systems are in households and the rest 5% in industries and hotels. Search showed that the number of total area of installed collectors will be doubled

until 2005 and reach to 9.8million m^2 until 2010. Greek market is represented entirely by glassed collectors [6].

3.3.3 Germany

From the total installed collector area about 80% is used for water heating. Most of them are for family homes but latest research showed that there have been efforts to develop large-scale systems.

More than 50%of the installed systems are roof integrated. Two cycle systems with a water-glycol solution are preferred. About 70% of the systems are flat plate and 30% evacuated tube collectors [2,3].

3.3.4 Austria

Austrian market has increased rapidly since 1989. From the total solar heaters installed, a 20% are for water heating purpose by self-constructing groups based on the “Association for Renewable Energy. Austria has a tradition of self-building houses, which is the main reason for individual construction [5].

The end of 1999 showed the installation of a total of 2,0 million square meters of thermal sun collectors in Austria. The rate of growth since 1990 has been particularly striking. At the beginning of the 90’s around 80,000 m^2 were installed per year. In 1995 however 200,000 m^2 (2) collector areas were mounted for the first time [5].

Around one quarter of the collector area installed comprises plastic absorbers, which are used to heat swimming pools. The remaining 75% of the collector area, mainly flat plate collectors, are used to prepare warm water in single and multiple family houses and for space heating in single-family houses. The most common systems are with pump circulation and freeze protection [5].

3.3.5 Netherlands

According to 1998 data an estimated 10,000 domestic hot water systems had been installed.

By the year 2000 the number of solar water heaters had increased to 50,000.

Unlike other countries drain back systems are primary used in Netherlands. An estimated 95% of domestic hot water systems use a circulation drain back system. That happens because of the fact; water is most preferable than glycol antifreeze solutions [2,3].

3.3.6 Denmark

There are about 16,000 systems with a total collector area of 150,000 m^2. By the end of 2001 the total number of water heaters would reach 37,000.

Closed loop systems with antifreeze solutions are mostly used [2,3].

3.4 U.S.A market

The solar water heating industry has difficulties gaining a permanent share of the hot water market around the U.S.A. According to statistical data [15], in the United States the existing solar water heaters show energy shaves of nearly 52%. This percentage based on the installed base of both home and industries. It is estimated that 6-9 million solar water heaters are installed every year

In the past the solar water heating industry tended to install expensive and oversize systems to cover about 80-90% of all household water needs. Nowadays solar water heating industry tends towards cost effective systems. These systems are easier on installation and moreover require less maintenance expenses. Nowadays the manufacture companies are reduced compared to mid 70’s early 80’s.

This shows that the solar water heater industry is nearly invisible throughout the supply and distribution chain, which has serious implications for the success of solar water heating industry [4].

3.5 Australian market

The solar water heating industry is well established in Australia. The share of the exporting production is based in large companies. Most of the systems are for domestic purposes and swimming pool heating. Although the production of solar water heating has decreased compared to mid 1980's, it is estimated that 600,000 systems have already been produced of which 350,000 to 400,000 of them are installed in Australian households.

Thermosiphon systems have taken over the market, as they are cheaper than pumped systems. The systems basically used are integrated collectors placed on the roofs [2].

3.6 Japanese market

The market for solar water heaters has been shrinking continuously for the past several years due to the long payback period for solar systems. In 1985 257,000 solar water-heating systems have been manufactured. Since then there was a huge decrease in annual production. The number of systems manufactured in 1998 dropped to 80,000.

About 80% of the systems are thermosiphon systems [2,14].

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CHAPTER 4: SWH RELIABILITY & QUANTITATIVE SURVEY

4.1 Introduction

There are a number of important reliability issues associated with most types of solar water heating systems. They are important to understand in order to produce a reliable, properly functioning solar water heating system. Fortunately, in today's environment there are solutions for most of these problems. This chapter starts by describing the basic parts of a solar water heating system, which are most commonly repaired and replaced. The various research has been done after conducting a list of companies. The second part of this chapter is based on a quantitative survey according to data collecting from the same list of companies and data obtained from Greece. For the quantitave survey two major areas are analysed. First of all is the awareness people have for the solar water heating systems. Secondly is the image of solar water heating systems.

4.2 Reliability survey

Most reliability problems associated with solar water heating systems have known solutions. Although there are also known ways in which to avoid them in the first place, the same problem continues to surface. This chapter starts describing the basic parts of a solar water heating system, which are most commonly repaired and replaced. The method followed is simple and based on the experience of the companies dealing with solar water heating systems. They were asked to identify the areas where most problems occur and the main reasons cause them.

4.2.1 Freeze protection

The U.K is a country where the temperature very often drops below zero, especially in wintertime. The method of the freeze protection used is very critical. If water can freeze inside a pipe or tank it will split it over as the water expands while freezing.

Most commonly circulation systems freeze on pump failure and on power protection. Freeze problems are observed in multiple collector array systems with circulation freeze protection when the controller and pump appear functional. The reason for that is often due to scaling in some tubes or flow imbalance arrays.

In drainback systems using small modules, sensors and controller failure can lead to frozen collectors. In severe climates failure of the air vent valve to open in draindown systems causes draining to be too slow and freezing can occur. In order to avoid these entire problems collector and all supply/return piping is tilted to allow water to fully drain from the system where the pump is off.

4.2.2 Overheat protection

It is very common for a solar water heating system to reach very high temperatures for the reasons stated above:

- The system is not operated for a day or longer.
- The storage tank is too small compared to collector area.

High temperatures also accelerate problems associated with poor water quality.

Active solar water heating systems using a differential controller generally shut the pump off at a maximum temperature between 70-80°C. Passive systems generally use temperature pressure relief valve to discharge water from the storage when it reaches about 80°C. The disadvantage of the systems is that they are not designed for continuous use and they always fail prematurely if the system is frequently in a condition of stagnation.

4.2.3 Poor water quality

Most solar water heating systems start to perform poorly if mineral deposits or debris collect in the system. Most of the companies conducted mentioned that generally poor water quality leads to early pump and tank failure in systems where cold supply water flows directly through the collector on the way to the storage tank. Usually this is seen as freeze damage. There are two common problems associated with poor water quality:

a) *Corrosion*: Corrosion results from acidic water and can be an adequate problem in well water sites, where water quality is not controlled. Solder flux may cause a closed loop fluid to become acidic, promoting corrosion.
b) *Scaling*: Scaling is a problem in areas with hard water. Certain system types are a problem in areas with hard water. Open loop circulation systems are quite sensitive to collector scaling. Closed loop systems usually have the scaling at the heat exchanger, which require regular maintenance to remove. Sensate

4.2.4 Mixing valve and tempering valve failure

Solar water heating systems can reach very high temperatures in summer or when they are not used for a period of time. One of the most important devices in a solar water heating system is the mixing valve. Their main task is to mix cold water with hot water in order to keep the hot water below maximum safety temperatures.

Nowadays certain tempering valves are a major maintenance problem with mean lifetime as little as 3-4 years. Cold water delivery is generally the result of a tempering valve failure. Tempering valves cause feed through between hot/cold lines, especially in larger buildings with large hot water circulation loops as the pressure will not be equal to the hot water circulation loops.

4.2.5 Storage tank failure

Solar contractors have discovered that fibreglass storage tanks have resins in the material, which can raise the pH and cause leaks in copper piping. Also fibreglass lifetime is shortened by exposure to high temperatures, which can be quite high especially when dealing with solar applications. Water heaters are generally set to 55-60°C

Welded stainless steel tanks are often characterised as the highest quality solar storage tanks material. They can fail just like fibreglass tanks, depending on the sape of tank, tank wall thickness, and quality of weld. High temperatures also highlight problems caused by thermal expansion.

4.2.6 Air vent failure

In general, most contractors see failures of air vent valves as a real maintenance problem. On pressurised closed-loop systems, the valve is intended only for air venting during and immediately after filling. Several solar contractors maintain air vent valves are unnecessary, if air is properly purged from the system initially. It is believed that air vent valves have close to a 100% failure rate within 5 years.

When air vents fail the system looses fluid from the loop, fails to operate, and damage to the system or the mechanical space can result. For glycol systems, solar fluid may boil under "no load" circumstances. If present, an air vent valve may release fluid vapour, and/or the pressure relief may exhaust fluid, leading to low fluid levels and potential vapour lock.

4.3 Quantitative survey

While technology and aesthetics of solar water heating systems has been improve during the past 20 years the number of homeowners installing them has not grown as dramatically. This is the second part of the survey that has been carried out in order to obtain some statistical data about the role of solar water heaters in people’s life. The data as explained in the beginning have been collected from U.K are based on the answers the companies provided. It has to be mentioned that the data collected from Greece are not official but are based in research from a village with a population of 3000. However it is believed that some useful conclusions can be drawn.

4.3.1 Purpose of research

As it was referred, the image of solar water heaters has been improved especially during the last 20 years, however people are still negative (especially in U.K) of having a solar water heating system. The purpose of this research is:

- Gain an understanding of consumer awareness and image of solar water heating systems
- Identify the extend or lack of consumer knowledge and understanding of solar water heating systems
- Identify the key barriers to purchase and ways to generate increased purchase interest

➢ Determine the purchase interest levels in newer solar systems.

4.3.2 Awareness and usage of various water heating systems

As it is seemed from the statistics most of the responders are aware with solar water heating systems. Only a small number of them use solar energy to heat water (U.K) but on the other hand it seems that the main source of gaining information is Internet.

4.3.2.1 Awareness of water heating systems

The graph presented below is the statistics of which systems people know for water heating. It is clear that there is a difference on the data obtains from U.K compared to the data obtained from Greece. Responders from U.K seem to be more familiar with the traditional sources of water heating such as gas and electricity (98% and 95% respectively). Surprisingly nearly 1/3 are aware of solar energy as a primary source of water heating. Greek responders are more familiar with SWH (95%) but they seem not to consider the idea of gas either by it self or as a back up.

	Data from U.K companies	Data from Greece
Gas with solar	15%	2%
Electricity with solar	12%	65%
Solar	32%	95%
Electricity	98%	92%
Gas	95%	10%

Table 4a: Percentage data for awareness of water heating systems

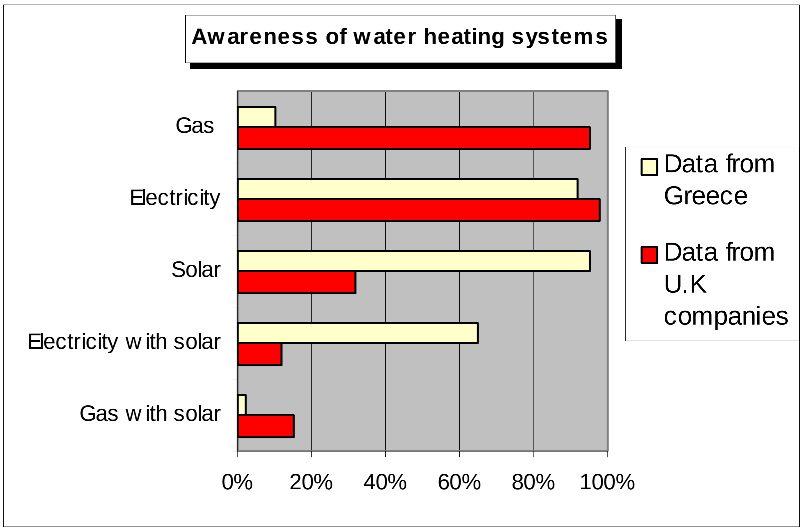

Figure 4.1: Awareness of water heating systems

4.3.2.2 Sources of SWH awareness

Sources of solar water heating awareness are very different on both countries. While more than 50% of the responders in U.K have learned about SWH from Internet the percentage in Greece is only 1%. As it was mentioned in the above the research in Greece is based on data collected from a village and most of the people are not aware of the Internet. Nearly 30% in both countries have been informed from magazines. The percentage related to home viewers is quite high in Greece where most of the people have answered this as the primary source of awareness.

	Data from U.K companies	Data from Greece
Magazines	28%	30%
Advertising (T.V, radio)	20%	58%
Friend	35%	60%
Have seen on homes	42%	87%
Internet	57%	1%

Table 4b: Percentage data for sources of SWH awareness

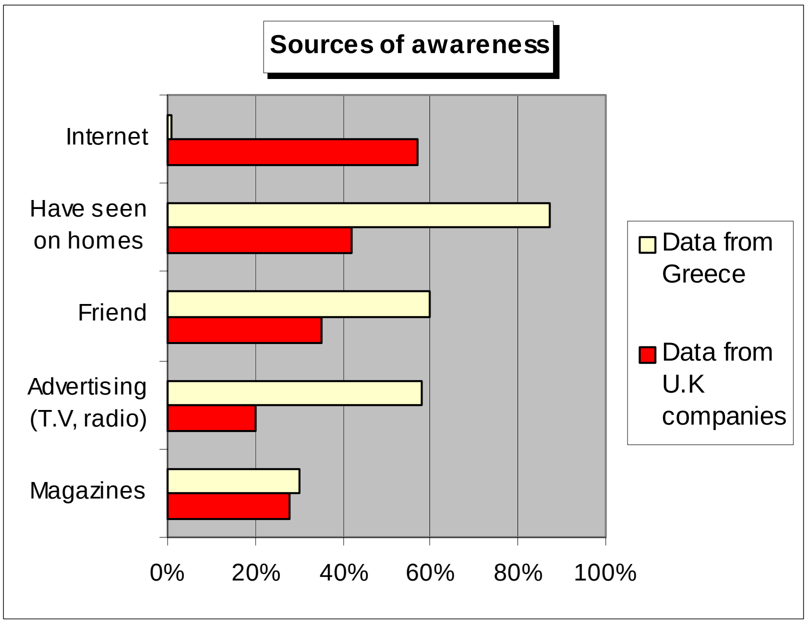

Figure 4.2: Sources of awareness

4.3.2.3 Usage of water heating systems

In this part of the research there is an extremely high difference of systems used to heat the water in both countries. According to experience and the data obtained, the people use electricity and gas for water-heating purpose is more than 90% in U.K. In comparison with U.K. data the percentage is lower in Greece where only 19% use electricity. On the other hand the difference is quite high when it is referred to solar as a primary source. The Greeks seem to use more solar water heating with a percentage as high as 70% compared to 2% of U.K. people. Another important parameter is that in Greece there are still families (12%) who use wood and especially wood boilers.

	Data from U.K companies	Data from Greece
Gas with solar	3%	0%
Electricity with solar	7%	15%
Solar	2%	70%
Electricity	93%	19%
Gas	90%	1%
Wood boilers		12%

Table 4c: Percentage data for usage of water heating systems

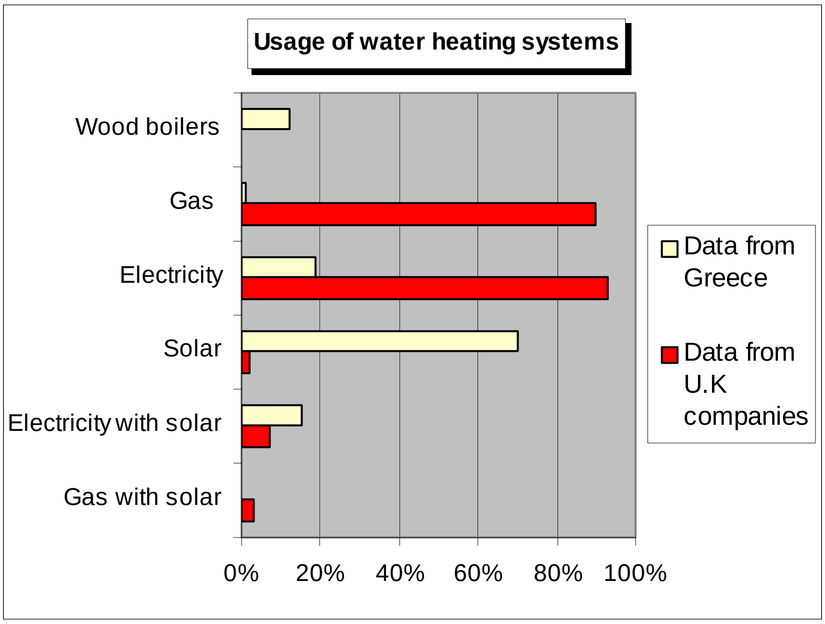

Figure 4.3: Usage of water heating systems

4.3.3 Image of SWH

Overall these data seem to give the impression that the only reason that the standards are the same is when safety is concerned. For specific questions like hot water capacity, money savings and environmental concerns they do not agree. There is a quite big difference in people's opinion about hot water capacity where Greeks believe that they can achieve much more water using a solar water heater. Also the maintenance cost is a big concern where the systems in U.K require often maintenance

	Data from U.K companies	Data from Greece
Save money	15%	85%
Better for environment	77%	15%
Use less gas/electricity	48%	70%
More hot water capacity	7%	90%
Safer to people	65%	60%
Less maintenance expenses	0%	5%

Table 4d: Percentage data for image of SWH

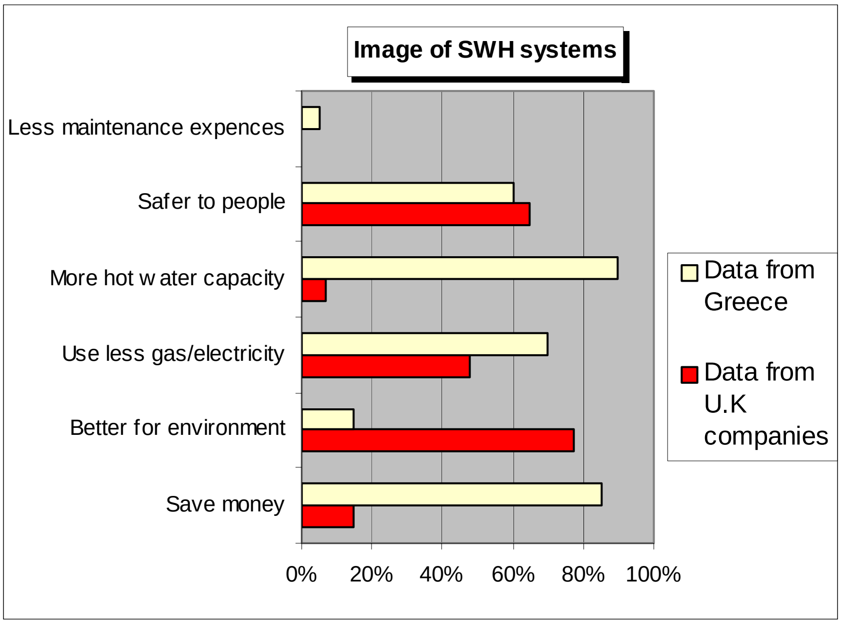

Figure 4.4: Image of SWH

4.3.4 Disadvantages of SWH systems

The two common perceived disadvantages of solar water heating systems include the cost of purchase the system. Most U.K responders believe that the limited number of Sunny days during the year is a major disadvantage of purchasing a SWH. High maintenance costs and not much hot water are the next two negative opinions received from U.K responders. The aesthetics is a major concern for Greek responders because of the structure of most houses and the type of system usually used (e.g. thermosiphon systems) effect the overall appearance of the house.

	Data from U.K companies	Data from Greece
Cost of purchase	70%	80%
Not enough sun	90%	0%
Not much hot water	65%	2%
Appearance	5%	34%
High maintenance cost	68%	10%

Table 4e: Percentage data for disadvantages of SWH systems

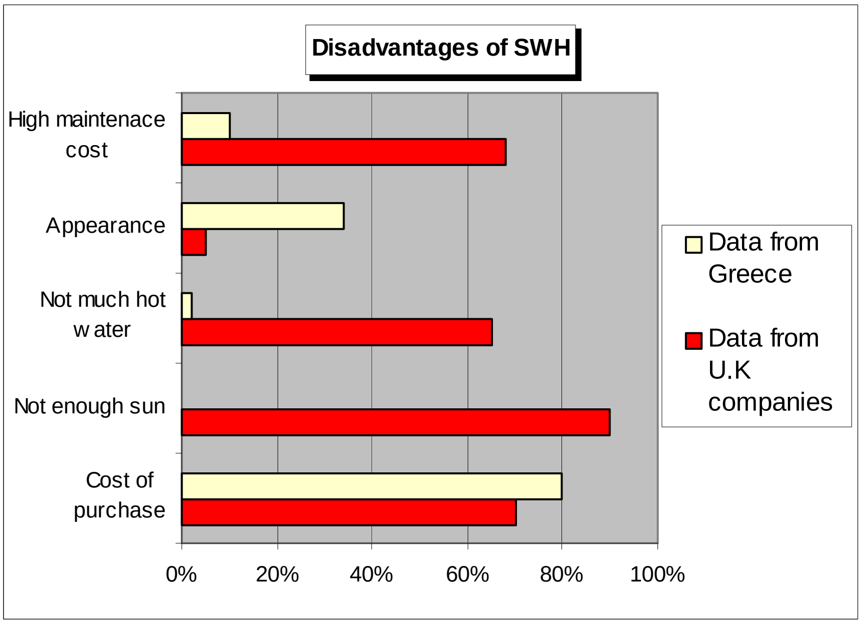

Figure 4.5: Disadvantages of SWH systems

4.3.5 Consideration factors

When asked to rate the importance of a variety of factors on their decision to purchase solar water heating, if they were interested in it, almost all of the responders consider most of the factors to be important. A consideration scale was used from 1-5. (1= not at all important, 5=very important)

Interestingly U.K responders seem not to be concerned about the brand of the system in comparison with Greek responders who think that brand name is crucial for their system. Also nearly half of the Greek responders (47%) seem not to consider the environmental effects of the solar water heaters.

