A Cost-Effective and an Economic Analysis of Alternative Water Heating Systems in North Cyprus

Arif Yurtsev

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Economics

Eastern Mediterranean University
November 2015
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Cem Tanova
Acting Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Doctor of Philosophy in Economics.

Prof. Dr. Mehmet Balcılar
Chair, Department of Economics

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Doctor of Philosophy in Economics.

Prof. Dr. Glenn P. Jenkins
Supervisor

Examining Committee

1. Prof. Dr. Mehmet Balcılar
2. Prof. Dr. Glenn P. Jenkins
3. Prof. Dr. Metin Karadağ
4. Prof. Dr. Zeynel A. Özdemir
5. Prof. Dr. Sevin Uğural

ABSTRACT

This dissertation reports on a cost-effectiveness and an economic analysis of four types of water heating system operating in North Cyprus where there is an unreliable water supply. These systems are electric water heating, a solar water heating system (SWHS) with electricity back-up, the SWHS with a liquefied petroleum gas (LPG) water heater, and an LPG water heater alone.

This study finds that in situations where there is a winter or a rainy season, the choice of the source of energy for SWHS's back-up during this period is critical for its overall cost-effectiveness. Although an SWHS with electricity back-up is far superior to using electricity alone, it is inferior to heating water with either an LPG water heater alone or an SWHS with an LPG back-up.

It is found that in the conditions of North Cyprus, an SWHS with an LPG heater back-up is both financially and economically the most cost-effective, most convenient and most environmentally friendly system for households with more than two members, while LPG water heater alone are the most cost-effective for smaller households. Furthermore, if a reliable supply of water is available, the cost of heating water is reduced by 15% for the SWHS with LPG back-up and for the heating of water by the LPG heater alone.

A major finding that emerges from this study is that in climates where SWHSs are not able to deliver adequate energy throughout the year, it is very important to take into consideration what is to be used as the source of back-up energy. Many countries have been providing financial incentives to promote SWHSs and it is usually assumed that electricity will be the back-up source of energy when solar energy is insufficient. This study points to the critical importance of having a policy for SWHSs that does not simply promote the installation of SWHSs, but that also promotes the appropriate auxiliary source of energy for supplementing the SWHS.

Keywords: Cost-effectiveness analysis; water heater systems; households; North Cyprus.

ÖZ

Bu tezin amacı su kalitesinin içilebilir bir seviyede olmadığı ve kesintisiz su arzının sağlanamadığı Kuzey Kıbrıs'ta su ısıtma sistemlerinin maliyet-etkililik ve ekonomik analizini yapmaktır. Günümüzde kullanımda olan su ısıtma sistemleri, elektrikli su ısıtma sistemleri, gazlı su ısıtma sistemleri ve elektrik veya gaz yedekli güneş enerjisi sistemleridir.

Bu çalışma kış mevsiminin veya yağışlı sezonun hüküm sürdüğü yerlerde, bu periyotta güneş enerjisi sistemlerinde kullanılan yedek enerji kaynağının bu sistemlerin maliyet açısından etkinliğinde önemli bir etkiye sahip olduğunu ortaya koymaktadır. Elektrik yedekli güneş su ısıtma sistemleri elektrikli ısıtıcılara kıyasla çok daha az maliyetli olmasına rağmen bu sistemlerin gaz yedekli sistemlerden veya gazlı su ısıtıcılarından daha masraflı olduğu hesap edilmiştir.

Kuzey Kıbrıs'taki mevcut koşullarda, tek veya iki kişilik hanelerde gazlı su ısıtıcılarının, daha çok bireyin ikame ettiği hanelerde ise gaz yedekli güneş enerji sistemlerinin hem finansal, hem ekonomik yönden maliyet açısından en etkin; ayrıca çevresel etki bakımından da en çevreci sistemler olduğu bulunmuştur. Bunun yanısıra, kesintisiz içilebilir su arzının sağlanabildiği durumlarda bu sistemlerden yararlanarak sıcak su temin etmenin maliyetinin 15% azalacağı hesap edilmiştir.

Bu çalışmadaki en önemli bulgu, güneş enerjisinin yeterli olmadığı zamanlarda güneş enerji sistemlerinde yedek olarak kullanılacak enerji kaynağını hesaba katmaktır. Birçok ülke çevresel kaygılardan dolayı su ısıtma amaçlı güneş enerji sistemlerinin yaygınlaşması için mali teşvikler temin etmektedirler ve genellikle

elektrik enerjisinin sisteme yedek olarak kullanılacağı varsayılmaktadır. Bu çalışma sadece güneş enerji sistemlerinin teşvikini düzenleyen politikaların değil sisteme uygun yedek enerji kaynağını dikkate alarak teşvik edici politikalar yapmanın önemine işaret etmektedir.

Anahtar Kelimeler: Maliyet-etkililik analizi; su ısıtma sistemleri; hanehalkı analizi; Kuzey Kıbrıs.

ACKNOWLEDGMENT

I would like to thank my supervisor Prof. Glenn P. Jenkins for proposing this very interesting research topic and for his time and valuable effort on this study. I also wish to thank Dr. Cafer Kızılörs from the department of mechanical engineering who took his time to respond to my all questions in detail and provide some important technical information which is used in the analysis.

Finally, I am grateful to my family and my friends who have always supported me and have been very patient with me throughout this research.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

1.1 Background

Cyprus is the third largest island in the Mediterranean. Its climate is characterized by hot, dry, summers and mild winters. The island has abundance of solar energy with over 300 sunny days throughout the year. The average daily sunshine is 12.5 hours during the summer months and 5.5 hours during the winter months. Furthermore, the average daily solar radiation is 5.4 kWh per m^2 over the year (Kalogirou, 1997). However, the island has a chronic shortage of surface water and groundwater as a result of inadequate rainfall. It is estimated that the groundwater level has decreased by over 90% from the 1960s to the present (Secretariat-General of The National Security Council, Republic of Turkey).[1]

In addition, many areas of North Cyprus have low-quality water in terms of salinity and scaling. Therefore, the water utility cannot supply reliable potable water to their customers. Another problem faced by residents is that North Cyprus experiences frequent electricity outages. From September 2013 to September 2014 a total of 166 electricity outages were caused by generation failures or inadequate generation capacity during the hours of peak demand (Ozbafli and Jenkins, 2015).

[1] Source: http://www.mgk.gov.tr/calismalar/calismalar/014_kktc_su_temini_elektrik_nakli_projeleri.pdf (accessed 14 November 2014).

Virtually 100 percent of the households have undertaken multiple investments to provide a reliable supply of water in order to overcome the problems of unreliable water and electricity supplies. First, in order to cope with intermittent water supply, residents install water tanks with an average size of 2 m^3 at the ground level of their house or apartment building. This allows them to maintain a continuous supply of water for household consumption, even when there are frequent interruptions in the supply of water from the utility.

Second, they also install water tanks with an average size of 1 m^3 on the roof of their house or apartment building. These rooftop tanks address both of these problems. They provide additional water storage, and at the same time provide water through gravity to the house in the case of electricity outages when a water pump would not operate.

Third, a water pump of about 1 hp is used to pump water into the tank on the roof. This pump is needed because of the lack of water pressure from the supply of water by the water utility. The various storage tanks are not pressurized. Fourth, if the household is heating its water with an SWHS, a hot water tank equipped with an electric heater at 3-kW rating with capacity in the range of 120–200 liters is installed below the storage tank on the roof.

According to the 2006 national census, 71.4 % of households have SWHSs in order to benefit from the use of solar energy for water heating (State Planning Organization).[2] The location of SWHSs on the roof of the building in tandem with the cold water storage tank allows residents to use hot water on sunny days, even if

[2] The latest information available on the intensity of use of SWHSs was recorded in the 2006 census.

there is an electricity outage or if there is no municipal water supply at that time. Such a system is shown in Figure 1.1.

Figure 1.1. Photograph of a typical dwelling adapted with ground and roof tanks and an SWHS in North Cyprus.

To summarize, residents have perceived these investments as averting expenditures against unreliable supplies of both water and electricity. When SWHSs are used, the system both conserves electricity and protects the consumer from the problem of unreliable electricity supply by heating water for a significant part of the year.

1.2 Water heating systems in use in North Cyprus

The water heating systems that are in use in North Cyprus are electrical water heaters, SWHSs with electricity back-up, gas (LPG) water heaters and SWHSs with gas back-up.[3] We consider electrical water heaters with storage tanks. The use of instant electric water heater systems has almost disappeared because of the frequent failure of the heating element due to the low quality of the water.

[3] We have used gas water heater, LPG water heater and gas heater interchangeably.

For many years the cost of electricity generation was partially subsidized by the state in North Cyprus. This was no doubt a factor that caused many people either to heat water using electricity or to use electricity as a back-up to an SWHS (Ilkan et al., 2005). Atikol and Güven (2003) estimated that the use of electricity for water heating constitutes 45% of the residential winter peak. However, the price of electricity doubled in the period February–August 2008 owing to a sharp increase in fuel oil prices (Cyprus Turkish Electricity Authority, Kib-Tek).[4] The high price of electricity caused some residents to shift to gas heaters for the purpose of water heating.

According to the gas-heater sellers interviewed, demand for gas heaters has been increasing, particularly since 2008. However, there is no data related to number of households using gas heaters alone or as a back-up to an SWHS. It is important to point out that a hydrophore unit is required to pump the water into the gas heater owing to the low water pressure. Low water pressure causes temperature of the water to be fluctuated uncomfortably if a tap is turned on in the house while someone is in the shower. Therefore, combination of gas heater with an SWHS also protects the consumer from the problem of unreliable electricity supply by heating water when SWHS is in use.

To put it differently, installing an SWHS enhances the reliability of providing hot water on demand under current conditions. In spite of this fact, yet around 30% of households do not use an SWHS for water heating. As it is specified in section 1.3, low-quality water is likely a reason for this among others such as unwillingness of landlord's to install SWHSs and households' desired hot water temperature in

[4] Source is available at http://www.kibtek.com/Tarifeler/95-2012%20TARIFE%20%C3%9CCRETLERI.pdf (accessed on 15 November 2014).

summer months (the mains water temperature in the summer months might be comfortable for some households) etc.

1.2.1 Utilization from SWHSs for the purpose of water heating

SWHSs are the most widely used solar energy applications worldwide (Hang et al., 2012). Global SWHS capacity grew at a rate of 15% annually in the period 2007–2012 and had reached an estimated 282 GW_{th} by the end of 2012 (REN21, 2013). Many countries have been providing financial incentives to promote SWHSs in order to ensure that SWHSs are financially feasible for their residents owing to increased concerns about the environmental impacts of energy consumption.[5] In particular, some countries, such as Israel and Spain, have legislated a requirement that SWHSs should be installed in new buildings and those undergoing major renovations (Roulleau and Lloyd, 2008). Some developing countries, such as Kenya, are now also implementing this policy.[6]

SWHSs have been in widespread use for many decades in Cyprus. South Cyprus, where 93% of houses have an SWHS, is the world's leader on a per capita basis (Kalogirou, 2009b). Since 2004, 20% of investment costs in SWHSs have been subsidized in South Cyprus. Moreover, legislative regulations for the compulsory installation of SWHSs entered into force on 1st January 2010 (Cyprus Institute of

[5] It is estimated that electricity and heat generation accounted for 42% of global CO_2 emissions in 2012 (International Energy Agency (IEA), 2014).