	Data from U.K companies	Data from Greece
Type of warranty	85%	85%
Maintenance costs	87%	78%
Hot water delivery	92%	90%
Price of the system fully installed	90%	88%
Brand name	30%	75%
Help to environment	64%	47%

Table 4f: Percentage data for consideration factors

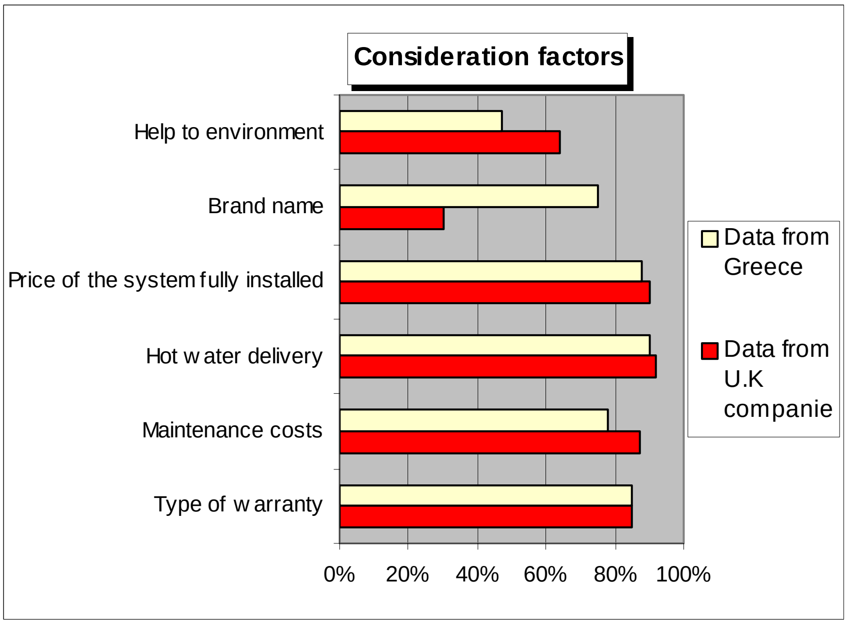

Figure 4.6: Consideration factors

4.3.6 Attitudinal statement

Again in this part a scale of 1-5 was used (1=completely disagree, 5=completely agree) in order to give answers to the questions asked. There is no statement where all the respondents from both countries think the same. The higher percentage is presented at the question related to the environment, where 80% of the respondents (78% for Greek respondents) seem to believe the solar water heaters are environmental friendly.

The part where there is a big difference is when related with the cost, and the existence of solar water heater in every house. The U.K respondents are quite negative to the fact that solar water heaters require little maintenance and on the idea of a SWH in every house.

	Data from U.K companies	Data from Greece
Environmental friendly	80%	78%
Economic sense	32%	93%
SWH in every house	22%	67%
Solar require little maintenance	15%	74%

Table 4g: Percentage data for attitudinal statement

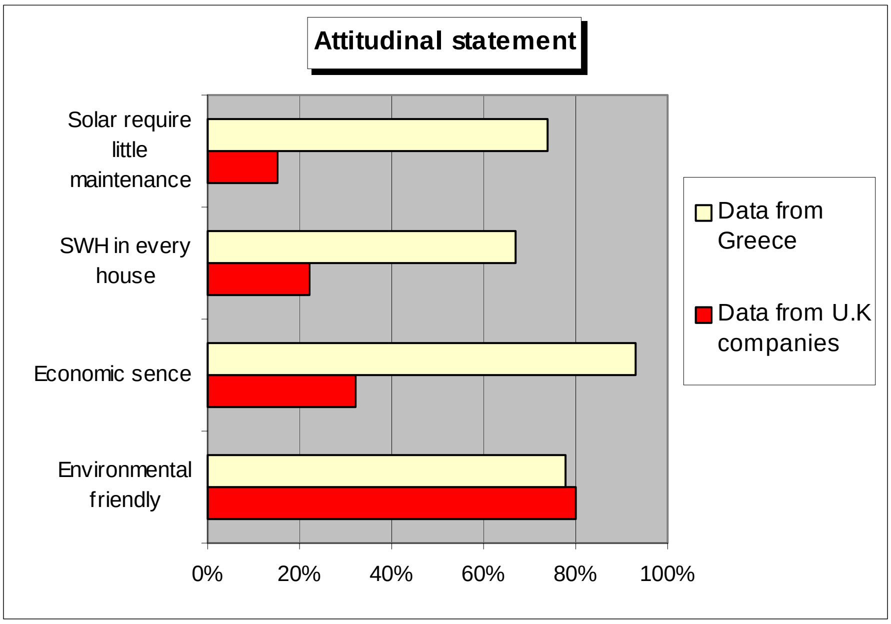

Figure 4.7: Attitudinal statement

4.3.7 SWH system cost

On average respondents feel that a fully installed solar water heating system cost between £2500-£3000. At this point it has to be mentioned that the cost standards for a solar water heating system in Greece are much lower. The prices had to be scaled in such a way to be representative for both countries. In fact people were really aware how much a system would cost. According to companies data, a system for an average family of 4-5 persons would cost between £2500-£3000. Quite a few believed that the cost of the system would be higher than £3000.

U.K price (£)	Data from U.K companies	Data from Greece	Greek price (Drachmas × 10^3)
Under £2000	6%	4%	250-300
£2000-£2500	18%	12%	300-350
£2500-£3000	65%	68%	350-400
£3000-£3500	67%	58%	450-500
£3500-£4000	8%	7%	500-550
£4000-£5000	7%	6%	550-600
Over £5000	4%	1%	Over 600

Table 4h: Percentage data for SWH system cost

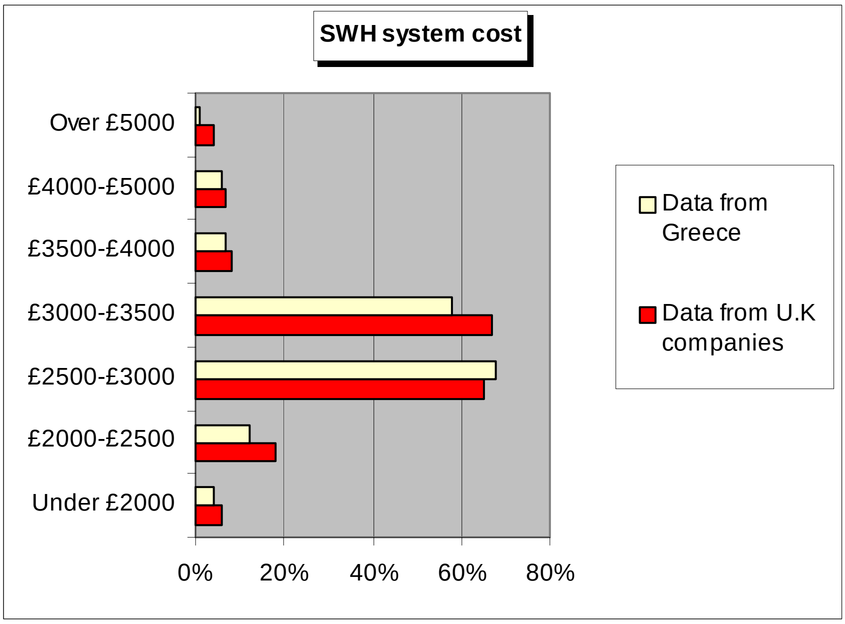

Figure 4.8: SWH system cost

4.3.8 Reasons for not considering SWH

According to the data the basic reasons for not considering a SWH is the weather. People believe that the conditions are not appropriate for hot water during the whole year. On the other hand Greek responders thing the weather conditions are appropriate. The major concern for responders from both countries is the cost. People believe that SWH systems are quite expensive compared to other sources of water heating. Also a high percentage of responders

(65% U.K) answered that SWH could not offer them enough money savings. Lack of awareness or lack of availability appears to be a major reason for not considering SWH. Quite a few people (34%) responded that SWH has not been proposed to them buy anyone. This justifies the idea that SWH are not very popular in U.K.

	Data from U.K companies	Data from Greece
Not mentioned	34%	10%
Too expensive	67%	74%
Not much information	42%	4%
Not save enough money	65%	2%
Weather conditions	88%	0%

Table 4i: Percentage data for reasons for not considering SWH

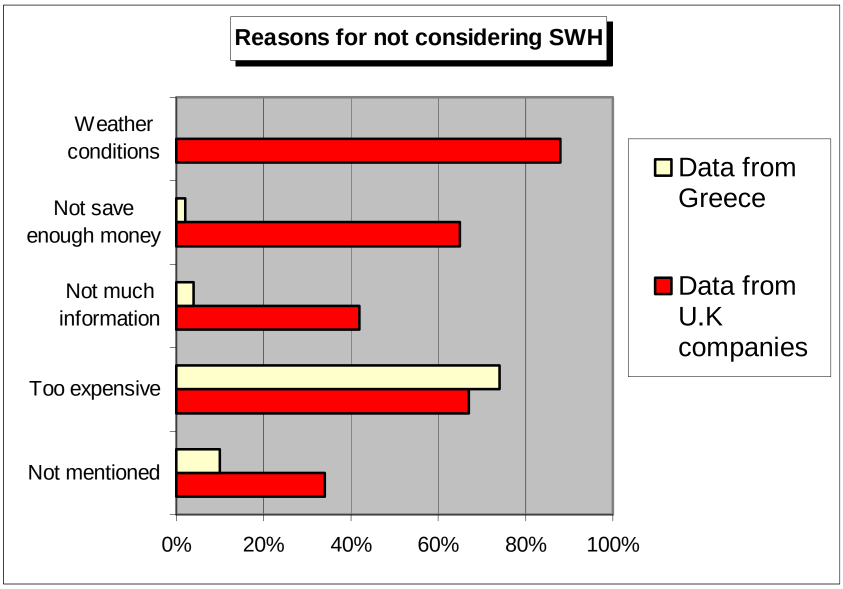

Figure 4.9: Reasons for not considering SWH

4.4 References

1) Data obtained after conducting companies around U.K. The list of these companies was provided from "National Energy Foundation" in Milton Keynes. For further information refer to: www.natenergy.org.uk.

2) Data from Greece obtained with the help of my brother Nikolaos Panapakidis and my two cousins Panagiotis Vamvakaris and Nikolaos Gougoulis. The data collected from the village called Nea Peramos.

Comment: The investigation areas and the answers had been chosen before. The only task of the responders was just to choose and "*tick" (√)*. They could choose minimum 1 and maximum 3 questions from each section.

CHAPTER 5: LIFE CYCLE COST (LCC)

5.1 Introduction

Economics play a central role in any customer's decision to purchase a solar water heater system. The customer, whether a homeowner or a corporation, is unlikely to buy a solar energy system if they know that its only benefits are to the environment. Obviously, any company considering solar power generation is going to look very carefully at economics to ensure that such a project will be profitable to themselves and to their shareholders.

This guide was developed to help illustrate the process involved in completing a Life Cycle Cost (LCC) economic analysis of competing energy solutions [2]. It also introduces the concept of accounting for subsidies and/or externalities in an economic analysis, an increasingly important issue to many policy and other decision makers. The intent behind the "real example format" and links to required resources is to illustrate the type of practical considerations and resources needed for a comprehensive, yet straightforward comparison of the economic and environmental costs of alternatives [2].

To help illustrate the number of variables that can influence an economic analysis of SDWH, the list below has been considered:

a) Performance variables

- Solar energy available
- Outdoor air temperature & cold water temperature.
- Collector tilt and orientation (varies with architectural design, aesthetics)
- Collector shading (varies with shade from buildings and/or site objects)
- Hot water used, time of use (varies by family size and habits)
- Hot water delivery temperature (varies from 50-70°C)
- Auxiliary water heater size and type (varies considerably)
- Solar energy system size and type (varies considerably) [5]

b) Economic variables

- Current and future fuel costs
- Current and future inflation rate
- Discount rate, or "cost of capital." This is generally the interest rate the homeowner earns to lend (or pays to borrow) money; also referred to as "time value of money" from the investor's standpoint.
- Homeowners income tax rate (varies with income)
- Financing terms (loan period, interest rate, etc.)
- Investment time period (length of time homeowner intends to live in home, mortage period, etc., depending on individual investment considerations)
- System replacement and maintenance costs over time [5]

This guide was developed to help illustrate the process involved in completing the “Life Cycle Cost” (LCC) economic analysis of competing energy solutions. For the “Life Cycle Cost” a series of spreadsheet templates are developed to represent several different types of water heating systems. The spreadsheets calculate 10, 15, 20, 25, 30-year LCC as well as the effective annual cost to own. Examples using three type of SWH as well as general considerations are provided. These examples include comparison of electric and gas water heaters with flat plate, evacuated tube and drainback solar water heater systems considering also a 20% of the amount financed. The complete economic analysis is presented in separate spreadsheets in Appendix 3. All the data were provided from U.S.A and U.K water heating companies. The equivalent prices, according to specification (e.g. 1st hour rating, energy factor, rated storage volume and input kWh) for each water heater, were taken after conducted various companies around U.K

5.2 Economic indicators

An economic analysis takes into account a great number of variables that describe the strength of the current market. These variables are combined to form a figure of merit that allows comparison of investment alternatives. In the case of solar energy alternatives, figures of merit are typically used in two ways. First, they provide a useful comparison between the SDHW systems and a conventional method of heating such as electricity or natural gas. Secondly, they allow designers to evaluate and optimise SDHW systems [1,2].

Many figures of merit are available for comparison of SDHW systems and there is no single correct choice. Different figures of merit are appropriate to different economic situations [2]. Two such figures of merit have been applied to analyse the convectional SDHW system comparing it with other domestic systems. The LCC is the sum of all costs associated with a system over a chosen analysis period, and is adjusted for inflation so that it is reported in today's U.K sterlings.

5.2.1 Payback period

The payback period is calculated in the following manner. The fuel savings for the j^{th} year, Cs_j, are defined in equation 5.2.1.1 in which FL is the energy saved, C_F is the unit cost of fuel, and i_F is the fuel cost inflation rate.

$$Cs_j = FLC_F\,(1+i_F)^{j-1} \qquad (5.2.1.1)$$

Summing the expression over the time required for payback yield equation 5.2.1.2

$$Cs_j = \sum_{j=1}^{N_p} FLC_F\,(1+i_F)^{j-1} \qquad (5.2.1.2)$$

Summing the geometric series results in equation 5.2.1.3

$$Cs = \frac{FLC_F\,[(1+i_F)^{N_p}-1]}{i_F} \qquad (5.2.1.3)$$

Solving for N_p, The payback period:

$$N_p = \frac{\ln\left[\dfrac{C_s i_F}{FLC_F}+1\right]}{\ln(1+i_F)} \qquad (5.2.1.4)$$

The above analysis includes the discounting of fuel savings so that they are reported in today's U.K pounds. It is common to neglect the fuel savings discounting in which case the payback period is given by equation 5.2.1.5 and is referred to as simple payback period. N is the number of years in the analysis and C_{SYS} is the initial system cost [1,2,7].

$$N_p = \frac{C_{SYS}}{NFLC_F} \tag{5.2.1.5}$$

5.2.2 Life cycle savings and the P_1, P_2 method

Life cycle savings are calculated using equation 5.2.2.1. P_1 is the ratio of the life cycle fuel cost savings to the first year fuel cost savings. P_2 is the ratio of the life cycle expenditures incurred because of the investment to the initial investment amount. C_A is the cost per unit area of the system and C_E is the area independent cost [2].

$$LCS = P_1 \sum_{i=1}^{12} C_{F_i} l_i f_i - P_2 \left(C_A A_C + C_E \right) \tag{5.2.2.1}$$

Writing equation 5.2.2.1 with the summation allows monthly variation in the cost of fuel. P_1 is given by equation:

$$P_1 = \left(1 - C\bar{t} \right) PWF(N_e, i_F, d) \tag{5.2.2.2}$$

P_2 is given by equation:

$$P_2 = D + (1-D) \frac{PWF(N_{\min}, 0, d)}{PWF(N_L, 0, d)}$$

$$-\bar{t}(1-D)\left[PWF(N_{\min}, 0, d)\left(1 - \frac{1}{PWF(N_L, 0, d)} \right) + \frac{PWF(N_{\min}, 0, d)}{PWF(N_L, 0, d)} \right]$$

$$+ M_s \left(1 - C\bar{t} \right) PWF(N_e, i_F, d) + tV(1-\bar{t}) PWF(N_e, i_F, d) \text{ [2,3,]}$$

$$-\frac{C\bar{t}}{N_D} PWF(N'_{\min},0,d) - \frac{R_v}{(1+d)^{N_e}}(1-C\bar{t}) \qquad (5.2.2.3)$$

Where the meaning for each symbol is:

- C= income producing flag (1 for income producing installation, 0 otherwise)
- D= market discount rate (best alternative investment)
- m= annual mortage rate
- i= general inflation rate
- N_e= period of economic analysis
- N_L= term of loan
- N_{min}= years over which mortage payments contribute to the analysis
- $N'_{\min}$ = years over which depreciation contributes to the analysis
- N_D= depreciation lifetime in years
- t = property tax rate
- $\bar{t}$ = effective income tax rate
- D= ratio of down payment to initial investment
- M_s= ratio of miscellaneous costs to initial investment
- V= ratio of assessed valuation of solar energy system in first year to initial investment
    - of the system
- R_v= ratio of resale value at end of period of analysis to initial investment [2,3]

Each PWF (N,i,d) term is the present worth factor calculated from the three given parameters using equation 5.2.2.4. This factor is useful for calculating the present worth of a series of regular future payments, discounted at a rate of d, over N years at an inflation rate of i.

$$PWF(N.i.d) = \sum_{j=1}^{N} \frac{(1+i)^{j-1}}{(i+d)^{j}} \qquad (5.2.2.4)$$

There is the implicit assumption that the variables (such as inflation rate) will not change over the course of the analysis, a reasonable assumption when the analysis lasts over a few years. However, for solar to be profitable, much longer analysis must be employed [2,3,4].

5.3 System specifications

In the sections below there is a description of the systems specification used for the LCC. It is intended to give as exact as possible values for a better understanding. The prices presented here have been selected after contacting various companies and local plumbing contractors [10]. However these prices are can be different depending on the companies.

5.3.1 Electric water heater

This section describes each one of the financial inputs used for the economic analysis. The first type of water heater considered is the electric water heater. As mentioned at the introduction the systems were selected from a list of electric water heater companies, based in U.K and U.S.A. The prices, which satisfied the system's specifications, were taken after contacting companies based in U.K. The type of electric water heater was selected from "A.O Smith Water Products" [8], using an ELJF –190L (see Appendix 1) water heater. The cost of the system was determined equal to £1184 (£584 for the electric water heater + £600 installation costs).

This cost estimate was also obtained from a plumbing contractor [10]. It includes electrical wiring and circuit breaker materials and installation, connection to hot/cold water piping stub outs. Also included in the cost of a separate electrical service to serve only the water heater. Hot and cold water distributions are not included as this is common to all heater types being compared.

5.3.2 Electric water heater and solar systems

The total cost of the system is plus the actual cost of the flat plate solar collector system. According to companies prices for an open loop flat plate collector between 2-7 m^2 is £2000-£4000 [11]. It was decided that a high efficiency flat plate collector to be chosen where the cost of the system is £2950 [9] (4m^2 collector area suitable for 4-5 persons). The installation cost for the system is included in the price. The system includes flexible tubing, pump, fitting, and control unit, temperature sensor. The total cost of the system including the electric water heater as a back is raised to £4134.

Similarly, the evacuated tube system is supplied by a company called “Solarsence” [20]. The tubes themselves are manufactured by “Thermomax” [12]. A typical 20 tube system comprises manifolds, pre-insulated high hot water cylinder, circulation pump, valves, pipes and fittings, digital controller with temperature read outs, pipe insulation and antifreeze. A fully installed system, including VAT (5%) costs £3390. If the cost of the back up electric water heater is added (£1184 including installation) then the total cost is raised to £4574.

Similarly, the same procedure has been followed for passive system. A drain back system supplied from “AES Ltd” [13] has been chosen for comparison with the two active systems described above. The total cost of the system is £3639 including installation (£2455 for the drainback system + 1184 for the electric water heater as back up).

5.3.3 Gas water heater

The total cost of the gas water heater plus installation was estimated as £1610. This cost is based on a system using an “MHS Boilers” [22], using a “Tudor NHRE 18” 185L gas water heater. The cost of the water heater itself is £710 plus the £900 cost obtained from a plumbing contractor [10] based on a number of assumptions regarding the specific installation. All water heating system components and installation costs specific to the gas water heater were accounted for in order to allow a meaningful comparison to electric and other water heaters. The cost estimate includes the water heater share of the pipe gas line material and installation and connection to the hot/cold pipe stub outs. A typical installation diagram of a gas water heater is presented in Appendix 2.

5.3.4 Gas water heater and solar systems

As above, the same solar systems are going to be used. The cost of the solar systems plus the gas water heater is increased. Using the flat plate solar water heating system, the cost is £4912 including installation (£3302 for the system +1610 for the gas back up). Similarly the cost of the evacuated tube collector has increased to £5352 (£3742 for the system + £1610 for the gas back up). The same system from “AES Ltd” [13] was examined as before. The total cost of the system including installation and the gas water heater has raised to £4417 (£2807 for the drain back system + £1610 for the gas water heater as back up).

The main reason for that is the active systems require an extra storage tank when the gas water heater is used where the price of the tank is £352 [14], as they cannot be used with single tank. It was attempted to find the best prices for the systems in order to have a meaningful comparison between the electric and the gas back up water heaters.

At this point it has to be mentioned that the accuracy of installed costs will vary from contractor, location and the number of system involved. Additional cost associated with additional structural works depends on the system installed weight and the load bearing capacity of the existing roof structure. Other costs not included here may be associated with some installations include added space for solar water heater equipment and the cost of building details designed to integrate the solar collector in the roof system so they are less visible.

5.4 Financial inputs

All the examples have been analysed in such a way that it was assumed the homebuyer is purchasing a home in a residential area with no financed amount. However the spreadsheets can be used even if an amount is financed on the total home loan amount borrowed.

5.4.1 Loan term and interest rate

A loan term of maximum 360 months was used for the examples, as a 30-year mortgage equals to 360 months. All the examples assume a 10, 15, 20, 25, 30 years mortgage, as this is common both for new home purchases as well as refinancing for an addition or remodel. The maximum 30 years mortgage is a typical example but the proposed analysis can be used in whatever time is required.

An interest rate of 8% was assumed for this example as the most possible lending rate for the exact period. As before this is only an assumption. The financial rates vary with the prime lending rate. For a better analysis an exact value might have better results. It has been noted that the cost effectiveness of solar water heaters is improved at lower financing rates, longer mortgage period and lower down payment.

5.4.2 Nominal discount rate

A nominal discount rate of 7.5% was taken for the examples. This therefore assumes a real discount rate of 5.5% [16] along with the inflation rate of 2.0% for the year 2001 [15]. This results in a nominal discount rate of 7.5 %.

The discount rate is highly variable and being that is therefore independent on a specific application. Here it is not intended to be represented as a fixed suitable value to all installations. The examples do not assume a risk adjusted discount rate. That means it was taken as no difference between the solar and the non-solar cases. Discount rate will vary with each particular households economic situation. The discount rate was basically selected based on criteria for the given application.

5.4.3 General inflation rate

A general inflation rate of 2.0% was selected for all the examples using year 2000 [15] as the reference. It was assumed that the inflation rate would remain almost the same or nearly to 2.0% for the net 30 years. The inflation rate is a general estimation and it is based from data based on the “Bank of England” website data. The actual future might be different from the data presented here. But in order to move to a meaningful analysis of then solar water heaters some assumptions have to be made without considering any other economic parameters.

5.4.4 Income tax

An income tax of 20% was selected for the example using an average annual salary of less than £29000 [16]. For higher than this amount the income tax bracket increases to 40%. As it was mentioned the income tax has been chosen as average. For higher salaries, there might be a difference in saving cost. The chosen value it is not intended to be a representative for as a fixed value suitable for all.

5.5 Maintenance& replacement costs

Repair and replacement costs are so central to the success of solar water heating. On the other hand they are difficult to obtain. Again it has to be mentioned that the replacement and repair cost depends on the manufacturer and the type of the system used. The reason for this is the best approximation of the life cycle costing. For gas and electric water heaters replacement varies from quality of materials made from and companies specifications. The life of a water heater depends not only on its construction but also on the type of use. Commercial water heaters have a shorter life than residential heaters. Some other factors are the amount of use, degree of regular maintenance water quality and water temperature set point.

The cost of replacing a solar system or system component varies considerably with the type of the system and the effort required to service failure components. Again the serviceability of the solar system components is another major factor. The cost of replacing the solar unit itself is included when failure components cannot be serviced. From a general view, pumps differential controllers, collector sensors, special valves and solar storage tanks need to be replaced every 10-15 years. The collector unit by itself most of the time lasts 20-30 years.

5.5.1 Pumps

Pumps are the solar water heater components most frequently replaced. The most common pumped systems are draindown, drainback or closed loop. Circulating freeze protection systems were not so often found. Drainback systems experience the most pump failures, generally due to insufficient reservoir fluid levels. These were the most expensive to replace due to their size, head requirements relative to the pumps found in other type systems. Below there is a summary of findings after conducting companies working with solar water heaters.

The average age of pumps replaced varies between 5-10 years. The oldest pumps were mostly found in closed loop systems and have never experienced any problems such as pressure loss. They also appeared to have little or no air loss. The most common reasons causing a pump failure according to research are:

- Plumping leaks, affecting pump and electrical
- Air in the pump (cavitation)
- Overheating which is a product of poor system design, such as underside pump or improper collector area to storage volume ratio.

The average cost of a pump varies from one company to other. According to "Imagination Solar Ltd" [22], a pump unit with 3 litres drain back for 1 panel including drain back vessel, power supply, controller, radiation sensor and tank sensor, costs £298.31

5.5.2 Controls

"Energy Engineering" [21] was the company conducted to get all the appropriate information for controls. According to company's information most controls are a matter of replacement. It could be possible to have the electronic circuit repaired but that happens very rarely. A large part of the repairs involving simple controls had to do with sensors (thermistors) replacement and not the control itself. Actual control failures were rather uncommon. Below there are some useful data for control's cost and replacement:

- Average price of differential control unit: £95.00 to £185.00 (Depends on facilities and Digital Readout includes Sensors) retail prices.
- Average age of controls replaced: 20 years
- Average control replacement service: (Cost to replace Labour + travelling) £45.00 + tax 25 miles radius
- Average repair control cost: Not economic to repair.

According to search the most common causes of sensor or control failure are moisture, in the case of thermistors, and improperly water proofed wiring connections. With controls the problem is often due to improper plumping leakage.

As it was mentioned replacement of thermistors is quite cheap and reasonable and would not cot much. In case of controls with digital readouts, especially those multi-loop systems could be very expensive to replace them. The actual cost may increase if the labour costs considered.

5.5.3 Collectors

In terms of lifetime and replacement this is the most difficult section solar water heating system component to evaluate. From the companies conducted just a few of them were not able to give an exact average replacement age. Most of them certified that the solar collectors would last for at least 20-25 years.

There is the possibility for the solar collectors to be replaced earlier than a company proposed. According to discussion from a plumping contractor [10], the main reason that solar collector replacement is highly acidic or alkaline fluid and poor mounting. In a drain back or closed loop system the pH and mineral content can be controlled.

5.5.4 Tanks

This section tries to give a brief overview about tanks, including four port water heaters, stainless drainback. Also some other types of storage tanks are considered (i.e. glass-lined steel, polypropylene). The most common cause of premature glass lined steel tank failure are the leaks in plumbing above the tank causing outside corrosion. The main problem arises from the fact that tank replacement is not so common. Therefore the findings may not be as accurate as the other parts of solar water heaters.

According to research the average age of tanks replacement varies between 9-12 years. Like the other parts of solar water heater the cost of the tank varies from one company to another. The prices are £140-£350 for tanks with storage capacity 100-190L [13,14]. It is possible for some passive thermosiphon tanks to be repaired.

5.6 Environmental value

The environmental value more commonly referred to as "environmental impact" class of "externality". The quality of the environment now and in the future is an important issue worldwide. For this reason externalities are beginning to show up in the decision making process, but in limited ways. In general the social cost of gas and electricity generation can apply to environmental impacts, impacts on production and trade balances. Unfortunately due to the limited amount of resources externalities were not applied to the "Life Cycle Costing". It would be quite interesting if externalities could be calculated and determine the difference in savings using solar water heaters.

5.7 Performance rating of systems

The thermal performance rating is based on the system design and performance projections derived from testing of the collector components. These components are used in the systems or from testing and evaluation as a whole. The type of auxiliary system (e.g. gas or electric) utilised will have a large impact on the overall performance of the system. These differences arise because different types of auxiliary systems have varying stand by losses and fuel conversion efficiencies. Although the auxiliary system may affect the solar system's performance, the solar output is mostly independent of the auxiliary system used. Because gas back-up systems have lower efficiencies and higher stand by losses than do electric systems, it should be expected that the entire system's performance will be lower even if the solar output from both system types is equal.

5.7.1 Solar Energy Factor (SEF) & Solar Fraction (SF)

According to "Solar Energy Certification Corporation" (SRCC) [6], Solar Energy Factor (SEF) is used for performance rating for solar domestic water heating systems. The SEF is defined as the energy delivered by the system divided by the electrical or gas energy put into the system. The SEF is presented as a number similar to the Energy Factor (EF) given to convectional water heaters [6].

$$SEF = \frac{Q_{DEL}}{Q_{AUX} + Q_{PAR}} \tag{5.8.1.1}$$

Q_{DEL} =Energy delivered to the hot water load (kWh)

Q_{AUX} =Daily amount of energy used by the auxiliary water heater or back up element with a solar system (kWh)

Q_{PAR} =Daily amount of energy used to power pumps, controllers or any other item needed to operate the SDWH (kWh).

The SEF can be converted to an equivalent solar fraction (SF) as follows.

$$SF = \frac{EF}{SEF} \tag{5.8.1.2}$$

The solar fraction is the portion of the total convectional total heating load (delivered energy and tank standby losses) provided by solar energy. Sometimes an alternate definition for solar fraction is used. In this definition, SF is the portion of the water heating load (losses not included) provided by solar energy. The alternate method of calculating solar fraction will yield higher solar fractions [6].

According to data from companies [17], solar water heaters can achieve 1500-2000 kWh/year. For the entire systems used, the companies were conducted and found that the solar fraction for each one of the systems is as follows.

a) Electric water heater + solar system

- Flat plate: 0.530
- Evacuated tube: 0.508
- Drain back: 0.463

For flat plate and evacuated tube (active systems) it required additional 150-200 kWh/year for pump and control in the case of gas water heater as back up.

b) Gas water heater + solar system

- Flat plate: 0.365
- Evacuated tube: 0.351
- Drain back: 0.319

5.7.2 Fuel cost

The rates assumed for the example were obtained form “Scottish Power” [18]. The average rates for electricity and gas are 7p/kWh and 3.1p/kWh respectively. Because fuel costs depend on usage, solar savings and weather conditions as a function of the time of the year, average residential rates were used for simplicity.

This fact can have significant impact on the total savings associated with a particular system. This is easily explained if it is assumed that a home has an electric water heater and the monthly electricity usage with water heating subtracted out, has already used the baseline electricity allowance. All of the solar water heating savings for that month would be at the higher marginal cost.

5.7.3 Fuel escalation rate

The rates assumed for the example are the same as inflation rate for the next 30 years. Generally the fuel escalation rates are an estimate of future costs of fuel and are based only on current available sources of data. Here it was assumed as 2.0% due to difficulty of obtain this kind of information.

5.7.4 Fuel usage

The estimated fuel usage based on data obtained from water heater companies. The annual energy used of a standard water heater varies between 3000-3500 kWh/day [8,9,19]. Assuming that an average house needs about 3200 kWh/year for water heating the annual cost of operation is as follows:

For electric water heater: $3200 \times$ Unit cost of fuel (£/kWh)= 3200×0.07 £/kWh=£224

For gas water heaters: $3200 \times$ Unit cost of fuel (£/kWh)= 3200×0.031 £/kWh=£99.2

Considering now the solar systems with electric and gas back up water heaters.

a) Electric water heater + solar system
   - Flat plate: $3200 \times (1 - SF)$ $\times$ Unit cost of fuel (£/kWh)= $3200 \times (1 - 0.530) \times 0.07$ £/kWh=£105.28
   - Evacuated tube: $3200 \times (1 - SF)$ $\times$ Unit cost of fuel (£/kWh)= $3200 \times (1 - 0.508)$ $\times$ 0.07 £/kWh =£110.21

- Drainback: $3200 \times (1 - SF)$ $\times$ Unit cost of fuel (£/kWh)= $3200 \times (1 - 0.463)$ $\times$ 0.07 £/kWh =£120.29

Total savings per year:

- Flat plate: £118.72
- Evacuated tube: £113.79
- Drainback: £103.71

b) Gas water heater + solar system

- Flat plate: $3200 \times (1 - SF)$ $\times$ Unit cost of fuel (£/kWh)= $3200 \times (1 - 0.365)$ $\times$ 0.031 £/kWh=£62.99
- Evacuated tube: $3200 \times (1 - SF)$ $\times$ Unit cost of fuel (£/kWh)= $3200 \times (1 - 0.351)$ $\times$ 0.031 £/kWh =£64.38
- Drainback: $3200 \times (1 - SF)$ $\times$ Unit cost of fuel (£/kWh)= $3200 \times (1 - 0.319)$ $\times$ 0.031 £/kWh =£67.55

Considering also the case of an additional amount of about 200 kWh/year energy required for the pump costing: 3200$\times$Unit cost of fuel (£/kWh)= 200×0.07 £/kWh=£14

Flat plate: £62.99+£14=£76.99

Evacuated tube: £64.38+£14=£78.38

Drainback: £67.55+£14=£82.55

Total savings per year:

- Flat plate: £39.5
- Evacuated tube: £20.82
- Drainback: £16.7

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Bank of England". At the end of April 2000 the inflation rate was 2.3%. Similarly at the end of April 2001 the inflation rate was 1.8%. A value of 2% was assumed

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CHAPTER 6: DISCUSSION, CONCLUSIONS & RECOMMENDATIONS

6.1 Introduction

The project overall referred to solar water heaters, their impacts in Europe and some countries from the rest of the world. There was a quantitative and reliability survey to examine people's opinion about the solar water heating technology and finally a Life Cycle Cost example in order to make a meaningful comparison with gas and electric water heaters.

In Chapter 1 there was a brief overview of the most common solar water heating system today. Some useful information about components and types of systems was provided. Also there was a brief description about the new development systems and a comparison with the systems extensively used nowadays. Chapter 1 concluded with the benefits of solar water heater.

In chapter 2 there was greater emphasis on the types of solar collectors used, the materials for collector components and heat management and storage. Each type of solar collector was described analytically with its advantages and disadvantages. Materials for flat plate collector components were examined carefully stating the appropriate materials used comparing each one separately. Finally Chapter 2 concluded with the antifreeze solutions most commonly used.

Chapter 3 was a basic overview of the solar water heating market around Europe and some countries of the world. Special attention was given to U.K market where the current situation was explained. There was an overview of the most common systems used as well as an estimation of price range. In this chapter there was a discussion about the results of the reliability and quantitative survey, economic analysis and some strategic guidelines for better market development of SWH in the U.K. As it was mentioned in Chapters 4 and 5, all the work been done is only based on sample data and it cannot considered as official for today's situation of SWH in U.K. However some useful results can be drawn.

6.2 Discussion of reliability and quantitative survey

As it was referred on Chapter 4 the main objectives were to identify the areas where the most problems occur when dealing with a solar water heater and to investigate, based on people's opinion, how popular is solar technology in U.K compared to data collected from Greece.

Freeze protection was one major problem, especially in U.K., where it is a common fact for temperatures to fall below 0°C. It was mentioned that the problems were caused usually to pipes. The main reason for freezing is usually pump failure and power protection. As a solution it would be proposed that the pipes should be heavily insulated and wrapped with protective tape or other materials where exposed to outdoors.

The next problem was the overheat protection where the system was not operated for a day or longer or the storage tank is too small compared to collector area. Different methods for overheat protection was mentioned for active and passive systems. A good solution would be the purchase of a system, which is 100% appropriate for climate and pattern of hot water use. Also the systems used occasionally it should be covered to be protected in some way from overheating.

An interesting area of problems caused is when the SWH start to perform poorly due to mineral deposits or debris collects in the system. Most of the companies interviewed, mentioned that poor water quality could lead to early pump and tank failure. Corrosion and scaling are the two most common problems resulting from poor water quality. Corrosion always caused from acidic water, while scaling caused in areas with hard water. When dealing with poor water quality it is difficult to suggest a specific solution. An alternative choice would be the checking of water quality before installing any system to ensure that water is appropriate and therefore to avoid problems in the near future. However if it is not feasible to avoid hard water use it could be suggested the frequently cleaning of the system.

Two of the main important devices in SWH systems are the mixing and tempering valves. Their main task is to mix hot water with cold water. There is not an exact solution to be proposed for mixing and tempering valves. The only thing that can be proposed is careful installation.

Next thing considered was the storage tank failure, especially those manufactured with fibreglass. The most appropriate proposed high quality storage tanks are the stainless steel tanks. However they can fail as well, especially when high temperatures occur. As a solution it would be proposed, that the temperatures to be kept as low as possible when dealing with fibreglass tanks. It could be suggested also to have an expansion tank if a pressure reducer is used on the supply.

The most interesting part of the survey was the quantitative survey where opinions of responders from two different countries were compared. The question areas had been studied and the most appropriate answers had been chosen before sending the data to SWH companies and to Greece. As it was mentioned, the research was not based on official data but on the people's personal opinion. Some useful results have been obtained which show what people believe for solar water heating status. There were not many points that responders declared the same opinion.

It is important to say that the cost of a SWH system was one of the main reasons respondents considered as negative in both countries. Although the cost of the solar system in U.K. cannot be compared with a system in Greece, Greek people think that it is still expensive.

Technology plays a central role in British people's lives as more than 50% answered that any information related to solar water heating has been obtained from Internet. At this point it must be reminded again that the results from Greece obtained from a village with 3000 residents, where according to experience people in villages are not familiar with Internet compared to cities. Therefore only 1% has gained information using web pages. The main source of information for Greek respondent was advertisements on T.V and radio (58%) and seen installed on house roofs (87%).

British people seemed to trust more the traditional sources of water heating like gas and electricity (93% and 90% respectively), although quite a few (32%) are aware of solar systems as a water heating method. This percentage was far behind the one obtained from Greece as 95% answered positive to awareness of solar water heating. At this stage a good point to be mentioned is that gas is not so popular to them as only 2% responded that solar system with gas or as a back up, can be used.

The factors considered for purchasing solar water heating system is the price of the system fully installed the hot water delivery and the type of warranty that companies offer. Responders from countries answered positively with percentages reaching more than 80%. British people seem to consider more the environmental impacts of SWH compared to Greeks (47%). Important is the brand name for Greeks as at present, there are quite a few manufacture companies of solar systems.

Maintenance costs and weather conditions are the two main reasons for discouraging British people from obtaining a solar water heating system. Life cycle costing comes to prove the above fact as discussed more analytically below. Maintenance cost are also quite in U.K compared to Greek standards. The case of replacement costs has not been considered for the reason that it would decrease people's interest.

6.3 Discussion of Life Cycle Cost (LCC) method

The life cycle cost was carried in an effort to investigate the total system, the effective cost and total savings for a period of 30 years. It has to be remembered again that the data was obtained from companies and they are not representative for every system. The most common systems considered are the ones that are extensively used around U.K such as systems with flat plate collectors, systems with evacuated tube collectors and drainback systems. The main task was to complete the life cycle costing using as accurate as possible economic input data in order to make the system more reliable to people.

The main purpose of the example considered was to provide a meaningful comparison of the two most common sources, as obtained from Chapter 4, electric and gas water heating. Both of them were examined individually and as back ups to various solar systems. The life cycle costing method has been followed for two separate cases. Firstly it was assumed that not amount was financed and secondly a financed amount of 20% considered.

The important part of the analysis was to choose the appropriate systems suitable for each occasion. The gas and electric water heater should meet the daily demand of hot water for an average family as well as being economically feasible. Considering the fact that the price of each system differs from one company to another and many companies concentrate on production of either gas or water heaters only, it was quite difficult to meet the cost limits set from the beginning

Using one of “A.O.Smith” the electric water heater was selected with a price of £584. Similarly the gas water heater was selected from “MHS Boilers” with a price of £710. The problem was that in the price of water heaters were not included any installation cost. A plumping contractor was contacted in order to give have a good estimation of the installation costs.

The same procedure was followed for the choice of the appropriate solar systems. According to research carried out during the project’s duration, there are many companies, which manufacture and install solar systems and more specifically, they concentrate on water heaters. It was assumed that the solar water heater could withstand the demands of an average family house of 4-5 persons. The flat plate collector considered first. A high efficiency model with a collector area of $4m^2$ was selected. The system included flexible tubing pump, fitting control unit and temperature sensor.

An evacuated tube collector supplied by “Solarsence” was chosen as the appropriate one. That system consisting of 20 tubes, compromises manifolds, pre-insulated high hot water cylinder circulation pumps and valves. Finally a drainback system supplied from “AES Ltd” was selected in order to have a better comparison between the systems.

All the examples were considered in such a way that is assumed the homeowner purchases a house with no amount being financed. It was decided that life cycle costing would be used for a term of maximum 30 years. An interest rate of 8% was assumed as a typical lending rate for the specified period of analysis. Income tax was taken as 20% based on an annual salary of less than £29000. All the financial inputs were obtained through research and conducts with persons familiar with financial inputs.

Maintenance and replacement costs were not considered with specified prices but based on assumptions. Generally replacement and maintenance costs vary from system to system. The material quality of each component and companies specifications for each system, are the two factors considered to be crucial for exact estimations. Therefore, it was not possible to be considered with exact valued. However a specific method was followed for the best results.

Environmental and externality values were not considered in life cycle cost analysis due to the limited information sources.

For the electric water heater, every 5 years £100 had to be spent on maintenance costs. The system was supposed to last a maximum of 15 years. That year a replacement system cost was considered. The same procedure was followed with the gas water heater considering the replacement cost after 15 years of system's life.

In the case of solar water heating systems the method followed was different compared to first one. A standard maintenance cost of £50 was assumed for every single year. There was no exact answer from companies for maintenance costs therefore it was decided the least amount to be used. The electric or gas waters used as back up had to be replaced every 15 years. Also a replacement cost of £250 was considered every 10 years for pumps, controls or valves.

6.3.1 Annual fuel cost and total savings

The graph below (figure 6.1) shows the electricity and gas annually cost for a period of 30 years. In order to complete the life cycle cost example some prices for the electricity and gas had to be obtained. It was assumed that the prices for fuel cost and electricity as on peak due to the different rates in off peal values. It was taken for electricity £0.007 p/kWhr and for gas 0.031 p/kWhr.

It is clear that the electric water heater required starts with an annual cost of £224, where after 30 years the total electricity cost has reached almost £400. The electricity cost required for the electric water heater is far greater compared to other sources of water heating. The rest of the systems the cost for the first year is estimated between £75-£120. The lowest cost is for flat plate collector using gas water heater as back up.

By the time that the electric water heater required higher annual operating cost, and the solar systems with electric water heaters as back up were required almost less than £100 for only the first year, it was assumed that the total electricity savings would be very high in the case of the solar systems using electric water heater as back up. The graph below (figure 6.2) shows the total annual savings for the period of 30 years. The total saving of solar systems using electric water heater are greater than the systems using gas water heater. More specifically for the flat plate collector, they starts with £118 for the first year and at the end of the 30 year period analysis the savings have raised to £210. At the same time using a gas back up heater using the same solar system start with nearly £22 and by the end of the 30 year period the total savings have reached only to £39.