[6] For information about the solar thermal ordinances that have been brought into force by municipal governments in various countries and the financial incentives that have recently been offered around the world to promote diffusion of SWHSs, see http://www.solarthermalworld.org and http://solarordinances.eu.

Energy).[7] However, there are currently neither subsidies nor legislative regulations mandating SWHS installation in North Cyprus.

In the design of policies and regulations to promote the use of SWHSs in South Cyprus or elsewhere, very little attention has been given to the source of energy that is to be used to supplement solar energy at the times of the year when a back-up source of energy is needed. Usually the implicit assumption is that electricity will be the back-up source of energy when solar energy is insufficient.

The choice of the back-up system is particularly important for countries with significant fluctuations in the weather, such as those that experience rainy seasons or winters. This is due to the fact that the required heating load is much greater in the winter than that in the summer owing to the considerably colder mains water temperature and higher tank heat losses. It is at this time of the year that the proportional contribution of the SWHS to the heating load (when it is used in combination with electricity back-up) is at its lowest.

1.2.2 SWHS configuration in North Cyprus

Thermosyphon or natural circulation solar water heaters consisting of flat plate collectors (panels), a hot water tank fitted with an auxiliary electric element and connecting pipes are the most widely used systems. They heat water and use natural circulation to transport it from the collector to the tank. Natural circulation occurs because the density of the water decreases as the temperature increases. Therefore, when the solar collector array absorbs solar radiation, the water in the collector is heated, and thus expands and rises through the collector header into the top of the hot

[7] Source is available at http://www.cie.org.cy/menuEn/pdf/publications/Build_Up_Skills_Report-Analysis_of_the_National_Status%20_Quo%20_En.pdf (accessed 21 May 2015).

water tank. The cooler water in the tank sinks to the bottom and flows down to the collector. This circulation continues until sunset.

The SWHSs available on the market are either locally manufactured or imported from Turkey. Local SWHSs are manufactured with lower-quality materials and using less-advanced manufacturing techniques than imported SWHSs.[8] However, they consist of two flat plate collectors with total net absorber area in the range 3.2–4.0 m^2, while imported SWHS consist of one collector with net absorber area in the range 1.6–2.2 m^2.

Locally manufactured systems dominate the market as they can be purchased at lower prices than systems imported from abroad.[9] Although the local manufacturers receive no tariff protection from imports, they have been quite successful in competing with imports and capturing the local market. The development of this industry is a good example of the potential for linkages between efficient and competitive local enterprises and the demand for equipment designed to produce energy from renewable energy sources. In this study, we evaluate the financially and economically feasibilities of locally manufactured SWHSs.

Some residents use an SWHS combined with a gas heater as back-up. Households with such a system invest in both an SWHS and a gas heater. However, this has a convenience factor in that the system supplies instant hot water in the winter season. Furthermore, this almost eliminates the wastage of water (and also energy which has

[8] The panels of imported SWHSs are more durable against hard water, and hence their lifetimes are longer compared with locally manufactured panels (Atikol et al., 2013).

[9] Retail prices of the panels are correlated with the types of materials used. Panels made of copper cost almost twice as much as panels made of steel; however, they have higher thermal conductivity. This study considers the copper panels owing to they have been prevalent in the market since the beginning of the 2010s.

been used to heat the water) in the pipes from the roof to the places within the house where it is needed. It is important to point out that waste of the water and the energy is a serious drawback for SWHSs when electricity is used as a back-up source of energy even though it both enhances the reliability of consuming hot water on demand and lead to energy saving.

Gas heaters are used when the contribution of SWHSs to the total required heating load is not sufficiently high.[10] They are connected to the cold water mains because hot water flowing through the hot water tank of an SWHS potentially harms the heater's thermal performance and also shortens its life. In other words, the gas heater is not an auxiliary source of energy for the SWHS. It completely replaces the SWHS when it is in use. An electrical element may be used to supplement the heating of the water in the spring and in the fall while the SWHS is in use.

1.3 The Northern Cyprus Water Supply Project (NCWSP)

The Northern Cyprus Water Supply Project was implemented in order to address chronic water shortages. It will transport water for household consumption and irrigation from southern Turkey to Northern Cyprus via pipelines under the Mediterranean. Construction of the project started in March 2011 and is expected to be completed in the near future. Once the project is accomplished, annually 75 million meter cube of water which of 37.76 million meter cube (50.3%) is allocated for household consumption and the remaining for irrigation purposes will be transported for a period of 50 years (Secretariat-General of The National Security Council, Republic of Turkey).[11] Thus, it is projected reliable (continuously

[10] Gas heaters are mainly used in dwellings with one to three members in the period November–February and in dwellings with more than three members in the period October–March.

[11] Total 172.3 million meter cube of water consumption of which 31.43 million meter cube in residential, 139 million meter cube in agriculture and 1.96 million meter cube in industrial sector was

pressurized) potable water to be gradually supplied to all households in consequence of implementation of this project.