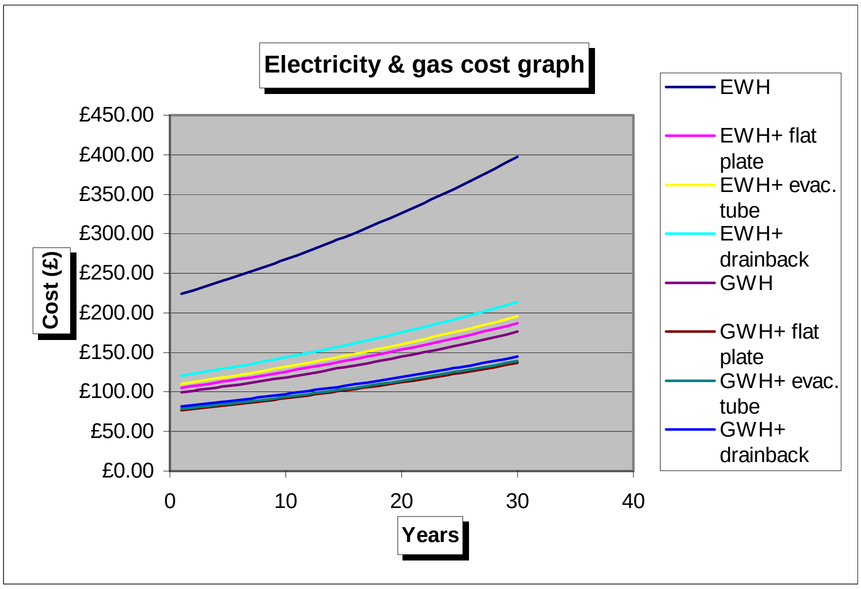


Figure 6.1: Electricity and gas cost graph

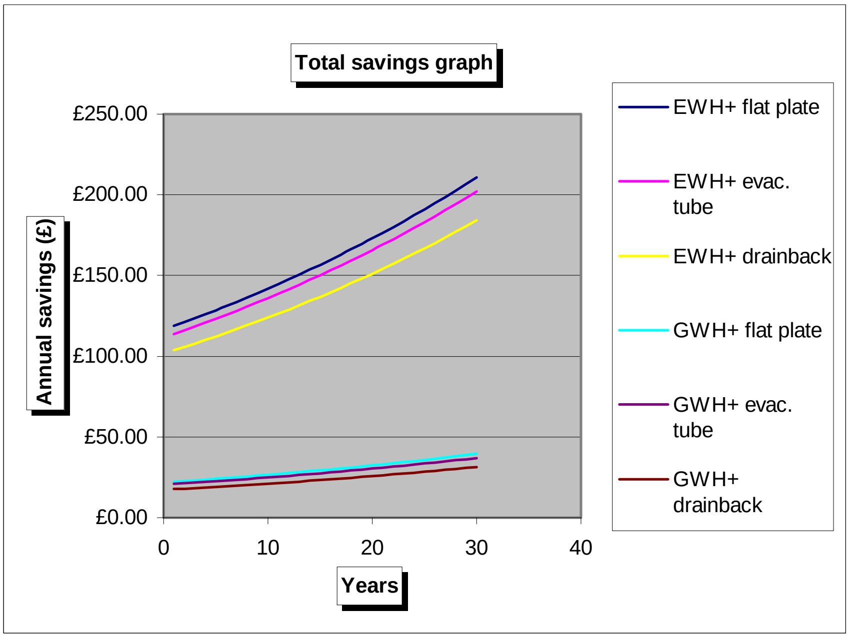


Figure 6.2: Total savings graph

6.3.2 Effective cost

The effective cost is the cost to install, maintain, fix, replace and operate the water heating system over a 30 year period (figure 6.3). In this case the gas water heating system is the least costly option followed by the electric water heater. The solar systems, which use electric or gas water heaters as back up, are far more expensive. Gas water heaters used with evacuated tube collector is at the top with a total effective cost of more than £500. The cheapest option from the solar systems is the electric water heater with the drainback system with a total cost about £470.

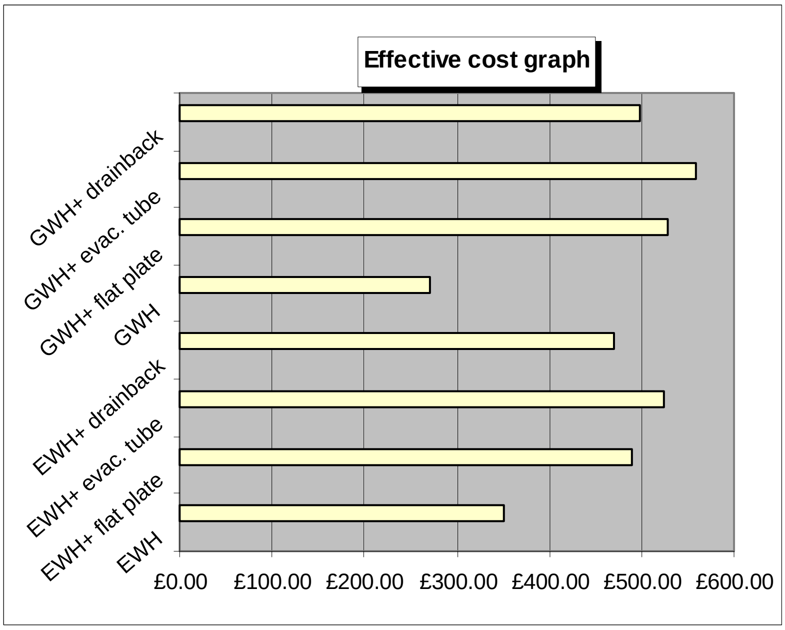


Figure 6.3: Effective cost graph

Similarly the same procedure has been followed separately for gas and electric water heaters with solar systems, considering now the case where 20% of the amount has been financed. The main difference at this stage is the yearly loan payment for the amount financed. The annual loan varies depending on the initial system cost. For the systems which no amount has been finance there is no annual loan payment. For the financed amounts, the lowest annual loan payment is for drainback system with £291 and the highest for the evacuated tube with gas back up.

Even with the amount financed there is not big difference in effective cost. Considering first the case with electric water heaters, it still has the lowest effective cost with less than £400. There was expected a decrease in effective cost for the systems financed but as it can be seen from the graph the difference is least.

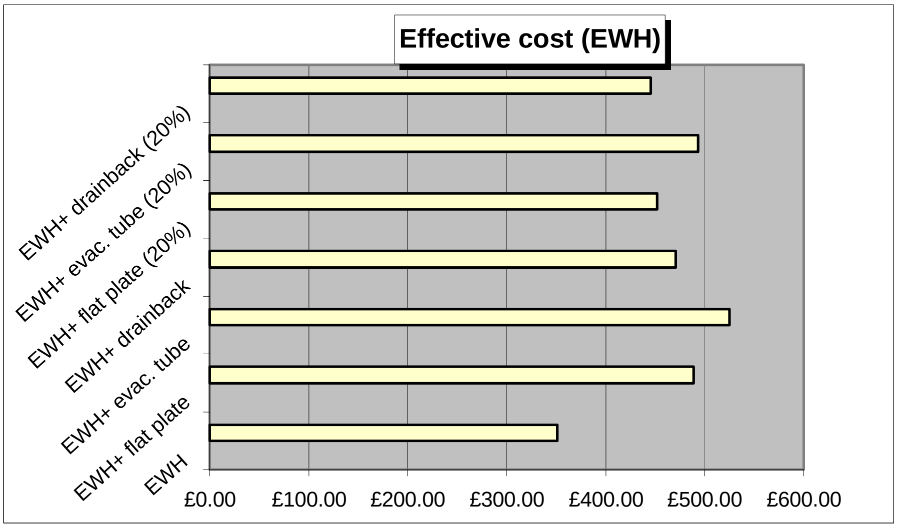


Figure 6.4: Effective cost graph (EWH)

Coming to the case of the gas, there is an obvious difference between the systems financed to those not. The effective cost of the financed systems is far lower than the other systems. For the financed systems the flat plate collector has got the lowest effective cost with only £215 pounds compared to drainback system with £498.

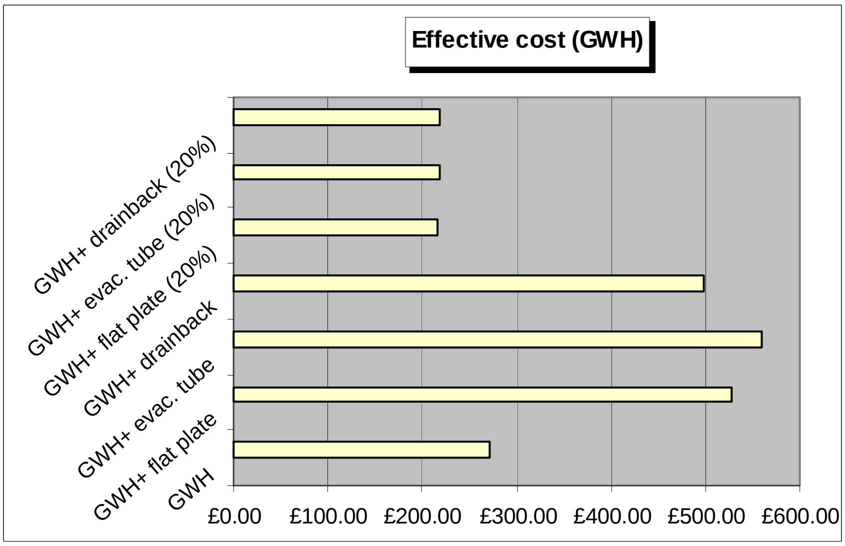


Figure 6.5: Effective cost graph (GWH)

6.3.3 Life Cycle Cost (LCC) results

As was mentioned on Chapter 5 the LCC is the sum of all costs associated with a system over a chosen analysis period, and is adjusted for inflation so that is reported in today's U.K sterlings. The basic objective here was to evaluate the justification of solar equipment. Gas water heater has the lowest value with less than £4000 where at the same time evacuated tube system with gas water heater exceeds £8000.

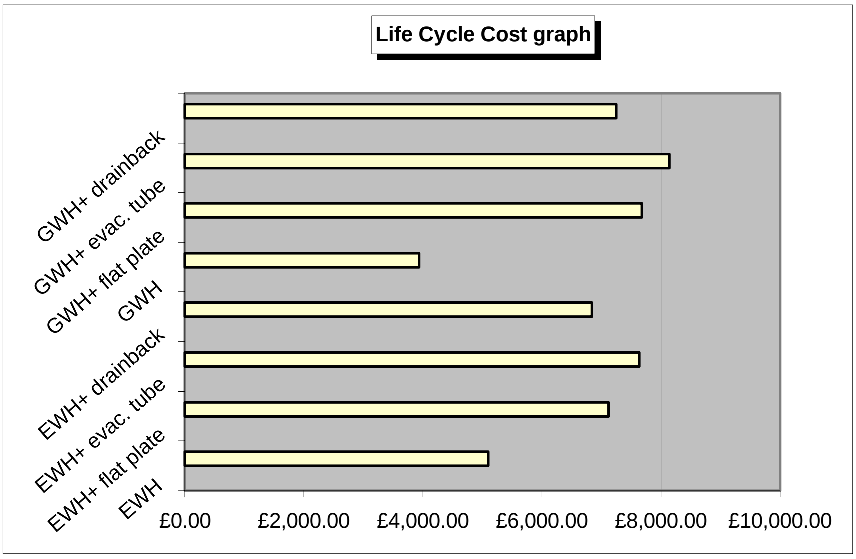


Figure 6.6: Life Cycle Cost graph

Similarly, considering the systems as before with the difference of amount financed for the systems, it is noticed that the electric water heater has the lowest value compared to other systems (figure 6.7). It was expected that the life cost of financed systems to be lower. From the graph it can be seen that the life cycle cost of an electric water heater with drainback system is lower than the evacuated tube system with 20% of the amount financed. The financed systems as it can be noticed from graph exceed the cost of £6000.

An obvious difference can be noticed in the case when gas water heaters are considered. Here the systems with 20% amount financed are over £3000 with the flat plate collector to be the least costly option (figure 6.8). The most costly is the evacuated tube with a life cycle cost exceeding £8000.

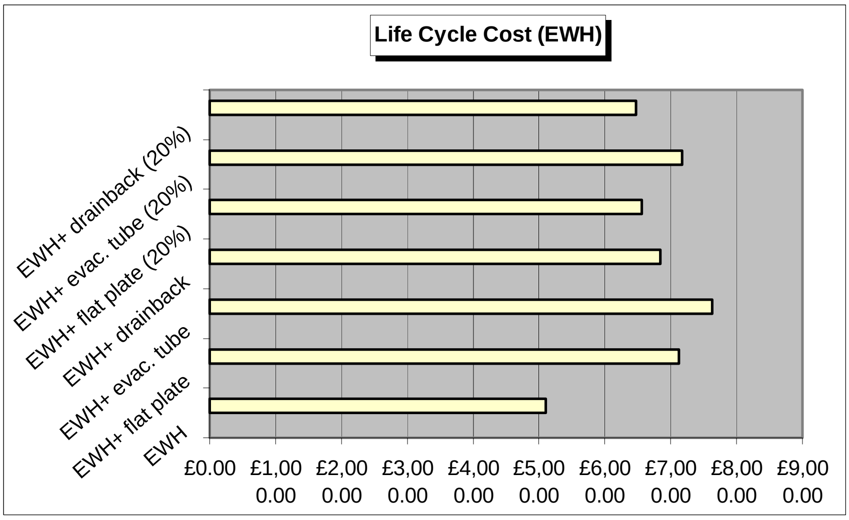


Figure 6.7: Life Cycle Cost graph (EWH)

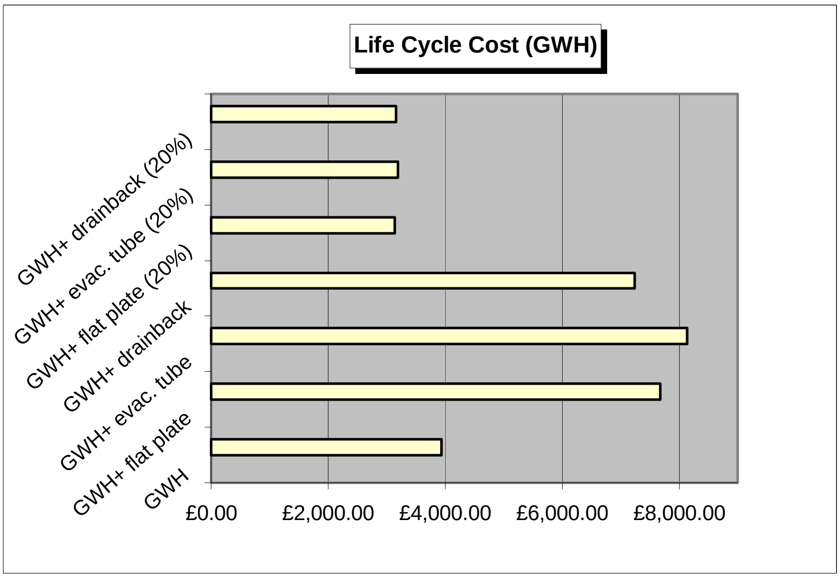


Figure 6.8: Life Cycle Cost graph (GWH)

6.4 Conclusion

Concluding the report it has to be mentioned that comparing to data obtained from the quantitative survey, reliability survey and life cycle costing, people seem to be a bit confused about the solar water heating industry today. It seems that there is not much trust in companies where this using components with cheap materials resulting to usual maintenance and in the worst case replacement. Especially in the U.K., they even prefer the traditional sources of water heating such as electricity and gas than using a solar system. Although they are aware of solar systems they don't trust them for reasons, more or less expected (i.e. cost of purchase and installation, maintenance expenses, weather conditions). It appears to be a lack of information, and that can be considered as a major disadvantage of companies' profile.

Life Cycle Cost example has come to prove what peoples believes. Considering just some sample data and making the appropriate assumptions it has been proved that overall to purchase a solar water heating system is expensive. But alternative solutions can be considered such as the use of a solar water heating system with gas water heater as back up which reduces the cost. Grants could be a good solution to encourage people of purchasing a solar water heater.

6.5 Recommendations

The guidelines have been produced in order to suggest some various methods and solutions for improvement and better information of the solar water heating technology. Quality problems, as mainly described in chapter 4, have given a bad name in solar water heating industry in the past. Although the problems occurred long time ago, people seem not to be confident having difficulties to trust today's improvements. As it was mentioned on chapter 4 the main problem concern the durability of the systems as well as problems related with installation and maintenance.

The only solution to keep the confidence of people is to manufacture systems reliable and operate according to specifications. Good quality components must be used with good quality installation. That will help to decrease maintenance cost and extend the system's life.

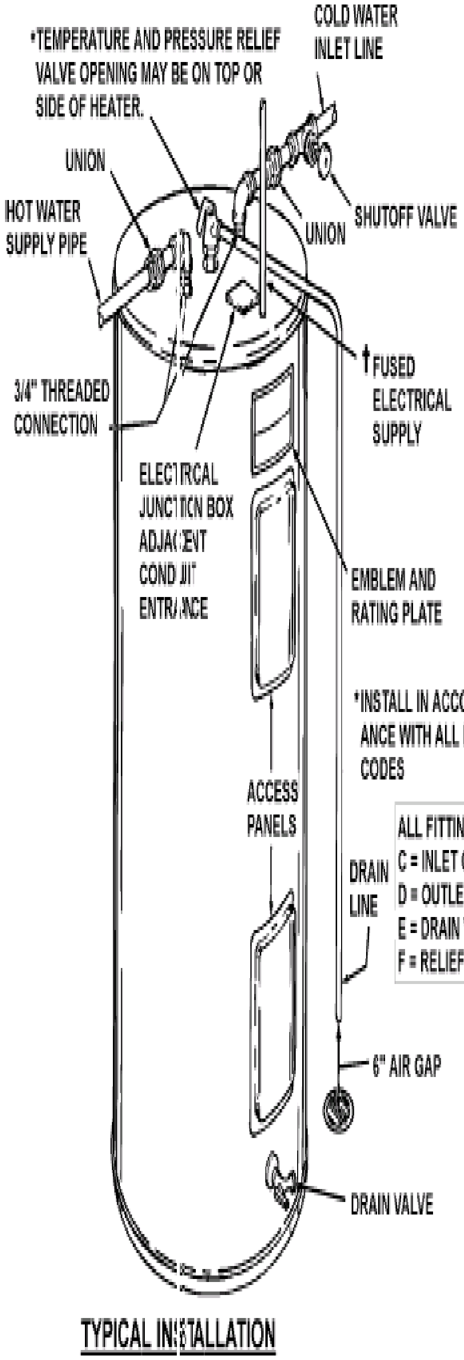
Considering the example of the Life Cycle Cost, it has been proved that maintenance and replacement cost can increase the overall cost of a solar water heating system to high standards even if a 30 year period is used. The installers should give longer-term warranties as this seem one of the major factors for people consider about.

Based on the research data from chapter 4 it seem like public awareness of solar water heating technology is low. People believe U.K does not receive enough solar energy for solar water heating systems to work efficiently. Advertising and general publicity must be increased and not only based on Internet information.

Grants to homeowners would be difficult to introduce but it is believed that it would have the largest impact to market growth. Based on the Life cycle costing analysis grants in some occasions do not make big difference (solar system + electric water heater) but on the other hand there are cases where grants would be a big advantage (solar system + gas water heater).

ENERGY SAVER

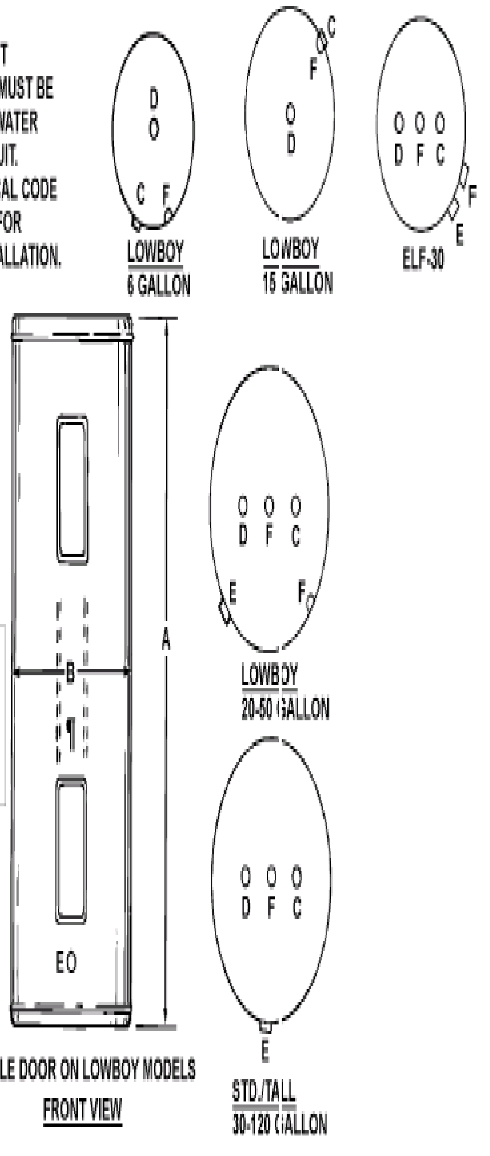
ELECTRIC GLASS-LINED WATER HEATER



TYPICAL INSTALLATION

†OVERCURRENT PROTECTION MUST BE SUPPLIED IN WATER HEATER CIRCUIT. CONSULT LOCAL CODE OR NEC-1984 FOR PROPER INSTALLATION.

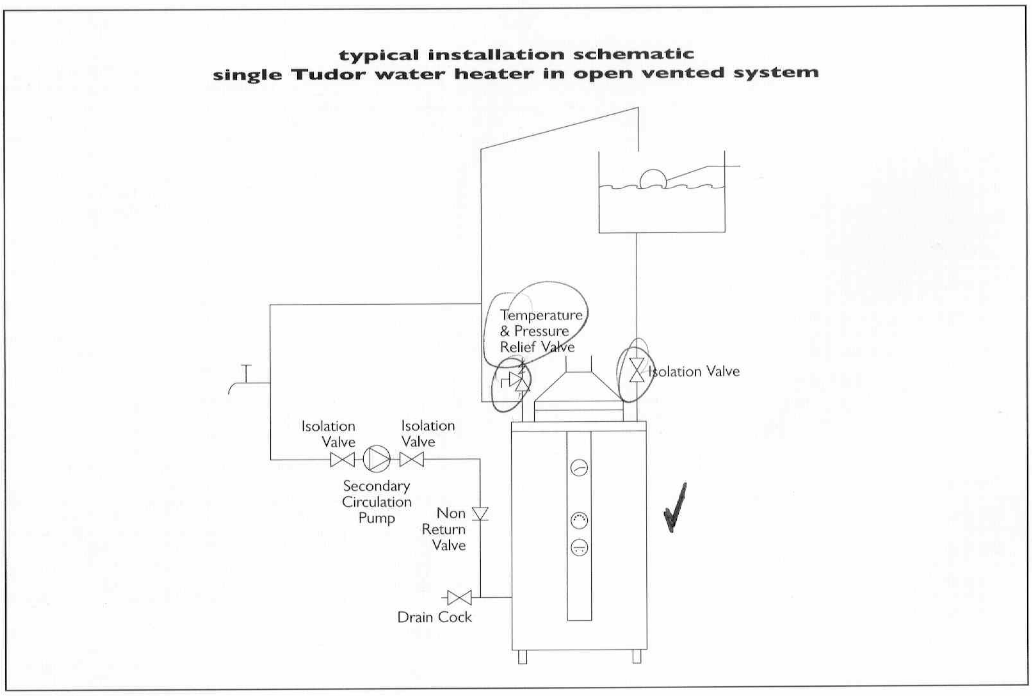
ALL FITTINGS 3/4" NPT
C = INLET OPENING
D = OUTLET OPENING
E = DRAIN VALVE OPENING
F = RELIEF VALVE OPENING

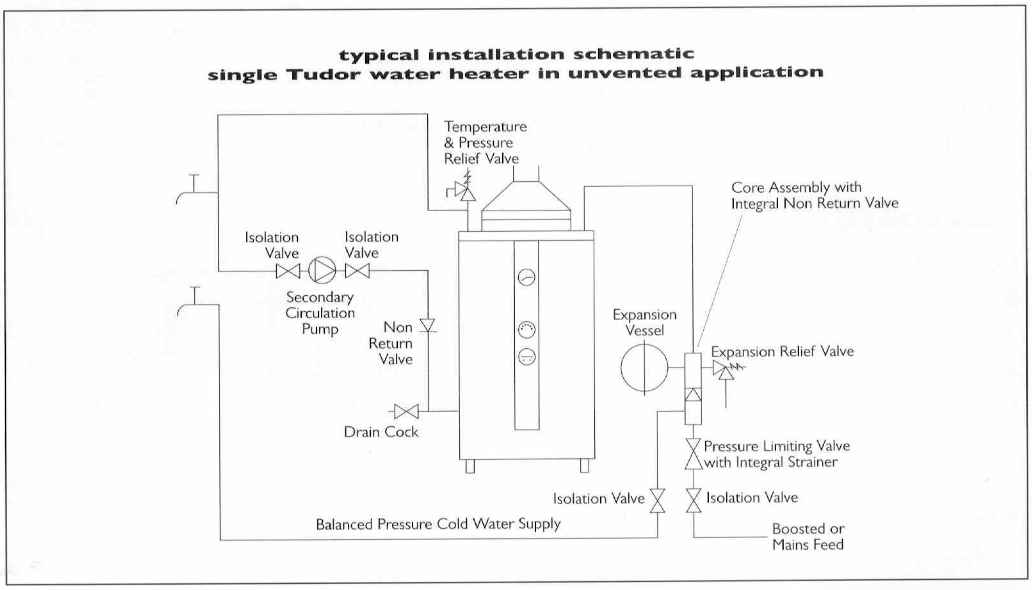


¶SINGLE DOOR ON LOWBOY MODELS

FRONT VIEW

TOP VIEW





unvented installations

Tudor water heaters are approved for use on unvented systems where the cold water feed is either mains fed or supplied via a break tank and booster pump.

In order to satisfy the requirements of the Building Regulations (G3) Tudor water heaters must be installed in conjunction with an additional kit of components (unvented kit) when serving an unvented hot water system.

Approved and matched unvented kits are available from MHS Boilers and comprise as a minimum the following essential safety controls:

- Temperature and pressure relief valve
- Pressure limiting valve with integral strainer
- Core (manifold) assembly with integral non return valve or individual components as applicable.
- Expansion relief valve
- Expansion vessel

LIFE CYCLE COST-Electric water heater

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			**ENERGY INPUTS**		
Installed Cost	£1,184.00	Electric water heater			
Amount Financed	£0.00				
Loan Term	360	Months			
Interest Rate	8.0%				
Real Discount Rate	5.5%		E5 Electric Usage (Base)	3200	kWhr/yr Base Elec Usage
Gen. Inflation Rate	2.0%		E6 Electric Cost	0.070	£/kWhr
Income Tax	20.0%		E7 Elec. Escalation Rate	2.00	%/year

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Anual cost
£5,101.63	£351.02

Yearly Elec Usage, kWhr/yr	3,200
Yearly Elec Cost, £/yr	£224.00

Real Elec. Escalation Rate	0.00%
Nominal Discount Rate	0.0761

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Interest Deduction	Maintainance Cost	Replacement Cost	Environmental Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Replacement Cost (Current £)	Environmental Value (Current £)
0	£1,184.00							£1,184.00			2.000	£0.00		
1		£0.00	£224.00	£0.00	0.00	£0.00	£0.00	£224.00	£0.00	£0.00	1.020	£0.00	£0.00	£0.00
2		£0.00	£228.48	£0.00	0.00	£0.00	£0.00	£228.48	£0.00	£0.00	1.040	£0.00	£0.00	£0.00
3		£0.00	£233.05	£0.00	0.00	£0.00	£0.00	£233.05	£0.00	£0.00	1.061	£0.00	£0.00	£0.00
4		£0.00	£237.71	£0.00	0.00	£0.00	£0.00	£237.71	£0.00	£0.00	1.082	£0.00	£0.00	£0.00
5		£0.00	£242.46	£0.00	110.41	£0.00	£0.00	£352.87	£0.00	£0.00	1.104	£100.00	£0.00	£0.00
6		£0.00	£247.31	£0.00	0.00	£0.00	£0.00	£247.31	£0.00	£0.00	1.126	£0.00	£0.00	£0.00
7		£0.00	£252.26	£0.00	0.00	£0.00	£0.00	£252.26	£0.00	£0.00	1.149	£0.00	£0.00	£0.00
8		£0.00	£257.31	£0.00	0.00	£0.00	£0.00	£257.31	£0.00	£0.00	1.172	£0.00	£0.00	£0.00
9		£0.00	£262.45	£0.00	0.00	£0.00	£0.00	£262.45	£0.00	£0.00	1.195	£0.00	£0.00	£0.00
10		£0.00	£267.70	£0.00	121.90	£0.00	£0.00	£389.60	£0.00	£0.00	1.219	£100.00	£0.00	£0.00
11		£0.00	£273.05	£0.00	0.00	£0.00	£0.00	£273.05	£0.00	£0.00	1.243	£0.00	£0.00	£0.00
12		£0.00	£278.52	£0.00	0.00	£0.00	£0.00	£278.52	£0.00	£0.00	1.268	£0.00	£0.00	£0.00
13		£0.00	£284.09	£0.00	0.00	£0.00	£0.00	£284.09	£0.00	£0.00	1.294	£0.00	£0.00	£0.00
14		£0.00	£289.77	£0.00	0.00	£0.00	£0.00	£289.77	£0.00	£0.00	1.319	£0.00	£0.00	£0.00
15		£0.00	£295.56	£0.00	0.00	£1,593.51	£0.00	£1,889.07	£0.00	£0.00	1.346	£0.00	£1,184.00	£0.00
16		£0.00	£301.47	£0.00	0.00	£0.00	£0.00	£301.47	£0.00	£0.00	1.373	£0.00	£0.00	£0.00
17		£0.00	£307.50	£0.00	0.00	£0.00	£0.00	£307.50	£0.00	£0.00	1.400	£0.00	£0.00	£0.00
18		£0.00	£313.65	£0.00	0.00	£0.00	£0.00	£313.65	£0.00	£0.00	1.428	£0.00	£0.00	£0.00
19		£0.00	£319.93	£0.00	£0.00	£0.00	£0.00	£319.93	£0.00	£0.00	1.457	£0.00	£0.00	£0.00
20		£0.00	£326.33	£0.00	£148.59	£0.00	£0.00	£474.92	£0.00	£0.00	1.486	£100.00	£0.00	£0.00
21		£0.00	£332.85	£0.00	£0.00	£0.00	£0.00	£332.85	£0.00	£0.00	1.516	0.00	£0.00	£0.00
22		£0.00	£339.51	£0.00	£0.00	£0.00	£0.00	£339.51	£0.00	£0.00	1.546	0.00	£0.00	£0.00
23		£0.00	£346.30	£0.00	£0.00	£0.00	£0.00	£346.30	£0.00	£0.00	1.577	0.00	£0.00	£0.00
24		£0.00	£353.23	£0.00	£0.00	£0.00	£0.00	£353.23	£0.00	£0.00	1.608	0.00	£0.00	£0.00
25		£0.00	£360.29	£0.00	£164.06	£0.00	£0.00	£524.35	£0.00	£0.00	1.641	£100.00	£0.00	£0.00
26		£0.00	£367.50	£0.00	£0.00	£0.00	£0.00	£367.50	£0.00	£0.00	1.673	0.00	£0.00	£0.00
27		£0.00	£374.85	£0.00	£0.00	£0.00	£0.00	£374.85	£0.00	£0.00	1.707	0.00	£0.00	£0.00
28		£0.00	£382.34	£0.00	£0.00	£0.00	£0.00	£382.34	£0.00	£0.00	1.741	0.00	£0.00	£0.00
29		£0.00	£389.99	£0.00	£0.00	£0.00	£0.00	£389.99	£0.00	£0.00	1.776	0.00	£0.00	£0.00
30		£0.00	£397.79	£0.00	£0.00	£0.00	£0.00	£397.79	£0.00	£0.00	1.811	0.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Electric Backup Water Heater
DRAINBACK SYSTEM

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			ENERGY INPUTS		
Installed Cost	£3,639.00	Drainback+Back up Heater	Solar Fraction	46.3%	
Amount Financed	£0.00				
Loan Term	360	Months			
Interest Rate	8.0%				
Real Discount Rate	5.5%		Electric Usage (Base)	3200	kWhr/yr Base Elec Usage (usage without solar)
Gen. Inflation Rate	2.0%		Electric Cost	0.070	£/kWhr
Income Tax	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Annual cost		
£5,862.99	£403.41		
		Elec, Usage (solar) kWh/year	3200.000
		Yearly Elec Cost	£224.00

		INDIVIDUAL YEARLY ECONOMIC INPUTS
Real Elec. Escalation Rate	0.00%	
Nominal Discount Rate	0.0761	

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Interest Deduction	Maintenance Cost	Replacement Cost	Environmental Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Cost (Current £)	Value (Current £)
0	£1,184.00						£0.00	£1,184.00			2.00			
1		£0.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.0200	£50.00	£0.00	£0.00
2		£0.00	£228.48	£0.00	£51.00	£0.00	£0.00	£279.48	£0.00	£0.00	1.0404	£50.00	£0.00	£0.00
3		£0.00	£233.05	£0.00	£53.06	£0.00	£0.00	£286.11	£0.00	£0.00	1.0612	£50.00	£0.00	£0.00
4		£0.00	£237.71	£0.00	£54.12	£0.00	£0.00	£291.83	£0.00	£0.00	1.0824	£50.00	£0.00	£0.00
5		£0.00	£242.46	£0.00	£55.20	£0.00	£0.00	£297.67	£0.00	£0.00	1.1041	£50.00	£0.00	£0.00
6		£0.00	£247.31	£0.00	£56.31	£0.00	£0.00	£303.62	£0.00	£0.00	1.1262	£50.00	£0.00	£0.00
7		£0.00	£252.26	£0.00	£57.43	£0.00	£0.00	£309.69	£0.00	£0.00	1.1487	£50.00	£0.00	£0.00
8		£0.00	£257.31	£0.00	£58.58	£0.00	£0.00	£315.89	£0.00	£0.00	1.1717	£50.00	£0.00	£0.00
9		£0.00	£262.45	£0.00	£59.75	£0.00	£0.00	£322.21	£0.00	£0.00	1.1951	£50.00	£0.00	£0.00
10		£0.00	£267.70	£0.00	£60.95	£304.75	£0.00	£633.40	£0.00	£0.00	1.2190	£50.00	£250.00	£0.00
11		£0.00	£273.05	£0.00	£62.17	£0.00	£0.00	£335.22	£0.00	£0.00	1.2434	£50.00	£0.00	£0.00
12		£0.00	£278.52	£0.00	£63.41	£0.00	£0.00	£341.93	£0.00	£0.00	1.2682	£50.00	£0.00	£0.00
13		£0.00	£284.09	£0.00	£64.68	£0.00	£0.00	£348.77	£0.00	£0.00	1.2936	£50.00	£0.00	£0.00
14		£0.00	£289.77	£0.00	£65.97	£0.00	£0.00	£355.74	£0.00	£0.00	1.3195	£50.00	£0.00	£0.00
15		£0.00	£295.56	£0.00	£67.29	£1,593.51	£0.00	£1,956.36	£0.00	£0.00	1.3459	£50.00	£1,184.00	£0.00
16		£0.00	£301.47	£0.00	£68.64	£0.00	£0.00	£370.11	£0.00	£0.00	1.3728	£50.00	£0.00	£0.00
17		£0.00	£307.50	£0.00	£70.01	£0.00	£0.00	£377.52	£0.00	£0.00	1.4002	£50.00	£0.00	£0.00
18		£0.00	£313.65	£0.00	£71.41	£0.00	£0.00	£385.07	£0.00	£0.00	1.4282	£50.00	£0.00	£0.00
19		£0.00	£319.93	£0.00	£72.84	£0.00	£0.00	£392.77	£0.00	£0.00	1.4568	£50.00	£0.00	£0.00
20		£0.00	£326.33	£0.00	£74.30	£371.49	£0.00	£772.11	£0.00	£0.00	1.4859	£50.00	£250.00	£0.00
21		£0.00	£332.85	£0.00	£75.78	£0.00	£0.00	£408.64	£0.00	£0.00	1.5157	£50.00	£0.00	£0.00
22		£0.00	£339.51	£0.00	£77.30	£0.00	£0.00	£416.81	£0.00	£0.00	1.5460	£50.00	£0.00	£0.00
23		£0.00	£346.30	£0.00	£78.84	£0.00	£0.00	£425.14	£0.00	£0.00	1.5769	£50.00	£0.00	£0.00
24		£0.00	£353.23	£0.00	£80.42	£0.00	£0.00	£433.65	£0.00	£0.00	1.6084	£50.00	£0.00	£0.00
25		£0.00	£360.29	£0.00	£82.03	£0.00	£0.00	£442.32	£0.00	£0.00	1.6406	£50.00	£0.00	£0.00
26		£0.00	£367.50	£0.00	£83.67	£0.00	£0.00	£451.17	£0.00	£0.00	1.6734	£50.00	£0.00	£0.00
27		£0.00	£374.85	£0.00	£85.34	£0.00	£0.00	£460.19	£0.00	£0.00	1.7069	£50.00	£0.00	£0.00
28		£0.00	£382.34	£0.00	£87.05	£0.00	£0.00	£469.39	£0.00	£0.00	1.7410	£50.00	£0.00	£0.00
29		£0.00	£389.99	£0.00	£88.79	£0.00	£0.00	£478.78	£0.00	£0.00	1.7758	£50.00	£0.00	£0.00
30		£0.00	£397.79	£0.00	£90.57	£0.00	£0.00	£488.36	£0.00	£0.00	1.8114	£50.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Electric Backup Water Heater
EVACUATED TUBE COLLECTOR

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			ENERGY INPUTS		
Installed Cost	£4,574.00	Evac. tube+Back up Heater	Solar Fraction	50.8%	
Amount Financed	£0.00				
Loan Term	360	Months			
Interest Rate	8.0%				
Real Discount Rate	5.5%		Electric Usage (Base)	3200	kWhr/yr Base Elec Usage (usage without solar)
Gen. Inflation Rate	2.0%		Electric Cost	0.070	£/kWhr
Income Tax	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Annual cost
£5,862.99	£403.41

Elec, Usage (solar) kWh/year	3200.000
Yearly Elec Cost	£224.00
Real Elec. Escalation Rate	0.00%
Nominal Discount Rate	0.0761

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Interest Deduction	Maintenance Cost	Replacement Cost	Environmental Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Cost (Current £)	Value (Current £)
0	£1,184.00						£0.00	£1,184.00			2.00			
1		£0.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.0200	£50.00	£0.00	£0.00
2		£0.00	£228.48	£0.00	£51.00	£0.00	£0.00	£279.48	£0.00	£0.00	1.0404	£50.00	£0.00	£0.00
3		£0.00	£233.05	£0.00	£53.06	£0.00	£0.00	£286.11	£0.00	£0.00	1.0612	£50.00	£0.00	£0.00
4		£0.00	£237.71	£0.00	£54.12	£0.00	£0.00	£291.83	£0.00	£0.00	1.0824	£50.00	£0.00	£0.00
5		£0.00	£242.46	£0.00	£55.20	£0.00	£0.00	£297.67	£0.00	£0.00	1.1041	£50.00	£0.00	£0.00
6		£0.00	£247.31	£0.00	£56.31	£0.00	£0.00	£303.62	£0.00	£0.00	1.1262	£50.00	£0.00	£0.00
7		£0.00	£252.26	£0.00	£57.43	£0.00	£0.00	£309.69	£0.00	£0.00	1.1487	£50.00	£0.00	£0.00
8		£0.00	£257.31	£0.00	£58.58	£0.00	£0.00	£315.89	£0.00	£0.00	1.1717	£50.00	£0.00	£0.00
9		£0.00	£262.45	£0.00	£59.75	£0.00	£0.00	£322.21	£0.00	£0.00	1.1951	£50.00	£0.00	£0.00
10		£0.00	£267.70	£0.00	£60.95	£304.75	£0.00	£633.40	£0.00	£0.00	1.2190	£50.00	£250.00	£0.00
11		£0.00	£273.05	£0.00	£62.17	£0.00	£0.00	£335.22	£0.00	£0.00	1.2434	£50.00	£0.00	£0.00
12		£0.00	£278.52	£0.00	£63.41	£0.00	£0.00	£341.93	£0.00	£0.00	1.2682	£50.00	£0.00	£0.00
13		£0.00	£284.09	£0.00	£64.68	£0.00	£0.00	£348.77	£0.00	£0.00	1.2936	£50.00	£0.00	£0.00
14		£0.00	£289.77	£0.00	£65.97	£0.00	£0.00	£355.74	£0.00	£0.00	1.3195	£50.00	£0.00	£0.00
15		£0.00	£295.56	£0.00	£67.29	£1,593.51	£0.00	£1,956.36	£0.00	£0.00	1.3459	£50.00	£1,184.00	£0.00
16		£0.00	£301.47	£0.00	£68.64	£0.00	£0.00	£370.11	£0.00	£0.00	1.3728	£50.00	£0.00	£0.00
17		£0.00	£307.50	£0.00	£70.01	£0.00	£0.00	£377.52	£0.00	£0.00	1.4002	£50.00	£0.00	£0.00
18		£0.00	£313.65	£0.00	£71.41	£0.00	£0.00	£385.07	£0.00	£0.00	1.4282	£50.00	£0.00	£0.00
19		£0.00	£319.93	£0.00	£72.84	£0.00	£0.00	£392.77	£0.00	£0.00	1.4568	£50.00	£0.00	£0.00
20		£0.00	£326.33	£0.00	£74.30	£371.49	£0.00	£772.11	£0.00	£0.00	1.4859	£50.00	£250.00	£0.00
21		£0.00	£332.85	£0.00	£75.78	£0.00	£0.00	£408.64	£0.00	£0.00	1.5157	£50.00	£0.00	£0.00
22		£0.00	£339.51	£0.00	£77.30	£0.00	£0.00	£416.81	£0.00	£0.00	1.5460	£50.00	£0.00	£0.00
23		£0.00	£346.30	£0.00	£78.84	£0.00	£0.00	£425.14	£0.00	£0.00	1.5769	£50.00	£0.00	£0.00
24		£0.00	£353.23	£0.00	£80.42	£0.00	£0.00	£433.65	£0.00	£0.00	1.6084	£50.00	£0.00	£0.00
25		£0.00	£360.29	£0.00	£82.03	£0.00	£0.00	£442.32	£0.00	£0.00	1.6406	£50.00	£0.00	£0.00
26		£0.00	£367.50	£0.00	£83.67	£0.00	£0.00	£451.17	£0.00	£0.00	1.6734	£50.00	£0.00	£0.00
27		£0.00	£374.85	£0.00	£85.34	£0.00	£0.00	£460.19	£0.00	£0.00	1.7069	£50.00	£0.00	£0.00
28		£0.00	£382.34	£0.00	£87.05	£0.00	£0.00	£469.39	£0.00	£0.00	1.7410	£50.00	£0.00	£0.00
29		£0.00	£389.99	£0.00	£88.79	£0.00	£0.00	£478.78	£0.00	£0.00	1.7758	£50.00	£0.00	£0.00
30		£0.00	£397.79	£0.00	£90.57	£0.00	£0.00	£488.36	£0.00	£0.00	1.8114	£50.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Electric Backup Water Heater
FLAT PLATE COLLECTOR

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS

Installed Cost	£4,134.00	Flat plate+Back up Heater
Amount Financed	£0.00	
Loan Term	360	Months
Interest Rate	8.0%	
Real Discount Rate	5.5%	
Gen. Inflation Rate	2.0%	
Income Tax	20.0%	

ENERGY INPUTS

Solar Fraction	53.0%	
Electric Usage (Base)	3200	kWhr/yr Base Elec Usage (usage without solar)
Electric Cost	0.070	£/kWhr
Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Annual cost
£5,862.99	£403.41