It should be pointed out that quality of water is an important factor that influences on the thermal performance and thereby financially viability of SWHSs (Kablan, 2004; Raisul Islam et al., 2013; Srinivas, 2011). Low-quality water in terms of salinity and scaling does not only cause scale formation in the solar panels but also shortens the lifetime of electrical element. This fact is consistent with the observed preferences of residents of North Cyprus on water heating systems.

In Famagusta, which has lowest quality of water in the country, the proportion of households using SWHSs is 65%, while the usage is 75% in Nicosia and Kyrenia, which have a higher-quality water supply (State Planning Organization). What is more, maintenance providers interviewed stated that residents using an SWHS with electricity back-up in Famagusta may potentially need to replace their element every year. In contrast, the lifetime of an element may be up to five years in Nicosia and Kyrenia.

To sum up, a high level of water quality will increase the lifetime of solar panels and electrical elements when the water utility supply pressurized potable water. Moreover, households using gas heaters will not have to buy a hydrophore unit to pressurize the water supply. As a result, the costs of hot water consumption for each of the water heating systems will decrease when NCWSP is accomplished.

---

reported in North Cyprus as of 2010 (Secretariat-General of The National Security Council, Republic of Turkey).

1.4 Objective of the dissertation

The objective of this dissertation is first to evaluate the financial feasibility of SWHSs versus electrical water heaters and to estimate annual energy (electricity) savings and hence environmental impacts in terms of savings of greenhouse gas (GHG) emissions, namely CO_2, NO_x and SO_2, resulting from the replacement of electrical heaters with SWHSs in North Cyprus. Secondly, we undertake to determine which of the alternative water heating system is financially the most cost-effective for providing a year-round supply of hot water to the North Cypriot households.

Thirdly, we conduct an economic cost-effectiveness analysis of the water heating systems, first from the perspective of the economy of North Cyprus and then from a global perspective by including environmental externalities costs measured by the social cost of carbon (SCC) into the analysis. Furthermore, we investigate how a reliable potable water supply would affect the relative cost-effectiveness of the alternative water heating systems. Finally, a design of energy policy for water heating depending on the results is recommended.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Many studies regarding SWHSs have mainly focused on technical issues such as thermal performance of SWHSs and modeling of the system. Apart from hundreds of those technical studies, nevertheless there are some studies in the literature that have been conducted on evaluating financial feasibility of SWHSs versus alternative water heaters and on assessing environmental effects of water heating systems including SWHSs.[12] We specify this study's contributions to the literature and present briefly previous relevant studies in this chapter.

Previous studies have not taken into consideration the impact of the lack of reliability of electricity and/or water supplies when evaluating the financial competitiveness of alternative water heating systems. Therefore, this is the first study that integrates the problems associated with both unreliable water and electricity supplies into cost-effectiveness analysis of the water heating systems. Moreover, it is the first study that conducts economic analysis of the water heating systems from the perspective of the economy of a country.

In addition, it is the first and only study in North Cyprus that compares cost-effectiveness of the alternative water heating systems. It is also the first and only

[12] Raisul Islam et al. (2013) made a review of the research on the technical and financial aspects of SWHSs.

study in North Cyprus that attempt to estimate annual energy and hence GHG emission savings resulting from the replacement of electrical heaters with SWHSs. Finally, it is one of the few studies that take into consideration potential sources of back-up energy for the SWHS while evaluating feasibility of the SWHSs versus conventional water heaters.

2.2 Financial analysis of SWHSs versus conventional systems

Atikol et al. (2013) and Kalogirou (2009b) found that SWHSs are more financially viable than electrical water heaters for hot water production in North Cyprus and South Cyprus, respectively. Atikol et al. (2013) calculated annual energy obtained from solar panels, taking into account average daily solar radiation data; they assumed that this is equivalent to annual energy savings by the household. However, Kalogirou (2009b) found that hot water supplied by SWHSs exceeds the hot water demand in summer in South Cyprus. Therefore, losses in summer as well as disregarded tank heat losses lead to energy savings being overestimated. In this study we take into consideration the coincidence of the hourly demand for hot water and the hot water supplied by SWHSs.

Gastli and Charabi (2011), Kablan (2004) and Ozsabuncuoglu (1995) evaluated the financial viability of SWHSs versus conventional water heaters in Oman, Jordan and Turkey, both of which have identical solar radiation levels to those in Cyprus. They found that SWHSs could be competitive with other types of water heating systems. Diakoulaki et al. (2001) and Kaldellis et al. (2005) carried out a cost–benefit analysis to compare SWHSs with conventional technologies in Greece. They found that although replacing electrical or diesel water heaters with SWHSs resulted in a considerable net social benefit, the use of natural gas for water heating gave greater net benefits owing to its lower cost.

In addition, a number of studies have recently conducted the financial analysis of SWHSs. Cassard et al. (2011) and Lin et al. (2015) found that SWHSs could be competitive with electrical water heating systems in some areas in USA and Taiwan, respectively. Giglio et al. (2014) and Naspolini and Rüther (2012) found that SWHSs could be financially feasible for low-income families in Brazil.

Allen et al. (2010), Fraisse et al. (2009), Han et al. (2010), Hang et al.(2012) and Li et al. (2011) have also examined the environmental benefits of SWHSs as a result of increased concern about the environmental impacts of energy consumption. Allen et al. (2010) and Fraisse et al. (2009) found that SWHSs are not competitive in UK and in France, although they provide large environmental benefits when displacing electrical system. Han et al. (2010) and Li et al. (2011) found that in addition to their environmental benefits, SWHSs are financially attractive for residents of Zhejiang and Dezhou in China. Hang et al. (2012) found that SWHSs are cost-effective when natural gas is used as a back-up source of energy to SWHSs and this system is also the most eco-friendly system in USA.

Furthermore, Gillingham (2009) and Ma et al. (2014) have evaluated financially attractiveness of SWHSs and effectiveness of present subsidy policies for promoting diffusion of installation of SWHSs in New Zealand and in China, respectively.

It is important to point out that almost all of these studies have conducted a financial analysis of SWHSs on the basis of a typical family size. However, energy saving estimations may vary significantly with the number of family members in a household, as this will affect the daily load volume (Cassard et al., 2011; Gillingham, 2009; Lin et al., 2015). For this reason, we evaluate financially and economically feasibilities of the alternative water heating systems for families with one to five members.[13] This enables both to find the most cost-effective water heating system depending on household size and estimate annual country-wide electricity savings resulting from the replacement of electrical heaters with SWHSs as number of dwelling with SWHSs is readily available.

2.3 Environmental studies on SWHSs

Some studies have been done to evaluate environmental impacts of the water heating systems including SWHSs with electricity back-up. Taborianski and Prado (2004) and Tsilingiridis et al. (2004) evaluated lifecycle environmental impacts of the water heating systems in use in Brazil and Greece. While many countries have been promoting SWHSs due to environmental concerns, the authors found that SWHSs are less eco-friendly for heating water than LPG in Brazil and natural gas in Greece because of the contribution of the electricity to the load.

2.3.1 Net energy analysis of SWHSs

Though SWHS has zero environmental pollutant in its operation phase, some levels of emissions are produced over its lifecycle, from the extraction of materials used and manufacturing process to its disposal. This fact leads to indirect environmental impacts caused by the SWHS throughout its life span to be estimated.

Life cycle analysis which is commonly referred to as net energy analysis of a system accounts for whole energy inputs through its lifecycle. Purpose of the net energy

[13] 95% of households in North Cyprus with SWHSs have one to five members (State Planning Organization).

analysis is to determine whether or not the energy supplied by the system predominate its energy requirement associated with the production, installation, maintenance etc. which is referred to as embodied energy (EE). A net energy analysis for an SWHS is performed comparing the EE with the quantity of energy saved by the SWHS. Generally, results of the analysis are presented in terms of energy payback period (EPP): the time necessary for the system to yield cumulative energy to break-even it's EE.[14] Hence, the shorter the EPP, the greater net energy gain and hence greater environmental gain during the system's life span (Allen et al., 2010).

A number of studies have been completed that conduct net energy analysis for SWHS (Allen et al., 2010; Ardente et al., 2005; Battisti and Corrado, 2005; Crawford and Treloar, 2004; Hernandez and Kenny, 2012; Kalogirou, 2004). Authors evaluated environmental impacts of SWHS over its lifecycle by estimating EPPs. Estimated EPPs depending on conventional energy source partially replaced by SWHS in these studies are shown in Table 2.1.

Table 2.1. Estimations of EPPs in reviewed studies

Author	Location	EPP (years)
Crawford and Treloar (2004)	Melbourne, Australia	0.5 - 2
Kalogirou (2004)	Nicosia, Cyprus	1.2 - 1.5
Ardente et al. (2005)	Palermo, Italy	< 2
Battisti and Corrado (2005)	Rome, Italy	0.4 - 1.6
Allen et al. (2010)	UK	2.9 - 5.2
Hernandez and Kenny (2012)	Ireland	1.2 - 3.5

[14] EPP=EE/annual energy savings. Annual energy savings have been considered constant for every year of the system's service life in estimating EPP (Hernandez and Kenny, 2012).

It can be seen from Table 2.1 that EPPs vary in the range of 0.5 – 2 years in the countries with relatively high levels of solar radiation such as Cyprus, Italy and Australia, implying energy savings rapidly compensate for the EE of the SWHS. Furthermore, the periods may be as low as 3 years even in the countries with maritime climate such as UK and Ireland. Consequently, EE is a small proportion of the life cycle energy savings for SWHS taking into consideration their life expectancies of 15-20 years.

Chapter 3

METHODOLOGY

3.1 Cost-effectiveness analysis

In this study we undertake a cost-effectiveness analysis of the alternative water heating technologies in order to identify the most financially and economically cost-effective (least-cost) system to provide hot water, taking into consideration the relevant costs, namely capital costs, and maintenance and operation costs (Jenkins et al., 2011b). Cost-effectiveness analysis is very useful at ranking the various options when the alternatives address desired quantitative outcomes for which are measured in physical units rather than be given monetary values.

This analysis computes cost-effectiveness ratios (CE ratios) for different alternatives and aims at choosing the least-cost alternative by comparing the resulting ratios. CE ratios are calculated by dividing the present value of total costs by the present value of a non-monetary quantitative measure of the benefits.

$$CE = \frac{\sum_{n=0}^{N} \frac{C_n + O_n + M_n}{(1+r)^n}}{\sum_{n=0}^{N} \frac{q_n}{(1+r)^n}} \qquad (1)$$

where q_n is annual hot water production, C_n is capital cost in year *n*, O_n is operation cost in year *n*, M_n is maintenance cost in year *n*, *r* is the real discount rate, *n* represents *n* year lifecycle, and *N* represents the lifespan of the analysis.