Elec, Usage (solar) kWh/year	3200.000
Yearly Elec Cost	£224.00

Real Elec. Escalation Rate	0.00%
Nominal Discount Rate	0.0761

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Interest Deduction	Maintenance Cost	Replacement Cost	Environmental Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Cost (Current £)	Value (Current £)
0	£1,184.00						£0.00	£1,184.00			2.00			
1		£0.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.0200	£50.00	£0.00	£0.00
2		£0.00	£228.48	£0.00	£51.00	£0.00	£0.00	£279.48	£0.00	£0.00	1.0404	£50.00	£0.00	£0.00
3		£0.00	£233.05	£0.00	£53.06	£0.00	£0.00	£286.11	£0.00	£0.00	1.0612	£50.00	£0.00	£0.00
4		£0.00	£237.71	£0.00	£54.12	£0.00	£0.00	£291.83	£0.00	£0.00	1.0824	£50.00	£0.00	£0.00
5		£0.00	£242.46	£0.00	£55.20	£0.00	£0.00	£297.67	£0.00	£0.00	1.1041	£50.00	£0.00	£0.00
6		£0.00	£247.31	£0.00	£56.31	£0.00	£0.00	£303.62	£0.00	£0.00	1.1262	£50.00	£0.00	£0.00
7		£0.00	£252.26	£0.00	£57.43	£0.00	£0.00	£309.69	£0.00	£0.00	1.1487	£50.00	£0.00	£0.00
8		£0.00	£257.31	£0.00	£58.58	£0.00	£0.00	£315.89	£0.00	£0.00	1.1717	£50.00	£0.00	£0.00
9		£0.00	£262.45	£0.00	£59.75	£0.00	£0.00	£322.21	£0.00	£0.00	1.1951	£50.00	£0.00	£0.00
10		£0.00	£267.70	£0.00	£60.95	£304.75	£0.00	£633.40	£0.00	£0.00	1.2190	£50.00	£250.00	£0.00
11		£0.00	£273.05	£0.00	£62.17	£0.00	£0.00	£335.22	£0.00	£0.00	1.2434	£50.00	£0.00	£0.00
12		£0.00	£278.52	£0.00	£63.41	£0.00	£0.00	£341.93	£0.00	£0.00	1.2682	£50.00	£0.00	£0.00
13		£0.00	£284.09	£0.00	£64.68	£0.00	£0.00	£348.77	£0.00	£0.00	1.2936	£50.00	£0.00	£0.00
14		£0.00	£289.77	£0.00	£65.97	£0.00	£0.00	£355.74	£0.00	£0.00	1.3195	£50.00	£0.00	£0.00
15		£0.00	£295.56	£0.00	£67.29	£1,593.51	£0.00	£1,956.36	£0.00	£0.00	1.3459	£50.00	£1,184.00	£0.00
16		£0.00	£301.47	£0.00	£68.64	£0.00	£0.00	£370.11	£0.00	£0.00	1.3728	£50.00	£0.00	£0.00
17		£0.00	£307.50	£0.00	£70.01	£0.00	£0.00	£377.52	£0.00	£0.00	1.4002	£50.00	£0.00	£0.00
18		£0.00	£313.65	£0.00	£71.41	£0.00	£0.00	£385.07	£0.00	£0.00	1.4282	£50.00	£0.00	£0.00
19		£0.00	£319.93	£0.00	£72.84	£0.00	£0.00	£392.77	£0.00	£0.00	1.4568	£50.00	£0.00	£0.00
20		£0.00	£326.33	£0.00	£74.30	£371.49	£0.00	£772.11	£0.00	£0.00	1.4859	£50.00	£250.00	£0.00
21		£0.00	£332.85	£0.00	£75.78	£0.00	£0.00	£408.64	£0.00	£0.00	1.5157	£50.00	£0.00	£0.00
22		£0.00	£339.51	£0.00	£77.30	£0.00	£0.00	£416.81	£0.00	£0.00	1.5460	£50.00	£0.00	£0.00
23		£0.00	£346.30	£0.00	£78.84	£0.00	£0.00	£425.14	£0.00	£0.00	1.5769	£50.00	£0.00	£0.00
24		£0.00	£353.23	£0.00	£80.42	£0.00	£0.00	£433.65	£0.00	£0.00	1.6084	£50.00	£0.00	£0.00
25		£0.00	£360.29	£0.00	£82.03	£0.00	£0.00	£442.32	£0.00	£0.00	1.6406	£50.00	£0.00	£0.00
26		£0.00	£367.50	£0.00	£83.67	£0.00	£0.00	£451.17	£0.00	£0.00	1.6734	£50.00	£0.00	£0.00
27		£0.00	£374.85	£0.00	£85.34	£0.00	£0.00	£460.19	£0.00	£0.00	1.7069	£50.00	£0.00	£0.00
28		£0.00	£382.34	£0.00	£87.05	£0.00	£0.00	£469.39	£0.00	£0.00	1.7410	£50.00	£0.00	£0.00
29		£0.00	£389.99	£0.00	£88.79	£0.00	£0.00	£478.78	£0.00	£0.00	1.7758	£50.00	£0.00	£0.00
30		£0.00	£397.79	£0.00	£90.57	£0.00	£0.00	£488.36	£0.00	£0.00	1.8114	£50.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Electric Backup Water Heater
DRAINBACK SYSTEM (20% of the amount financed)

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			ENERGY INPUTS		
Installed Cost	£3,639.00	Drainback+Back up Heater	Solar Fraction	46.3%	
Amount Financed	£2,911.20				
Loan Term	360	Months			
Interest Rate	8.0%				
Real Discount Rate	5.5%		Electric Usage (Base)	3200	kWhr/yr Base Elec Usage (usage without solar)
Gen. Inflation Rate	2.0%		Electric Cost	0.070	£/kWhr
Income Tax	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Annual cost		Elec, Usage (solar) kWh/year	3200.000		Real Elec. Escalation Rate	0.00%
£5,862.99	£403.41		Yearly Elec Cost	£224.00		Nominal Discount Rate	0.0761

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Interest Deduction	Maintenance Cost	Replacement Cost	Environmental Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Cost (Current £)	Value (Current £)
0	£1,184.00						£0.00	£1,184.00			2.00			
1		£0.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.0200	£50.00	£0.00	£0.00
2		£0.00	£228.48	£0.00	£51.00	£0.00	£0.00	£279.48	£0.00	£0.00	1.0404	£50.00	£0.00	£0.00
3		£0.00	£233.05	£0.00	£53.06	£0.00	£0.00	£286.11	£0.00	£0.00	1.0612	£50.00	£0.00	£0.00
4		£0.00	£237.71	£0.00	£54.12	£0.00	£0.00	£291.83	£0.00	£0.00	1.0824	£50.00	£0.00	£0.00
5		£0.00	£242.46	£0.00	£55.20	£0.00	£0.00	£297.67	£0.00	£0.00	1.1041	£50.00	£0.00	£0.00
6		£0.00	£247.31	£0.00	£56.31	£0.00	£0.00	£303.62	£0.00	£0.00	1.1262	£50.00	£0.00	£0.00
7		£0.00	£252.26	£0.00	£57.43	£0.00	£0.00	£309.69	£0.00	£0.00	1.1487	£50.00	£0.00	£0.00
8		£0.00	£257.31	£0.00	£58.58	£0.00	£0.00	£315.89	£0.00	£0.00	1.1717	£50.00	£0.00	£0.00
9		£0.00	£262.45	£0.00	£59.75	£0.00	£0.00	£322.21	£0.00	£0.00	1.1951	£50.00	£0.00	£0.00
10		£0.00	£267.70	£0.00	£60.95	£304.75	£0.00	£633.40	£0.00	£0.00	1.2190	£50.00	£250.00	£0.00
11		£0.00	£273.05	£0.00	£62.17	£0.00	£0.00	£335.22	£0.00	£0.00	1.2434	£50.00	£0.00	£0.00
12		£0.00	£278.52	£0.00	£63.41	£0.00	£0.00	£341.93	£0.00	£0.00	1.2682	£50.00	£0.00	£0.00
13		£0.00	£284.09	£0.00	£64.68	£0.00	£0.00	£348.77	£0.00	£0.00	1.2936	£50.00	£0.00	£0.00
14		£0.00	£289.77	£0.00	£65.97	£0.00	£0.00	£355.74	£0.00	£0.00	1.3195	£50.00	£0.00	£0.00
15		£0.00	£295.56	£0.00	£67.29	£1,593.51	£0.00	£1,956.36	£0.00	£0.00	1.3459	£50.00	£1,184.00	£0.00
16		£0.00	£301.47	£0.00	£68.64	£0.00	£0.00	£370.11	£0.00	£0.00	1.3728	£50.00	£0.00	£0.00
17		£0.00	£307.50	£0.00	£70.01	£0.00	£0.00	£377.52	£0.00	£0.00	1.4002	£50.00	£0.00	£0.00
18		£0.00	£313.65	£0.00	£71.41	£0.00	£0.00	£385.07	£0.00	£0.00	1.4282	£50.00	£0.00	£0.00
19		£0.00	£319.93	£0.00	£72.84	£0.00	£0.00	£392.77	£0.00	£0.00	1.4568	£50.00	£0.00	£0.00
20		£0.00	£326.33	£0.00	£74.30	£371.49	£0.00	£772.11	£0.00	£0.00	1.4859	£50.00	£250.00	£0.00
21		£0.00	£332.85	£0.00	£75.78	£0.00	£0.00	£408.64	£0.00	£0.00	1.5157	£50.00	£0.00	£0.00
22		£0.00	£339.51	£0.00	£77.30	£0.00	£0.00	£416.81	£0.00	£0.00	1.5460	£50.00	£0.00	£0.00
23		£0.00	£346.30	£0.00	£78.84	£0.00	£0.00	£425.14	£0.00	£0.00	1.5769	£50.00	£0.00	£0.00
24		£0.00	£353.23	£0.00	£80.42	£0.00	£0.00	£433.65	£0.00	£0.00	1.6084	£50.00	£0.00	£0.00
25		£0.00	£360.29	£0.00	£82.03	£0.00	£0.00	£442.32	£0.00	£0.00	1.6406	£50.00	£0.00	£0.00
26		£0.00	£367.50	£0.00	£83.67	£0.00	£0.00	£451.17	£0.00	£0.00	1.6734	£50.00	£0.00	£0.00
27		£0.00	£374.85	£0.00	£85.34	£0.00	£0.00	£460.19	£0.00	£0.00	1.7069	£50.00	£0.00	£0.00
28		£0.00	£382.34	£0.00	£87.05	£0.00	£0.00	£469.39	£0.00	£0.00	1.7410	£50.00	£0.00	£0.00
29		£0.00	£389.99	£0.00	£88.79	£0.00	£0.00	£478.78	£0.00	£0.00	1.7758	£50.00	£0.00	£0.00
30		£0.00	£397.79	£0.00	£90.57	£0.00	£0.00	£488.36	£0.00	£0.00	1.8114	£50.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Electric Backup Water Heater
EVACUATED TUBE COLLECTOR (20% of the amount financed)

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			**ENERGY INPUTS**		
Installed Cost	£4,574.00	Evac.tube+Back up Heater	Solar Fraction	50.8%	
Amount Financed	£3,659.20				
Loan Term	360	Months			
Interest Rate	8.0%				
Real Discount Rate	5.5%		Electric Usage (Base)	3200	kWhr/yr Base Elec Usage (usage without solar)
Gen. Inflation Rate	2.0%		Electric Cost	0.070	£/kWhr
Income Tax	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Annual cost		Elec, Usage (solar) kWh/year	3200.000		**INDIVIDUAL YEARLY ECONOMIC INPUTS**
£5,862.99	£403.41		Yearly Elec Cost	£224.00	Real Elec. Escalation Rate	0.00%
					Nominal Discount Rate	0.0761

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Interest Deduction	Maintenance Cost	Replacement Cost	Environmental Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Cost (Current £)	Value (Current £)
0	£1,184.00						£0.00	1,184.00			2.00			
1		£0.00	£224.00	£0.00	50.00	£0.00	£0.00	274.00	£0.00	£0.00	1.0200	£50.00	£0.00	£0.00
2		£0.00	£228.48	£0.00	51.00	£0.00	£0.00	279.48	£0.00	£0.00	1.0404	£50.00	£0.00	£0.00
3		£0.00	£233.05	£0.00	53.06	£0.00	£0.00	286.11	£0.00	£0.00	1.0612	£50.00	£0.00	£0.00
4		£0.00	£237.71	£0.00	54.12	£0.00	£0.00	291.83	£0.00	£0.00	1.0824	£50.00	£0.00	£0.00
5		£0.00	£242.46	£0.00	55.20	£0.00	£0.00	297.67	£0.00	£0.00	1.1041	£50.00	£0.00	£0.00
6		£0.00	£247.31	£0.00	56.31	£0.00	£0.00	303.62	£0.00	£0.00	1.1262	£50.00	£0.00	£0.00
7		£0.00	£252.26	£0.00	57.43	£0.00	£0.00	309.69	£0.00	£0.00	1.1487	£50.00	£0.00	£0.00
8		£0.00	£257.31	£0.00	58.58	£0.00	£0.00	315.89	£0.00	£0.00	1.1717	£50.00	£0.00	£0.00
9		£0.00	£262.45	£0.00	59.75	£0.00	£0.00	322.21	£0.00	£0.00	1.1951	£50.00	£0.00	£0.00
10		£0.00	£267.70	£0.00	60.95	£304.75	£0.00	633.40	£0.00	£0.00	1.2190	£50.00	£250.00	£0.00
11		£0.00	£273.05	£0.00	62.17	£0.00	£0.00	335.22	£0.00	£0.00	1.2434	£50.00	£0.00	£0.00
12		£0.00	£278.52	£0.00	63.41	£0.00	£0.00	341.93	£0.00	£0.00	1.2682	£50.00	£0.00	£0.00
13		£0.00	£284.09	£0.00	64.68	£0.00	£0.00	348.77	£0.00	£0.00	1.2936	£50.00	£0.00	£0.00
14		£0.00	£289.77	£0.00	65.97	£0.00	£0.00	355.74	£0.00	£0.00	1.3195	£50.00	£0.00	£0.00
15		£0.00	£295.56	£0.00	67.29	£1,593.51	£0.00	1,956.36	£0.00	£0.00	1.3459	£50.00	£1,184.00	£0.00
16		£0.00	£301.47	£0.00	68.64	£0.00	£0.00	370.11	£0.00	£0.00	1.3728	£50.00	£0.00	£0.00
17		£0.00	£307.50	£0.00	70.01	£0.00	£0.00	377.52	£0.00	£0.00	1.4002	£50.00	£0.00	£0.00
18		£0.00	£313.65	£0.00	71.41	£0.00	£0.00	385.07	£0.00	£0.00	1.4282	£50.00	£0.00	£0.00
19		£0.00	£319.93	£0.00	72.84	£0.00	£0.00	392.77	£0.00	£0.00	1.4568	£50.00	£0.00	£0.00
20		£0.00	£326.33	£0.00	74.30	£371.49	£0.00	772.11	£0.00	£0.00	1.4859	£50.00	£250.00	£0.00
21		£0.00	£332.85	£0.00	75.78	£0.00	£0.00	408.64	£0.00	£0.00	1.5157	£50.00	£0.00	£0.00
22		£0.00	£339.51	£0.00	77.30	£0.00	£0.00	416.81	£0.00	£0.00	1.5460	£50.00	£0.00	£0.00
23		£0.00	£346.30	£0.00	78.84	£0.00	£0.00	425.14	£0.00	£0.00	1.5769	£50.00	£0.00	£0.00
24		£0.00	£353.23	£0.00	80.42	£0.00	£0.00	433.65	£0.00	£0.00	1.6084	£50.00	£0.00	£0.00
25		£0.00	£360.29	£0.00	82.03	£0.00	£0.00	442.32	£0.00	£0.00	1.6406	£50.00	£0.00	£0.00
26		£0.00	£367.50	£0.00	83.67	£0.00	£0.00	451.17	£0.00	£0.00	1.6734	£50.00	£0.00	£0.00
27		£0.00	£374.85	£0.00	85.34	£0.00	£0.00	460.19	£0.00	£0.00	1.7069	£50.00	£0.00	£0.00
28		£0.00	£382.34	£0.00	87.05	£0.00	£0.00	469.39	£0.00	£0.00	1.7410	£50.00	£0.00	£0.00
29		£0.00	£389.99	£0.00	88.79	£0.00	£0.00	478.78	£0.00	£0.00	1.7758	£50.00	£0.00	£0.00
30		£0.00	£397.79	£0.00	90.57	£0.00	£0.00	488.36	£0.00	£0.00	1.8114	£50.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Electric Backup Water Heater
FLAT PLATE COLLECTOR (20% of the amount financed)

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			ENERGY INPUTS		
Installed Cost	£4,134.00	Flat plate+Back up Heater	Solar Fraction	53.0%	
Amount Financed	£3,307.20				
Loan Term	360	Months			
Interest Rate	8.0%				
Real Discount Rate	5.5%		Electric Usage (Base)	3200	kWhr/yr Base Elec Usage (usage without solar)
Gen. Inflation Rate	2.0%		Electric Cost	0.070	£/kWhr
Income Tax	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Annual cost		
£5,722.37	£393.73		

Elec, Usage (solar) kWh/year	3200.000
Yearly Elec Cost	£224.00
Real Elec. Escalation Rate	0.00%
Nominal Discount Rate	0.0761

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Interest Deduction	Maintenance Cost	Replacement Cost	Environmental Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Cost (Current £)	Value (Current £)
0	£1,184.00						£0.00	£1,184.00			2.00			
1		£0.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.02	£50.00	£0.00	£0.00
2		£0.00	£228.48	£0.00	£50.00	£0.00	£0.00	£278.48	£0.00	£0.00	1.04	£50.00	£0.00	£0.00
3		£0.00	£233.05	£0.00	£50.00	£0.00	£0.00	£283.05	£0.00	£0.00	1.06	£50.00	£0.00	£0.00
4		£0.00	£237.71	£0.00	£50.00	£0.00	£0.00	£287.71	£0.00	£0.00	1.08	£50.00	£0.00	£0.00
5		£0.00	£242.46	£0.00	£50.00	£0.00	£0.00	£292.46	£0.00	£0.00	1.10	£50.00	£0.00	£0.00
6		£0.00	£247.31	£0.00	£50.00	£0.00	£0.00	£297.31	£0.00	£0.00	1.13	£50.00	£0.00	£0.00
7		£0.00	£252.26	£0.00	£50.00	£0.00	£0.00	£302.26	£0.00	£0.00	1.15	£50.00	£0.00	£0.00
8		£0.00	£257.31	£0.00	£50.00	£0.00	£0.00	£307.31	£0.00	£0.00	1.17	£50.00	£0.00	£0.00
9		£0.00	£262.45	£0.00	£50.00	£0.00	£0.00	£312.45	£0.00	£0.00	1.20	£50.00	£0.00	£0.00
10		£0.00	£267.70	£0.00	£50.00	£304.75	£0.00	£622.45	£0.00	£0.00	1.22	£50.00	£250.00	£0.00
11		£0.00	£273.05	£0.00	£50.00	£0.00	£0.00	£323.05	£0.00	£0.00	1.24	£50.00	£0.00	£0.00
12		£0.00	£278.52	£0.00	£50.00	£0.00	£0.00	£328.52	£0.00	£0.00	1.27	£50.00	£0.00	£0.00
13		£0.00	£284.09	£0.00	£50.00	£0.00	£0.00	£334.09	£0.00	£0.00	1.29	£50.00	£0.00	£0.00
14		£0.00	£289.77	£0.00	£50.00	£0.00	£0.00	£339.77	£0.00	£0.00	1.32	£50.00	£0.00	£0.00
15		£0.00	£295.56	£0.00	£50.00	£1,593.51	£0.00	£1,939.07	£0.00	£0.00	1.35	£50.00	£1,184.00	£0.00
16		£0.00	£301.47	£0.00	£50.00	£0.00	£0.00	£351.47	£0.00	£0.00	1.37	£50.00	£0.00	£0.00
17		£0.00	£307.50	£0.00	£50.00	£0.00	£0.00	£357.50	£0.00	£0.00	1.40	£50.00	£0.00	£0.00
18		£0.00	£313.65	£0.00	£50.00	£0.00	£0.00	£363.65	£0.00	£0.00	1.43	£50.00	£0.00	£0.00
19		£0.00	£319.93	£0.00	£50.00	£0.00	£0.00	£369.93	£0.00	£0.00	1.46	£50.00	£0.00	£0.00
20		£0.00	£326.33	£0.00	£50.00	£371.49	£0.00	£747.81	£0.00	£0.00	1.49	£50.00	£250.00	£0.00
21		£0.00	£332.85	£0.00	£50.00	£0.00	£0.00	£382.85	£0.00	£0.00	1.52	£50.00	£0.00	£0.00
22		£0.00	£339.51	£0.00	£50.00	£0.00	£0.00	£389.51	£0.00	£0.00	1.55	£50.00	£0.00	£0.00
23		£0.00	£346.30	£0.00	£50.00	£0.00	£0.00	£396.30	£0.00	£0.00	1.58	£50.00	£0.00	£0.00
24		£0.00	£353.23	£0.00	£50.00	£0.00	£0.00	£403.23	£0.00	£0.00	1.61	£50.00	£0.00	£0.00
25		£0.00	£360.29	£0.00	£50.00	£0.00	£0.00	£410.29	£0.00	£0.00	1.64	£50.00	£0.00	£0.00
26		£0.00	£367.50	£0.00	£50.00	£0.00	£0.00	£417.50	£0.00	£0.00	1.67	£50.00	£0.00	£0.00
27		£0.00	£374.85	£0.00	£50.00	£0.00	£0.00	£424.85	£0.00	£0.00	1.71	£50.00	£0.00	£0.00
28		£0.00	£382.34	£0.00	£50.00	£0.00	£0.00	£432.34	£0.00	£0.00	1.74	£50.00	£0.00	£0.00
29		£0.00	£389.99	£0.00	£50.00	£0.00	£0.00	£439.99	£0.00	£0.00	1.78	£50.00	£0.00	£0.00
30		£0.00	£397.79	£0.00	£50.00	£0.00	£0.00	£447.79	£0.00	£0.00	1.81	£50.00	£0.00	£0.00

LIFE CYCLE COST-Gas water heater

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			**ENERGY INPUTS**		
Installed Cost	£1,610.00	Gas water heater			
Amount Financed	£0.00				
Loan Term	360	Months			
Interest Rate	8.0%				
Real Discount Rate	5.5%		Fuel Usage (Base)	3200	kWhr/yr Base Elec Usage
Gen. Inflation Rate	2.0%		Fuel Cost	0.031	£/kWhr
Income Tax Bracket	20.0%		Gas Escalation Rate	2.00	%/year

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Anual cost					
		Yearly Elec Usage, kWhr/yr	3,200			
		Yearly Fuel Cost, £/yr	£224.00	Real Elec. Escalation Rate	0.00%	**INDIVIDUAL YEARLY ECONOMIC INPUTS**
£3,514.20	£241.80			Nominal Discount Rate	0.0761	