The CE ratio is an estimate of the costs incurred to attain a unit of the outcome from each of the alternatives under consideration. Therefore, the CE ratios presented in the following analyses are estimates of the cost per cubic meter of hot water consumption of the alternative water heating technologies. In other words, CE ratios are levelized cost of hot water consumption per cubic meter (Short et al., 2005).

3.2 Methodology for estimating quantity of energy saved by SWHSs

The proportion of the annual heating load met by SWHSs significantly depends on daily hot water consumption, the size of hot water storage tank, the size and efficiency of solar panels, and climatic conditions (Allen et al., 2010; Tsilingiridis and Martinopoulos, 2010).

Dynamic simulation software programs such as TRNSYS, Watsun, and Polysun have in recent years been replacing design methods. However, design methods are still useful as they are less demanding in terms of data requirements (Kalogirou, 2009a; Koroneos and Nanaki, 2012; Martinopoulos et al., 2013; Raisul Islam et al., 2013).

The benefit in terms of the quantity of energy saved by the SWHSs is estimated using the f-chart method (Duffie and Beckman, 2006). The method is one of the design methods that is user-friendly and provides adequate estimates of long term thermal performance. It is important to note that TRNSYS which is the most widely used simulation program for estimating proportion of load supplied by SWHSs, and RETScreen software program have an energy model based on the f-chart method (Kalogirou, 2009a; Koroneos and Nanaki, 2012).[15]

[15] RETScreen is free-of-charge Excel-based software developed by the Government of Canada to analyze technical and economic viabilities of renewable energy projects, including SWHSs.

Duffie and Mitchell (1983) and Fanney and Klein (1983) compared its predictions with both TRNSYS simulation software estimates and experimental results in order to test validity of the f-chart method. They have shown that there is a very good agreement between these results and the f-chart estimates and hence they have validated this method.

The method correlates the results of large numbers of thermal performance simulations of solar heating systems. The resulting correlations give the proportion of the monthly heating load supplied by solar energy, f_i, as a function of two dimensionless parameters, X and Y, as follows:

$$f = 1.029Y - 0.065X - 0.245Y^2 + 0.0018X^2 + 0.0215Y^3 \tag{2}$$

X is related to the ratio of collector losses to heating loads,

$$X = \frac{A_c F_R' U_L (T_{ref} - T_a) \Delta t}{L} \tag{3}$$

and Y is related to the ratio of absorbed solar radiation to heating loads,

$$Y = \frac{A_c F_R' (\mathrm{T}\alpha) H_T N}{L} \tag{4}$$

where A_c is collector net absorber area (m^2), F_R' is collector heat exchanger efficiency factor, U_L is collector overall loss coefficient (W/m^2 °C), T_{ref} is the empirically derived reference temperature (100 °C), T_a is the monthly average ambient temperature (°C), Δt is total number of seconds in month, L is the total monthly heating load for hot water (J), $(\mathrm{T}\alpha)$ is the monthly average transmittance-absorbance product, H_T is the monthly average daily radiation incident on the collector surface per unit area (J/m^2), and N is number of days in the month.

X and Y can be rewritten as

$$X = F_R U_L * \frac{F_R'}{F_R} * \left(T_{ref} - T_a\right) * \Delta t * \frac{A_c}{L} \tag{5}$$

$$Y = F_R (T\alpha)_n * \frac{F_R'}{F_R} * \frac{(T\alpha)}{(T\alpha)_n} * H_T * N * \frac{A_c}{L} \tag{6}$$

where $F_R U_L$ and $F_R(T\alpha)_n$ are obtained from collector test results, $\frac{F_R'}{F_R}$ is equal to 1 as there is no heat exchanger in the hot water tanks in North Cyprus, and $\frac{(T\alpha)}{(T\alpha)_n}$ can be taken to be constant at 0.96 over a year (Duffie and Beckman, 2006).

It is important to point out that X has to be corrected for both storage size and mains water (cold water) temperature. The f-chart method was developed for a standard storage capacity of 75 liters of stored water per square meter of net collector area. Therefore, X has to be multiplied by a correction factor X_c / X defined by

$$\frac{X_c}{X} = \left(\frac{actual\ storage\ capacity}{standard\ storage\ capacity}\right)^{-0.25} \tag{7}$$

for

$$0.5 \leq \left(\frac{actual\ storage\ capacity}{standard\ storage\ capacity}\right) \leq 4 \tag{8}$$

What is more, cold water temperature, T_m and minimum acceptable hot water temperature (desired hot water temperature), T_w affect the average system operating temperature level and thereby affect the collector energy losses. Therefore, to account for the fluctuation of T_m and T_w, X has to be also multiplied by another correction factor X_{cc} / X defined by

$$\frac{X_{cc}}{X} = \frac{11.6 + 1.18T_w + 3.86T_m - 2.32T_a}{100 - T_a} \tag{9}$$

The f-chart method uses Rand profile which is the repetitive normalized profile of hourly hot water consumption adopted by Mutch (1974). The adjusted normalized

Rand profile with respect to daily hot water withdrawal of 120 liters for a household size of three is illustrated in Figure 3.1.

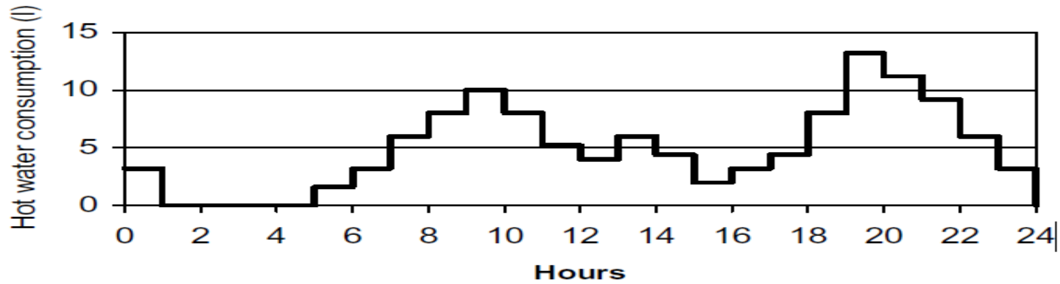

Figure 3.1. Daily hot water consumption profile (Kalogirou, 2009b)

It is Rand profile which is widely used in hourly simulations due to it is difficult to estimate residents' daily hot water consumption profile, particularly in developing countries (Kalogirou, 2009a; Shariah and Löf, 1997). Kalogirou (2009b) used this hot water consumption profile for residents of South Cyprus when evaluating the financial viability of SWHSs using TRNSYS simulation software. It should also be noted that Duffie and Beckman (2006) found that minor changes in time dependence of hot water demand have an insignificant effect on the annual energy contribution by SWHS.

The monthly total energy load, L to heat water to the desired temperature is calculated by

$$L = mC_p(T_d - T_m) \tag{10}$$

where m is monthly hot water consumption (liters), C_p is the specific heat of water (J/ liter °C), 4190 J/liter °C, T_d is the desired hot water temperature and T_m is the average temperature of water in the tank. L should also include losses from the hot water tank in the case where an SWHS and electrical heater are used.[16] Once the required monthly heating load and subsequently proportion of the monthly heating load, f_i is determined, the proportion of the annual heating load supplied by an SWHS, Ƒ can be estimated as follows:

$$Ƒ = \frac{\sum f_i L_i}{\sum L_i} \tag{11}$$

where $\sum f_i L_i$ yield annual energy saving by SWHSs.

[16] The rate of tank losses is estimated from the tank's heat loss coefficient and area (UA) and the temperature difference between the water in hot water tank and the ambient temperature, T_a based on the assumption that entire tank is at the desired hot water temperature, $L_t = UA*(T_d - T_a)$ (Duffie and Beckman, 2006). The connecting pipe losses in the case of SWHS usage are disregarded due to Cyprus's mild winter climate.

Chapter 4

DATA AND ASSUMPTIONS

4.1 Total SWHS installations in North Cyprus

North Cyprus has a total land area of 3,354 km^2 and it consists of five districts: Nicosia, Famagusta, Kyrenia, Guzelyurt and Iskele. According to the 2006 census, 50,953 (71.4%) of the total number of 71,376 dwellings had SWHSs in 2006.[17] The number of dwellings with SWHSs by district and by household size is shown in Table 4.1.

Table 4.1. Number of dwellings with SWHSs by district and by household size

	District					
Household size	Nicosia	Famagusta	Kyrenia	Guzelyurt	Iskele	Total
1	1,584	1,496	1,448	608	360	5,496
2	4,167	3,144	3,416	1,392	845	12,964
3	4,785	3,190	2,756	1,477	753	12,961
4	4,680	3,368	2,572	1,467	970	13,057
5	1,183	1,082	927	437	461	4,090
5+	648	590	566	225	356	2,385
Total	17,047	12,870	11,685	5,606	3,745	50,953

[17]The total number of dwellings in the country was recorded as 72,624 as of 2006. However, the number of dwellings with permanent households was 71,376 (State Planning Organization).

As can be seen from Table 4.1, about one-third of installed SWHSs are located in Nicosia and about half are located in Famagusta and Kyrenia. Furthermore, 95% of households with SWHSs have one to five members.[18]

4.2 Technical information for SWHSs

Cassard et al. (2011) and Fraisse et al. (2009) found that the absorber area of the collector is one of the most significant variables in estimating energy savings. It has been the normal manufacturing practice in North Cyprus to make the total absorber area of the locally manufactured collectors almost twice that of the imported SWHSs. Although the efficiency of the locally made collectors is lower than the imported solar collectors for same area, the overall supply of hot water from the local SWHS is very similar to that of the imported system (Atikol et al., 2013). Technical information for the types of SWHS that are imported is readily available and is used in the analysis because such data is not available for the locally manufactured SWHSs analyzed.[19]

We estimate average annual savings of households individually for each district taking family size into consideration while at the same time adjusting the size of the corresponding SWHS (Tsilingiridis and Martinopoulos, 2010). The correct sizing of the tank capacity for the household's daily water consumption is critical for the efficient utilization of the solar energy in the spring and fall. It is also critical in winter when solar radiation is low, if the required heating load during winter is being met largely by electrical energy. In this respect, we assume that households with one

[18] While we estimate total annual energy savings resulting from utilization of SWHSs, we omit electricity savings for household size of more than five.

[19] Imported SWHSs are certified by the Solar Rating & Certification Corporation (SRCC), which administers certification, rating and labeling programs for solar thermal collectors and complete SWHSs. The SRCC provides specific information on the collectors and systems certified under the various SRCC certification and ratings. For more information see: http://solar-rating.org.

or two, three, four or five members have system A, system B, and system C, respectively. The technical efficiency parameters and system sizes of the SWHSs analyzed are presented in Table 4.2.

Table 4.2. Characteristics of the SWHSs under evaluation

System	A	B	C
Family size	1–2 people	3 people	4–5 people
$F_R U_L$	4.00	3.79	3.64
$F_R(\tau\alpha)_n$	0.711	0.73	0.705
Tank capacity	120 liters	150 liters	200 liters
Net absorber area	1.62 m^2	2.11 m^2	2.23 m^2

Source: SRCC website: https://secure.solar-rating.org/Certification/Ratings/RatingsSummaryPage.aspx.