Year	Down Payment	Yearly Loan Payment	Yearly Fuel Cost	Interest Deduction	Maintainance Cost	Replacement Cost	Environmental Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Cost (Current £)	Environmental Value (Current £)
0	£1,184.00							£1,184.00			2.000	£0.00		
1		£0.00	£99.20	£0.00	0.00	£0.00	£0.00	£99.20	£0.00	£0.00	1.020	£0.00	£0.00	£0.00
2		£0.00	£101.18	£0.00	0.00	£0.00	£0.00	£101.18	£0.00	£0.00	1.040	£0.00	£0.00	£0.00
3		£0.00	£103.21	£0.00	0.00	£0.00	£0.00	£103.21	£0.00	£0.00	1.061	£0.00	£0.00	£0.00
4		£0.00	£105.27	£0.00	0.00	£0.00	£0.00	£105.27	£0.00	£0.00	1.082	£0.00	£0.00	£0.00
5		£0.00	£107.38	£0.00	110.41	£0.00	£0.00	£217.79	£0.00	£0.00	1.104	£100.00	£0.00	£0.00
6		£0.00	£109.52	£0.00	0.00	£0.00	£0.00	£109.52	£0.00	£0.00	1.126	£0.00	£0.00	£0.00
7		£0.00	£111.72	£0.00	0.00	£0.00	£0.00	£111.72	£0.00	£0.00	1.149	£0.00	£0.00	£0.00
8		£0.00	£113.95	£0.00	0.00	£0.00	£0.00	£113.95	£0.00	£0.00	1.172	£0.00	£0.00	£0.00
9		£0.00	£116.23	£0.00	0.00	£0.00	£0.00	£116.23	£0.00	£0.00	1.195	£0.00	£0.00	£0.00
10		£0.00	£118.55	£0.00	121.90	£0.00	£0.00	£240.45	£0.00	£0.00	1.219	£100.00	£0.00	£0.00
11		£0.00	£120.92	£0.00	0.00	£0.00	£0.00	£120.92	£0.00	£0.00	1.243	£0.00	£0.00	£0.00
12		£0.00	£123.34	£0.00	0.00	£0.00	£0.00	£123.34	£0.00	£0.00	1.268	£0.00	£0.00	£0.00
13		£0.00	£125.81	£0.00	0.00	£0.00	£0.00	£125.81	£0.00	£0.00	1.294	£0.00	£0.00	£0.00
14		£0.00	£128.33	£0.00	0.00	£0.00	£0.00	£128.33	£0.00	£0.00	1.319	£0.00	£0.00	£0.00
15		£0.00	£130.89	£0.00	0.00	£2,166.85	£0.00	£2,297.74	£0.00	£0.00	1.346	£0.00	£1,610.00	£0.00
16		£0.00	£133.51	£0.00	0.00	£0.00	£0.00	£133.51	£0.00	£0.00	1.373	£0.00	£0.00	£0.00
17		£0.00	£136.18	£0.00	0.00	£0.00	£0.00	£136.18	£0.00	£0.00	1.400	£0.00	£0.00	£0.00
18		£0.00	£138.90	£0.00	0.00	£0.00	£0.00	£138.90	£0.00	£0.00	1.428	£0.00	£0.00	£0.00
19		£0.00	£141.68	£0.00	£0.00	£0.00	£0.00	£141.68	£0.00	£0.00	1.457	£0.00	£0.00	£0.00
20		£0.00	£144.52	£0.00	£148.59	£0.00	£0.00	£293.11	£0.00	£0.00	1.486	£100.00	£0.00	£0.00
21		£0.00	£147.41	£0.00	£0.00	£0.00	£0.00	£147.41	£0.00	£0.00	1.516	0.00	£0.00	£0.00
22		£0.00	£150.35	£0.00	£0.00	£0.00	£0.00	£150.35	£0.00	£0.00	1.546	0.00	£0.00	£0.00
23		£0.00	£153.36	£0.00	£0.00	£0.00	£0.00	£153.36	£0.00	£0.00	1.577	0.00	£0.00	£0.00
24		£0.00	£156.43	£0.00	£0.00	£0.00	£0.00	£156.43	£0.00	£0.00	1.608	0.00	£0.00	£0.00
25		£0.00	£159.56	£0.00	£164.06	£0.00	£0.00	£323.62	£0.00	£0.00	1.641	£100.00	£0.00	£0.00
26		£0.00	£162.75	£0.00	£0.00	£0.00	£0.00	£162.75	£0.00	£0.00	1.673	0.00	£0.00	£0.00
27		£0.00	£166.00	£0.00	£0.00	£0.00	£0.00	£166.00	£0.00	£0.00	1.707	0.00	£0.00	£0.00
28		£0.00	£169.32	£0.00	£0.00	£0.00	£0.00	£169.32	£0.00	£0.00	1.741	0.00	£0.00	£0.00
29		£0.00	£172.71	£0.00	£0.00	£0.00	£0.00	£172.71	£0.00	£0.00	1.776	0.00	£0.00	£0.00
30		£0.00	£176.16	£0.00	£0.00	£0.00	£0.00	£176.16	£0.00	£0.00	1.811	0.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Gas Backup Water Heater

DRAINBACK SYSTEM (20% of the amount financed)

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			**ENERGY INPUTS**		
Installed Cost	£4,417.00	Drainback+BackupHeater	Solar Fraction	31.9%	Fuel Usage met by solar
Amount Financed	£3,533.60		Fuel Usage (Base)	3200	kWhr/yr Base Gas Usage (without solar)
Loan Term	360	Months	Fuel Cost	0.031	£/kWhr
Interest Rate	8.0%		Fuel Escalation Rate	2.00	%/year
Real Discount Rate	5.5%		Pump Electric Usage	200	kWhr/yr (pump's energy, etc)
Gen. Inflation Rate	2.0%		Electric Cost	0.07	£/kWh
Income Tax Bracket	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Annual cost				
£5,467.10	£376.17	Yearly Fuel Usage kWhr/yr	3200.000	Real Elec. Escalation Rate	0.00%
		Yearly Fuel Cost, £/yr	£0.00	Real Fuel Escalation Rate	0.00%
		Yearly Electric Cost, £/yr	£224.00	Nominal Discount Rate	7.61%

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Yearly Fuel Cost	Total cost	Interest Deduction	Maint. Cost	Replace. Cost	Environ. Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Replacement Cost (Current £)	Environmental Value (Current £)
0	£1,184.00									£1,184.00			2.000			£0.00
1		£0.00	£0.00	£224.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.020	£50.00	£0.00	£0.00
2		£0.00	£0.00	£224.00	£224.00	£0.00	£51.00	£0.00	£0.00	£275.00	£0.00	£0.00	1.040	£50.00	£0.00	£0.00
3		£0.00	£0.00	£224.00	£224.00	£0.00	£52.02	£0.00	£0.00	£276.02	£0.00	£0.00	1.061	£50.00	£0.00	£0.00
4		£0.00	£0.00	£224.00	£224.00	£0.00	£53.06	£0.00	£0.00	£277.06	£0.00	£0.00	1.082	£50.00	£0.00	£0.00
5		£0.00	£0.00	£224.00	£224.00	£0.00	£54.12	£0.00	£0.00	£278.12	£0.00	£0.00	1.104	£50.00	£0.00	£0.00
6		£0.00	£0.00	£224.00	£224.00	£0.00	£55.20	£0.00	£0.00	£279.20	£0.00	£0.00	1.126	£50.00	£0.00	£0.00
7		£0.00	£0.00	£224.00	£224.00	£0.00	£56.31	£0.00	£0.00	£280.31	£0.00	£0.00	1.149	£50.00	£0.00	£0.00
8		£0.00	£0.00	£224.00	£224.00	£0.00	£57.43	£0.00	£0.00	£281.43	£0.00	£0.00	1.172	£50.00	£0.00	£0.00
9		£0.00	£0.00	£224.00	£224.00	£0.00	£58.58	£0.00	£0.00	£282.58	£0.00	£0.00	1.195	£50.00	£0.00	£0.00
10		£0.00	£0.00	£224.00	£224.00	£0.00	£59.75	£304.75	£0.00	£588.50	£0.00	£0.00	1.219	£50.00	£250.00	£0.00
11		£0.00	£0.00	£224.00	£224.00	£0.00	£60.95	£0.00	£0.00	£284.95	£0.00	£0.00	1.243	£50.00	£0.00	£0.00
12		£0.00	£0.00	£224.00	£224.00	£0.00	£62.17	£0.00	£0.00	£286.17	£0.00	£0.00	1.268	£50.00	£0.00	£0.00
13		£0.00	£0.00	£224.00	£224.00	£0.00	£63.41	£0.00	£0.00	£287.41	£0.00	£0.00	1.294	£50.00	£0.00	£0.00
14		£0.00	£0.00	£224.00	£224.00	£0.00	£64.68	£0.00	£0.00	£288.68	£0.00	£0.00	1.319	£50.00	£0.00	£0.00
15		£0.00	£0.00	£224.00	£224.00	£0.00	£65.97	£2,166.85	£0.00	£2,456.82	£0.00	£0.00	1.346	£50.00	£1,610.00	£0.00
16		£0.00	£0.00	£224.00	£224.00	£0.00	£67.29	£0.00	£0.00	£291.29	£0.00	£0.00	1.373	£50.00	£0.00	£0.00
17		£0.00	£0.00	£224.00	£224.00	£0.00	£68.64	£0.00	£0.00	£292.64	£0.00	£0.00	1.400	£50.00	£0.00	£0.00
18		£0.00	£0.00	£224.00	£224.00	£0.00	£70.01	£0.00	£0.00	£294.01	£0.00	£0.00	1.428	£50.00	£0.00	£0.00
19		£0.00	£0.00	£224.00	£224.00	£0.00	£71.41	£0.00	£0.00	£295.41	£0.00	£0.00	1.457	£50.00	£0.00	£0.00
20		£0.00	£0.00	£224.00	£224.00	£0.00	£72.84	£371.49	£0.00	£668.33	£0.00	£0.00	1.486	£50.00	£250.00	£0.00
21		£0.00	£0.00	£224.00	£224.00	£0.00	£74.30	£0.00	£0.00	£298.30	£0.00	£0.00	1.516	£50.00	£0.00	£0.00
22		£0.00	£0.00	£224.00	£224.00	£0.00	£75.78	£0.00	£0.00	£299.78	£0.00	£0.00	1.546	£50.00	£0.00	£0.00
23		£0.00	£0.00	£224.00	£224.00	£0.00	£77.30	£0.00	£0.00	£301.30	£0.00	£0.00	1.577	£50.00	£0.00	£0.00
24		£0.00	£0.00	£224.00	£224.00	£0.00	£78.84	£0.00	£0.00	£302.84	£0.00	£0.00	1.608	£50.00	£0.00	£0.00
25		£0.00	£0.00	£224.00	£224.00	£0.00	£80.42	£0.00	£0.00	£304.42	£0.00	£0.00	1.641	£50.00	£0.00	£0.00
26		£0.00	£0.00	£224.00	£224.00	£0.00	£82.03	£0.00	£0.00	£306.03	£0.00	£0.00	1.673	£50.00	£0.00	£0.00
27		£0.00	£0.00	£224.00	£224.00	£0.00	£83.67	£0.00	£0.00	£307.67	£0.00	£0.00	1.707	£50.00	£0.00	£0.00
28		£0.00	£0.00	£224.00	£224.00	£0.00	£85.34	£0.00	£0.00	£309.34	£0.00	£0.00	1.741	£50.00	£0.00	£0.00
29		£0.00	£0.00	£224.00	£224.00	£0.00	£87.05	£0.00	£0.00	£311.05	£0.00	£0.00	1.776	£50.00	£0.00	£0.00
30		£0.00	£0.00	£224.00	£224.00	£0.00	£88.79	£0.00	£0.00	£312.79	£0.00	£0.00	1.811	£50.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Gas Backup Water Heater

DRAINBACK SYSTEM

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			**ENERGY INPUTS**		
Installed Cost	£4,417.00	Drainback+BackupHeater	Solar Fraction	31.9%	Fuel Usage met by solar
Amount Financed	£0.00		Fuel Usage (Base)	3200	kWhr/yr Base Gas Usage (without solar)
Loan Term	360	Months	Fuel Cost	0.031	£/kWhr
Interest Rate	8.0%		Fuel Escalation Rate	2.00	%/year
Real Discount Rate	5.5%		Pump Electric Usage	200	kWhr/yr (pump's energy, etc)
Gen. Inflation Rate	2.0%		Electric Cost	0.07	£/kWh
Income Tax Bracket	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Annual cost					
£5,467.10	£376.17	Yearly Fuel Usage kWhr/yr	3200.000	Real Elec. Escalation Rate	0.00%	
		Yearly Fuel Cost, £/yr	£0.00	Real Fuel Escalation Rate	0.00%	
		Yearly Electric Cost, £/yr	£224.00	Nominal Discount Rate	7.61%	

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Yearly Fuel Cost	Total cost	Interest Deduction	Maint. Cost	Replace. Cost	Environ. Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Replacement Cost (Current £)	Environmental Value (Current £)
0	£1,184.00									£1,184.00			2.000			£0.00
1		£0.00	£0.00	£224.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.020	£50.00	£0.00	£0.00
2		£0.00	£0.00	£224.00	£224.00	£0.00	£51.00	£0.00	£0.00	£275.00	£0.00	£0.00	1.040	£50.00	£0.00	£0.00
3		£0.00	£0.00	£224.00	£224.00	£0.00	£52.02	£0.00	£0.00	£276.02	£0.00	£0.00	1.061	£50.00	£0.00	£0.00
4		£0.00	£0.00	£224.00	£224.00	£0.00	£53.06	£0.00	£0.00	£277.06	£0.00	£0.00	1.082	£50.00	£0.00	£0.00
5		£0.00	£0.00	£224.00	£224.00	£0.00	£54.12	£0.00	£0.00	£278.12	£0.00	£0.00	1.104	£50.00	£0.00	£0.00
6		£0.00	£0.00	£224.00	£224.00	£0.00	£55.20	£0.00	£0.00	£279.20	£0.00	£0.00	1.126	£50.00	£0.00	£0.00
7		£0.00	£0.00	£224.00	£224.00	£0.00	£56.31	£0.00	£0.00	£280.31	£0.00	£0.00	1.149	£50.00	£0.00	£0.00
8		£0.00	£0.00	£224.00	£224.00	£0.00	£57.43	£0.00	£0.00	£281.43	£0.00	£0.00	1.172	£50.00	£0.00	£0.00
9		£0.00	£0.00	£224.00	£224.00	£0.00	£58.58	£0.00	£0.00	£282.58	£0.00	£0.00	1.195	£50.00	£0.00	£0.00
10		£0.00	£0.00	£224.00	£224.00	£0.00	£59.75	£304.75	£0.00	£588.50	£0.00	£0.00	1.219	£50.00	£250.00	£0.00
11		£0.00	£0.00	£224.00	£224.00	£0.00	£60.95	£0.00	£0.00	£284.95	£0.00	£0.00	1.243	£50.00	£0.00	£0.00
12		£0.00	£0.00	£224.00	£224.00	£0.00	£62.17	£0.00	£0.00	£286.17	£0.00	£0.00	1.268	£50.00	£0.00	£0.00
13		£0.00	£0.00	£224.00	£224.00	£0.00	£63.41	£0.00	£0.00	£287.41	£0.00	£0.00	1.294	£50.00	£0.00	£0.00
14		£0.00	£0.00	£224.00	£224.00	£0.00	£64.68	£0.00	£0.00	£288.68	£0.00	£0.00	1.319	£50.00	£0.00	£0.00
15		£0.00	£0.00	£224.00	£224.00	£0.00	£65.97	£2,166.85	£0.00	£2,456.82	£0.00	£0.00	1.346	£50.00	£1,610.00	£0.00
16		£0.00	£0.00	£224.00	£224.00	£0.00	£67.29	£0.00	£0.00	£291.29	£0.00	£0.00	1.373	£50.00	£0.00	£0.00
17		£0.00	£0.00	£224.00	£224.00	£0.00	£68.64	£0.00	£0.00	£292.64	£0.00	£0.00	1.400	£50.00	£0.00	£0.00
18		£0.00	£0.00	£224.00	£224.00	£0.00	£70.01	£0.00	£0.00	£294.01	£0.00	£0.00	1.428	£50.00	£0.00	£0.00
19		£0.00	£0.00	£224.00	£224.00	£0.00	£71.41	£0.00	£0.00	£295.41	£0.00	£0.00	1.457	£50.00	£0.00	£0.00
20		£0.00	£0.00	£224.00	£224.00	£0.00	£72.84	£371.49	£0.00	£668.33	£0.00	£0.00	1.486	£50.00	£250.00	£0.00
21		£0.00	£0.00	£224.00	£224.00	£0.00	£74.30	£0.00	£0.00	£298.30	£0.00	£0.00	1.516	£50.00	£0.00	£0.00
22		£0.00	£0.00	£224.00	£224.00	£0.00	£75.78	£0.00	£0.00	£299.78	£0.00	£0.00	1.546	£50.00	£0.00	£0.00
23		£0.00	£0.00	£224.00	£224.00	£0.00	£77.30	£0.00	£0.00	£301.30	£0.00	£0.00	1.577	£50.00	£0.00	£0.00
24		£0.00	£0.00	£224.00	£224.00	£0.00	£78.84	£0.00	£0.00	£302.84	£0.00	£0.00	1.608	£50.00	£0.00	£0.00
25		£0.00	£0.00	£224.00	£224.00	£0.00	£80.42	£0.00	£0.00	£304.42	£0.00	£0.00	1.641	£50.00	£0.00	£0.00
26		£0.00	£0.00	£224.00	£224.00	£0.00	£82.03	£0.00	£0.00	£306.03	£0.00	£0.00	1.673	£50.00	£0.00	£0.00
27		£0.00	£0.00	£224.00	£224.00	£0.00	£83.67	£0.00	£0.00	£307.67	£0.00	£0.00	1.707	£50.00	£0.00	£0.00
28		£0.00	£0.00	£224.00	£224.00	£0.00	£85.34	£0.00	£0.00	£309.34	£0.00	£0.00	1.741	£50.00	£0.00	£0.00
29		£0.00	£0.00	£224.00	£224.00	£0.00	£87.05	£0.00	£0.00	£311.05	£0.00	£0.00	1.776	£50.00	£0.00	£0.00
30		£0.00	£0.00	£224.00	£224.00	£0.00	£88.79	£0.00	£0.00	£312.79	£0.00	£0.00	1.811	£50.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Gas Backup Water Heater

EVACUATED TUBE COLLECTOR (20% of the amount financed)

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			ENERGY INPUTS		
Installed Cost	£5,352.00	Evac. Tube+BackupHeater	Solar Fraction	35.1%	Fuel Usage met by solar
Amount Financed	£0.00		Fuel Usage (Base)	3200	kWhr/yr Base Gas Usage (without solar)
Loan Term	360	Months	Fuel Cost	0.031	£/kWhr
Interest Rate	8.0%		Fuel Escalation Rate	2.00	%/year
Real Discount Rate	5.5%		Pump Electric Usage	200	kWhr/yr (pump's energy, etc)
Gen. Inflation Rate	2.0%		Electric Cost	0.07	£/kWh
Income Tax Bracket	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Annual cost				
£5,467.10	£376.17	Yearly Fuel Usage kWhr/yr	3200.000	Real Elec. Escalation Rate	0.00%
		Yearly Fuel Cost, £/yr	£0.00	Real Fuel Escalation Rate	0.00%
		Yearly Electric Cost, £/yr	£224.00	Nominal Discount Rate	7.61%

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Yearly Fuel Cost	Total cost	Interest Deduction	Maint. Cost	Replace. Cost	Environ. Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Replacement Cost (Current £)	Environmental Value (Current £)
0	£1,184.00									£1,184.00			2.000			£0.00
1		£0.00	£0.00	£224.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.020	£50.00	£0.00	£0.00
2		£0.00	£0.00	£224.00	£224.00	£0.00	£51.00	£0.00	£0.00	£275.00	£0.00	£0.00	1.040	£50.00	£0.00	£0.00
3		£0.00	£0.00	£224.00	£224.00	£0.00	£52.02	£0.00	£0.00	£276.02	£0.00	£0.00	1.061	£50.00	£0.00	£0.00
4		£0.00	£0.00	£224.00	£224.00	£0.00	£53.06	£0.00	£0.00	£277.06	£0.00	£0.00	1.082	£50.00	£0.00	£0.00
5		£0.00	£0.00	£224.00	£224.00	£0.00	£54.12	£0.00	£0.00	£278.12	£0.00	£0.00	1.104	£50.00	£0.00	£0.00
6		£0.00	£0.00	£224.00	£224.00	£0.00	£55.20	£0.00	£0.00	£279.20	£0.00	£0.00	1.126	£50.00	£0.00	£0.00
7		£0.00	£0.00	£224.00	£224.00	£0.00	£56.31	£0.00	£0.00	£280.31	£0.00	£0.00	1.149	£50.00	£0.00	£0.00
8		£0.00	£0.00	£224.00	£224.00	£0.00	£57.43	£0.00	£0.00	£281.43	£0.00	£0.00	1.172	£50.00	£0.00	£0.00
9		£0.00	£0.00	£224.00	£224.00	£0.00	£58.58	£0.00	£0.00	£282.58	£0.00	£0.00	1.195	£50.00	£0.00	£0.00
10		£0.00	£0.00	£224.00	£224.00	£0.00	£59.75	£304.75	£0.00	£588.50	£0.00	£0.00	1.219	£50.00	£250.00	£0.00
11		£0.00	£0.00	£224.00	£224.00	£0.00	£60.95	£0.00	£0.00	£284.95	£0.00	£0.00	1.243	£50.00	£0.00	£0.00
12		£0.00	£0.00	£224.00	£224.00	£0.00	£62.17	£0.00	£0.00	£286.17	£0.00	£0.00	1.268	£50.00	£0.00	£0.00
13		£0.00	£0.00	£224.00	£224.00	£0.00	£63.41	£0.00	£0.00	£287.41	£0.00	£0.00	1.294	£50.00	£0.00	£0.00
14		£0.00	£0.00	£224.00	£224.00	£0.00	£64.68	£0.00	£0.00	£288.68	£0.00	£0.00	1.319	£50.00	£0.00	£0.00
15		£0.00	£0.00	£224.00	£224.00	£0.00	£65.97	£2,166.85	£0.00	£2,456.82	£0.00	£0.00	1.346	£50.00	£1,610.00	£0.00
16		£0.00	£0.00	£224.00	£224.00	£0.00	£67.29	£0.00	£0.00	£291.29	£0.00	£0.00	1.373	£50.00	£0.00	£0.00
17		£0.00	£0.00	£224.00	£224.00	£0.00	£68.64	£0.00	£0.00	£292.64	£0.00	£0.00	1.400	£50.00	£0.00	£0.00
18		£0.00	£0.00	£224.00	£224.00	£0.00	£70.01	£0.00	£0.00	£294.01	£0.00	£0.00	1.428	£50.00	£0.00	£0.00
19		£0.00	£0.00	£224.00	£224.00	£0.00	£71.41	£0.00	£0.00	£295.41	£0.00	£0.00	1.457	£50.00	£0.00	£0.00
20		£0.00	£0.00	£224.00	£224.00	£0.00	£72.84	£371.49	£0.00	£668.33	£0.00	£0.00	1.486	£50.00	£250.00	£0.00
21		£0.00	£0.00	£224.00	£224.00	£0.00	£74.30	£0.00	£0.00	£298.30	£0.00	£0.00	1.516	£50.00	£0.00	£0.00
22		£0.00	£0.00	£224.00	£224.00	£0.00	£75.78	£0.00	£0.00	£299.78	£0.00	£0.00	1.546	£50.00	£0.00	£0.00
23		£0.00	£0.00	£224.00	£224.00	£0.00	£77.30	£0.00	£0.00	£301.30	£0.00	£0.00	1.577	£50.00	£0.00	£0.00
24		£0.00	£0.00	£224.00	£224.00	£0.00	£78.84	£0.00	£0.00	£302.84	£0.00	£0.00	1.608	£50.00	£0.00	£0.00
25		£0.00	£0.00	£224.00	£224.00	£0.00	£80.42	£0.00	£0.00	£304.42	£0.00	£0.00	1.641	£50.00	£0.00	£0.00
26		£0.00	£0.00	£224.00	£224.00	£0.00	£82.03	£0.00	£0.00	£306.03	£0.00	£0.00	1.673	£50.00	£0.00	£0.00
27		£0.00	£0.00	£224.00	£224.00	£0.00	£83.67	£0.00	£0.00	£307.67	£0.00	£0.00	1.707	£50.00	£0.00	£0.00
28		£0.00	£0.00	£224.00	£224.00	£0.00	£85.34	£0.00	£0.00	£309.34	£0.00	£0.00	1.741	£50.00	£0.00	£0.00
29		£0.00	£0.00	£224.00	£224.00	£0.00	£87.05	£0.00	£0.00	£311.05	£0.00	£0.00	1.776	£50.00	£0.00	£0.00
30		£0.00	£0.00	£224.00	£224.00	£0.00	£88.79	£0.00	£0.00	£312.79	£0.00	£0.00	1.811	£50.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Gas Backup Water Heater

EVACUATED TUBE COLLECTOR

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			ENERGY INPUTS		
Installed Cost	£5,352.00	Evac. Tube+BackupHeater	Solar Fraction	35.1%	Fuel Usage met by solar
Amount Financed	£0.00		Fuel Usage (Base)	3200	kWhr/yr Base Gas Usage (without solar)
Loan Term	360	Months	Fuel Cost	0.031	£/kWhr
Interest Rate	8.0%		Fuel Escalation Rate	2.00	%/year
Real Discount Rate	5.5%		Pump Electric Usage	200	kWhr/yr (pump's energy, etc)
Gen. Inflation Rate	2.0%		Electric Cost	0.07	£/kWh
Income Tax Bracket	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Annual cost				
£5,467.10	£376.17	Yearly Fuel Usage kWhr/yr	3200.000	Real Elec. Escalation Rate	0.00%
		Yearly Fuel Cost, £/yr	£0.00	Real Fuel Escalation Rate	0.00%
		Yearly Electric Cost, £/yr	£224.00	Nominal Discount Rate	7.61%

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Yearly Fuel Cost	Total cost	Interest Deduction	Maint. Cost	Replace. Cost	Environ. Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Replacement Cost (Current £)	Environmental Value (Current £)
0	£1,184.00									£1,184.00			2.000			£0.00
1		£0.00	£0.00	£224.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.020	£50.00	£0.00	£0.00
2		£0.00	£0.00	£224.00	£224.00	£0.00	£51.00	£0.00	£0.00	£275.00	£0.00	£0.00	1.040	£50.00	£0.00	£0.00
3		£0.00	£0.00	£224.00	£224.00	£0.00	£52.02	£0.00	£0.00	£276.02	£0.00	£0.00	1.061	£50.00	£0.00	£0.00
4		£0.00	£0.00	£224.00	£224.00	£0.00	£53.06	£0.00	£0.00	£277.06	£0.00	£0.00	1.082	£50.00	£0.00	£0.00
5		£0.00	£0.00	£224.00	£224.00	£0.00	£54.12	£0.00	£0.00	£278.12	£0.00	£0.00	1.104	£50.00	£0.00	£0.00
6		£0.00	£0.00	£224.00	£224.00	£0.00	£55.20	£0.00	£0.00	£279.20	£0.00	£0.00	1.126	£50.00	£0.00	£0.00
7		£0.00	£0.00	£224.00	£224.00	£0.00	£56.31	£0.00	£0.00	£280.31	£0.00	£0.00	1.149	£50.00	£0.00	£0.00
8		£0.00	£0.00	£224.00	£224.00	£0.00	£57.43	£0.00	£0.00	£281.43	£0.00	£0.00	1.172	£50.00	£0.00	£0.00
9		£0.00	£0.00	£224.00	£224.00	£0.00	£58.58	£0.00	£0.00	£282.58	£0.00	£0.00	1.195	£50.00	£0.00	£0.00
10		£0.00	£0.00	£224.00	£224.00	£0.00	£59.75	£304.75	£0.00	£588.50	£0.00	£0.00	1.219	£50.00	£250.00	£0.00
11		£0.00	£0.00	£224.00	£224.00	£0.00	£60.95	£0.00	£0.00	£284.95	£0.00	£0.00	1.243	£50.00	£0.00	£0.00
12		£0.00	£0.00	£224.00	£224.00	£0.00	£62.17	£0.00	£0.00	£286.17	£0.00	£0.00	1.268	£50.00	£0.00	£0.00
13		£0.00	£0.00	£224.00	£224.00	£0.00	£63.41	£0.00	£0.00	£287.41	£0.00	£0.00	1.294	£50.00	£0.00	£0.00
14		£0.00	£0.00	£224.00	£224.00	£0.00	£64.68	£0.00	£0.00	£288.68	£0.00	£0.00	1.319	£50.00	£0.00	£0.00
15		£0.00	£0.00	£224.00	£224.00	£0.00	£65.97	£2,166.85	£0.00	£2,456.82	£0.00	£0.00	1.346	£50.00	£1,610.00	£0.00
16		£0.00	£0.00	£224.00	£224.00	£0.00	£67.29	£0.00	£0.00	£291.29	£0.00	£0.00	1.373	£50.00	£0.00	£0.00
17		£0.00	£0.00	£224.00	£224.00	£0.00	£68.64	£0.00	£0.00	£292.64	£0.00	£0.00	1.400	£50.00	£0.00	£0.00
18		£0.00	£0.00	£224.00	£224.00	£0.00	£70.01	£0.00	£0.00	£294.01	£0.00	£0.00	1.428	£50.00	£0.00	£0.00
19		£0.00	£0.00	£224.00	£224.00	£0.00	£71.41	£0.00	£0.00	£295.41	£0.00	£0.00	1.457	£50.00	£0.00	£0.00
20		£0.00	£0.00	£224.00	£224.00	£0.00	£72.84	£371.49	£0.00	£668.33	£0.00	£0.00	1.486	£50.00	£250.00	£0.00
21		£0.00	£0.00	£224.00	£224.00	£0.00	£74.30	£0.00	£0.00	£298.30	£0.00	£0.00	1.516	£50.00	£0.00	£0.00
22		£0.00	£0.00	£224.00	£224.00	£0.00	£75.78	£0.00	£0.00	£299.78	£0.00	£0.00	1.546	£50.00	£0.00	£0.00
23		£0.00	£0.00	£224.00	£224.00	£0.00	£77.30	£0.00	£0.00	£301.30	£0.00	£0.00	1.577	£50.00	£0.00	£0.00
24		£0.00	£0.00	£224.00	£224.00	£0.00	£78.84	£0.00	£0.00	£302.84	£0.00	£0.00	1.608	£50.00	£0.00	£0.00
25		£0.00	£0.00	£224.00	£224.00	£0.00	£80.42	£0.00	£0.00	£304.42	£0.00	£0.00	1.641	£50.00	£0.00	£0.00
26		£0.00	£0.00	£224.00	£224.00	£0.00	£82.03	£0.00	£0.00	£306.03	£0.00	£0.00	1.673	£50.00	£0.00	£0.00
27		£0.00	£0.00	£224.00	£224.00	£0.00	£83.67	£0.00	£0.00	£307.67	£0.00	£0.00	1.707	£50.00	£0.00	£0.00
28		£0.00	£0.00	£224.00	£224.00	£0.00	£85.34	£0.00	£0.00	£309.34	£0.00	£0.00	1.741	£50.00	£0.00	£0.00
29		£0.00	£0.00	£224.00	£224.00	£0.00	£87.05	£0.00	£0.00	£311.05	£0.00	£0.00	1.776	£50.00	£0.00	£0.00
30		£0.00	£0.00	£224.00	£224.00	£0.00	£88.79	£0.00	£0.00	£312.79	£0.00	£0.00	1.811	£50.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Gas Backup Water Heater

FLAT PLATE COLLECTOR (20% of the amount financed)

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			**ENERGY INPUTS**		
Installed Cost	£4,912.00	Flat plate+BackupHeater	Solar Fraction	36.5%	Fuel Usage met by solar
Amount Financed	£3,929.60		Fuel Usage (Base)	3200	kWhr/yr Base Gas Usage (without solar)
Loan Term	360	Months	Fuel Cost	0.031	£/kWhr
Interest Rate	8.0%		Fuel Escalation Rate	2.00	%/year
Real Discount Rate	5.5%		Pump Electric Usage	200	kWhr/yr (pump's energy, etc)
Gen. Inflation Rate	2.0%		Electric Cost	0.07	£/kWh
Income Tax Bracket	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Yearly cost				
£5,467.10	£376.17	Yearly Fuel Usage kWhr/yr	3200.000	Real Elec. Escalation Rate	0.00%
		Yearly Fuel Cost, £/yr	£0.00	Real Fuel Escalation Rate	0.00%
		Yearly Electric Cost, £/yr	£224.00	Nominal Discount Rate	7.61%

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Yearly Fuel Cost	Total cost	Interest Deduction	Maint. Cost	Replace. Cost	Environ. Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Replacement Cost (Current £)	Environmental Value (Current £)
0	£1,184.00									£1,184.00			2.000			£0.00
1		£0.00	£0.00	£224.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.020	£50.00	£0.00	£0.00
2		£0.00	£0.00	£224.00	£224.00	£0.00	£51.00	£0.00	£0.00	£275.00	£0.00	£0.00	1.040	£50.00	£0.00	£0.00
3		£0.00	£0.00	£224.00	£224.00	£0.00	£52.02	£0.00	£0.00	£276.02	£0.00	£0.00	1.061	£50.00	£0.00	£0.00
4		£0.00	£0.00	£224.00	£224.00	£0.00	£53.06	£0.00	£0.00	£277.06	£0.00	£0.00	1.082	£50.00	£0.00	£0.00
5		£0.00	£0.00	£224.00	£224.00	£0.00	£54.12	£0.00	£0.00	£278.12	£0.00	£0.00	1.104	£50.00	£0.00	£0.00
6		£0.00	£0.00	£224.00	£224.00	£0.00	£55.20	£0.00	£0.00	£279.20	£0.00	£0.00	1.126	£50.00	£0.00	£0.00
7		£0.00	£0.00	£224.00	£224.00	£0.00	£56.31	£0.00	£0.00	£280.31	£0.00	£0.00	1.149	£50.00	£0.00	£0.00
8		£0.00	£0.00	£224.00	£224.00	£0.00	£57.43	£0.00	£0.00	£281.43	£0.00	£0.00	1.172	£50.00	£0.00	£0.00
9		£0.00	£0.00	£224.00	£224.00	£0.00	£58.58	£0.00	£0.00	£282.58	£0.00	£0.00	1.195	£50.00	£0.00	£0.00
10		£0.00	£0.00	£224.00	£224.00	£0.00	£59.75	£304.75	£0.00	£588.50	£0.00	£0.00	1.219	£50.00	£250.00	£0.00
11		£0.00	£0.00	£224.00	£224.00	£0.00	£60.95	£0.00	£0.00	£284.95	£0.00	£0.00	1.243	£50.00	£0.00	£0.00
12		£0.00	£0.00	£224.00	£224.00	£0.00	£62.17	£0.00	£0.00	£286.17	£0.00	£0.00	1.268	£50.00	£0.00	£0.00
13		£0.00	£0.00	£224.00	£224.00	£0.00	£63.41	£0.00	£0.00	£287.41	£0.00	£0.00	1.294	£50.00	£0.00	£0.00
14		£0.00	£0.00	£224.00	£224.00	£0.00	£64.68	£0.00	£0.00	£288.68	£0.00	£0.00	1.319	£50.00	£0.00	£0.00
15		£0.00	£0.00	£224.00	£224.00	£0.00	£65.97	£2,166.85	£0.00	£2,456.82	£0.00	£0.00	1.346	£50.00	£1,610.00	£0.00
16		£0.00	£0.00	£224.00	£224.00	£0.00	£67.29	£0.00	£0.00	£291.29	£0.00	£0.00	1.373	£50.00	£0.00	£0.00
17		£0.00	£0.00	£224.00	£224.00	£0.00	£68.64	£0.00	£0.00	£292.64	£0.00	£0.00	1.400	£50.00	£0.00	£0.00
18		£0.00	£0.00	£224.00	£224.00	£0.00	£70.01	£0.00	£0.00	£294.01	£0.00	£0.00	1.428	£50.00	£0.00	£0.00
19		£0.00	£0.00	£224.00	£224.00	£0.00	£71.41	£0.00	£0.00	£295.41	£0.00	£0.00	1.457	£50.00	£0.00	£0.00
20		£0.00	£0.00	£224.00	£224.00	£0.00	£72.84	£371.49	£0.00	£668.33	£0.00	£0.00	1.486	£50.00	£250.00	£0.00
21		£0.00	£0.00	£224.00	£224.00	£0.00	£74.30	£0.00	£0.00	£298.30	£0.00	£0.00	1.516	£50.00	£0.00	£0.00
22		£0.00	£0.00	£224.00	£224.00	£0.00	£75.78	£0.00	£0.00	£299.78	£0.00	£0.00	1.546	£50.00	£0.00	£0.00
23		£0.00	£0.00	£224.00	£224.00	£0.00	£77.30	£0.00	£0.00	£301.30	£0.00	£0.00	1.577	£50.00	£0.00	£0.00
24		£0.00	£0.00	£224.00	£224.00	£0.00	£78.84	£0.00	£0.00	£302.84	£0.00	£0.00	1.608	£50.00	£0.00	£0.00
25		£0.00	£0.00	£224.00	£224.00	£0.00	£80.42	£0.00	£0.00	£304.42	£0.00	£0.00	1.641	£50.00	£0.00	£0.00
26		£0.00	£0.00	£224.00	£224.00	£0.00	£82.03	£0.00	£0.00	£306.03	£0.00	£0.00	1.673	£50.00	£0.00	£0.00
27		£0.00	£0.00	£224.00	£224.00	£0.00	£83.67	£0.00	£0.00	£307.67	£0.00	£0.00	1.707	£50.00	£0.00	£0.00
28		£0.00	£0.00	£224.00	£224.00	£0.00	£85.34	£0.00	£0.00	£309.34	£0.00	£0.00	1.741	£50.00	£0.00	£0.00
29		£0.00	£0.00	£224.00	£224.00	£0.00	£87.05	£0.00	£0.00	£311.05	£0.00	£0.00	1.776	£50.00	£0.00	£0.00
30		£0.00	£0.00	£224.00	£224.00	£0.00	£88.79	£0.00	£0.00	£312.79	£0.00	£0.00	1.811	£50.00	£0.00	£0.00

LIFE CYCLE COST - Solar Water Heating with Gas Backup Water Heater

FLAT PLATE COLLECTOR

ECONOMIC ANALYSIS INPUTS

FINANCIAL INPUTS			**ENERGY INPUTS**		
Installed Cost	£4,912.00	Flat plate+BackupHeater	Solar Fraction	36.5%	Fuel Usage met by solar
Amount Financed	£0.00		Fuel Usage (Base)	3200	kWhr/yr Base Gas Usage (without solar)
Loan Term	360	Months	Fuel Cost	0.031	£/kWhr
Interest Rate	8.0%		Fuel Escalation Rate	2.00	%/year
Real Discount Rate	5.5%		Pump Electric Usage	200	kWhr/yr (pump's energy, etc)
Gen. Inflation Rate	2.0%		Electric Cost	0.07	£/kWh
Income Tax	20.0%		Elec. Escalation Rate	2.00	%/year (Nominal)

ECONOMIC ANALYSIS OUTPUTS

Life Cycle Cost, 30 yrs	Effective Yearly cost				
£5,467.10	£376.17				
		Yearly Fuel Usage kWhr/yr	3200.000	Real Elec. Escalation Rate	0.00%
		Yearly Fuel Cost, £/yr	£0.00	Real Fuel Escalation Rate	0.00%
		Yearly Electric Cost, £/yr	£224.00	Nominal Discount Rate	7.61%

INDIVIDUAL YEARLY ECONOMIC INPUTS

Year	Down Payment	Yearly Loan Payment	Yearly Electric Cost	Yearly Fuel Cost	Total cost	Interest Deduction	Maint. Cost	Replace. Cost	Environ. Credits	Net Cash Flow	Interest Payment	Unpaid Principal	Inflation rate	Maintenance Cost (Current £)	Replacement Cost (Current £)	Environmental Value (Current £)
0	£1,184.00									£1,184.00			2.000			£0.00
1		£0.00	£0.00	£224.00	£224.00	£0.00	£50.00	£0.00	£0.00	£274.00	£0.00	£0.00	1.020	£50.00	£0.00	£0.00
2		£0.00	£0.00	£224.00	£224.00	£0.00	£51.00	£0.00	£0.00	£275.00	£0.00	£0.00	1.040	£50.00	£0.00	£0.00
3		£0.00	£0.00	£224.00	£224.00	£0.00	£52.02	£0.00	£0.00	£276.02	£0.00	£0.00	1.061	£50.00	£0.00	£0.00
4		£0.00	£0.00	£224.00	£224.00	£0.00	£53.06	£0.00	£0.00	£277.06	£0.00	£0.00	1.082	£50.00	£0.00	£0.00
5		£0.00	£0.00	£224.00	£224.00	£0.00	£54.12	£0.00	£0.00	£278.12	£0.00	£0.00	1.104	£50.00	£0.00	£0.00
6		£0.00	£0.00	£224.00	£224.00	£0.00	£55.20	£0.00	£0.00	£279.20	£0.00	£0.00	1.126	£50.00	£0.00	£0.00
7		£0.00	£0.00	£224.00	£224.00	£0.00	£56.31	£0.00	£0.00	£280.31	£0.00	£0.00	1.149	£50.00	£0.00	£0.00
8		£0.00	£0.00	£224.00	£224.00	£0.00	£57.43	£0.00	£0.00	£281.43	£0.00	£0.00	1.172	£50.00	£0.00	£0.00
9		£0.00	£0.00	£224.00	£224.00	£0.00	£58.58	£0.00	£0.00	£282.58	£0.00	£0.00	1.195	£50.00	£0.00	£0.00
10		£0.00	£0.00	£224.00	£224.00	£0.00	£59.75	£304.75	£0.00	£588.50	£0.00	£0.00	1.219	£50.00	£250.00	£0.00
11		£0.00	£0.00	£224.00	£224.00	£0.00	£60.95	£0.00	£0.00	£284.95	£0.00	£0.00	1.243	£50.00	£0.00	£0.00
12		£0.00	£0.00	£224.00	£224.00	£0.00	£62.17	£0.00	£0.00	£286.17	£0.00	£0.00	1.268	£50.00	£0.00	£0.00
13		£0.00	£0.00	£224.00	£224.00	£0.00	£63.41	£0.00	£0.00	£287.41	£0.00	£0.00	1.294	£50.00	£0.00	£0.00
14		£0.00	£0.00	£224.00	£224.00	£0.00	£64.68	£0.00	£0.00	£288.68	£0.00	£0.00	1.319	£50.00	£0.00	£0.00
15		£0.00	£0.00	£224.00	£224.00	£0.00	£65.97	£2,166.85	£0.00	£2,456.82	£0.00	£0.00	1.346	£50.00	£1,610.00	£0.00
16		£0.00	£0.00	£224.00	£224.00	£0.00	£67.29	£0.00	£0.00	£291.29	£0.00	£0.00	1.373	£50.00	£0.00	£0.00
17		£0.00	£0.00	£224.00	£224.00	£0.00	£68.64	£0.00	£0.00	£292.64	£0.00	£0.00	1.400	£50.00	£0.00	£0.00
18		£0.00	£0.00	£224.00	£224.00	£0.00	£70.01	£0.00	£0.00	£294.01	£0.00	£0.00	1.428	£50.00	£0.00	£0.00
19		£0.00	£0.00	£224.00	£224.00	£0.00	£71.41	£0.00	£0.00	£295.41	£0.00	£0.00	1.457	£50.00	£0.00	£0.00
20		£0.00	£0.00	£224.00	£224.00	£0.00	£72.84	£371.49	£0.00	£668.33	£0.00	£0.00	1.486	£50.00	£250.00	£0.00
21		£0.00	£0.00	£224.00	£224.00	£0.00	£74.30	£0.00	£0.00	£298.30	£0.00	£0.00	1.516	£50.00	£0.00	£0.00
22		£0.00	£0.00	£224.00	£224.00	£0.00	£75.78	£0.00	£0.00	£299.78	£0.00	£0.00	1.546	£50.00	£0.00	£0.00
23		£0.00	£0.00	£224.00	£224.00	£0.00	£77.30	£0.00	£0.00	£301.30	£0.00	£0.00	1.577	£50.00	£0.00	£0.00
24		£0.00	£0.00	£224.00	£224.00	£0.00	£78.84	£0.00	£0.00	£302.84	£0.00	£0.00	1.608	£50.00	£0.00	£0.00
25		£0.00	£0.00	£224.00	£224.00	£0.00	£80.42	£0.00	£0.00	£304.42	£0.00	£0.00	1.641	£50.00	£0.00	£0.00
26		£0.00	£0.00	£224.00	£224.00	£0.00	£82.03	£0.00	£0.00	£306.03	£0.00	£0.00	1.673	£50.00	£0.00	£0.00
27		£0.00	£0.00	£224.00	£224.00	£0.00	£83.67	£0.00	£0.00	£307.67	£0.00	£0.00	1.707	£50.00	£0.00	£0.00
28		£0.00	£0.00	£224.00	£224.00	£0.00	£85.34	£0.00	£0.00	£309.34	£0.00	£0.00	1.741	£50.00	£0.00	£0.00
29		£0.00	£0.00	£224.00	£224.00	£0.00	£87.05	£0.00	£0.00	£311.05	£0.00	£0.00	1.776	£50.00	£0.00	£0.00
30		£0.00	£0.00	£224.00	£224.00	£0.00	£88.79	£0.00	£0.00	£312.79	£0.00	£0.00	1.811	£50.00	£0.00	£0.00