4.3 Assumptions on estimating monthly and annual heating load for the water heating systems

In order to estimate annual operating costs of the water heating systems and also to estimate the benefit of SWHSs in terms of energy saving, we first estimate the required monthly and hence annual heating load using equation (10). To do this, we assume that the desired hot water temperature is set at 50 °C in the case of SWHS and electricity usage, and at 45 °C in the case of gas heater usage, as hot water is not stored.

According to information obtained from various municipal water supply departments in the country, average monthly water consumption per capita is 4 m^3 in North Cyprus. Based on the RETScreen software assumption of hot water consumption, hot water consumption is assumed to be one third of total water consumption. Therefore, daily hot water consumption is taken as 40 liters/person. These assumptions are consistent with assumptions used in the literature: the hot water consumption is assumed to be in the range 30- 60 liters/person and set temperature of hot water is assumed to be at 45-50 °C (United Nations Environment Programme, 2014).

4.4 Estimated benefit of SWHSs in terms of energy saving

Once meteorological data and technical parameters of SWHSs have been gathered and the required monthly heating load determined, the proportion of the monthly load, and hence the proportion of the annual load supplied by SWHSs is estimated using the f-chart method. The energy savings for a typical household size of three based on daily average hot water consumption of 40 liters/person are presented in Table 4.3. (see appendix C).

Table 4.3. Monthly and annual energy saving estimates for a typical household size of three

Month	H_T,MJ/m^{2*}	T_a^*	T_m^*	L,MJ	X	Y	f	fL,MJ	fL,kWh**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Jan	8.9	12.2	14.8	797	2.71	0.52	0.31	243	67
(2) Feb	12.4	11.9	14.9	720	2.74	0.71	0.45	325	90
(3) Mar	17.4	13.9	16.9	753	2.99	1.06	0.66	499	138
(4) Apr	21.5	17.5	20.7	648	3.56	1.47	0.84	547	152
(5) May	26.1	21.6	25.4	570	4.52	2.10	1.00^{Ŧ}	570	158
(6) June	29.2	25.9	29.8	458	5.76	2.83	1.00^{Ŧ}	458	127
(7) July	28.5	29.3	33.3	396	7.19	3.30	1.00^{Ŧ}	396	110
(8) Aug	25.5	29.4	33.4	394	7.24	2.97	1.00^{Ŧ}	394	109
(9) Sep	21.2	26.8	30.6	440	6.04	2.13	0.96	423	117
(10) Oct	15.3	22.7	25.8	556	4.59	1.26	0.69	385	107
(11) Nov	10.3	17.7	20.3	653	3.47	0.70	0.40	265	73
(12) Dec	7.9	13.7	16.3	763	2.89	0.48	0.26	201	56
(13)Total				7149				4706	1304

* Meteorological data for Nicosia, Cyprus's capital, is used in the analysis. It is assumed that the cold water temperature, T_m, is equal to earth temperature (Kalogirou, 2003). Source: Stackhouse and Whitelock (2008).
** 1 MJ = 0.277 kWh.
Ŧ There is excess supply in the range 2–13% during the period May–August. Therefore, corresponding monthly proportions are corrected in order to avoid exaggerated outcomes.

Based on estimates from Table 4.3, all required heating load for water heating can be provided by an SWHS for the months May–September for a typical household size of three (see column 7). The total required heating load in winter is almost twice that of the total load in the summer, owing to considerably colder mains water temperature and higher tank heat losses during winter (see column 4). In addition, owing to low solar radiation levels in winter (see column 1), the proportion of the annual heating load met by SWHS is estimated to be 66%.[20]

Furthermore, monthly percentages of heating load met by SWHSs for household size of one to five in Nicosia are shown in Figure 4.1.[21]

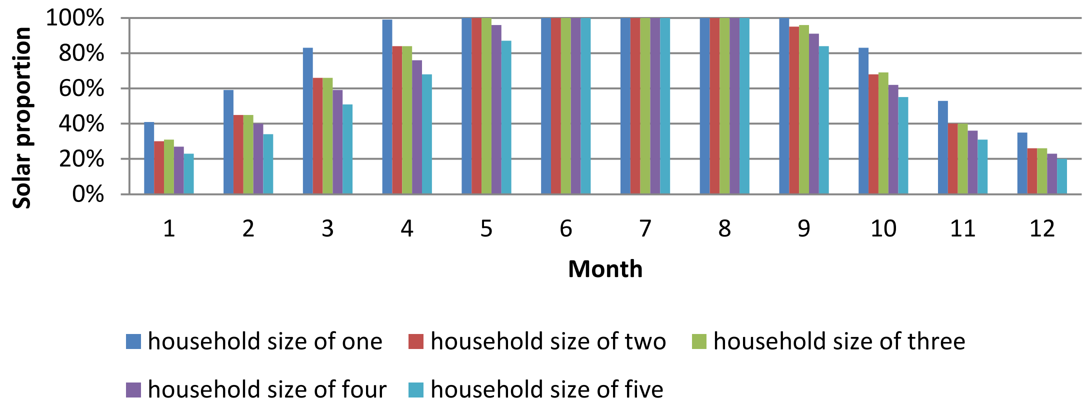

Figure 4.1. Proportion of heating load supplied by an SWHS for a household size of one to five.

Figure 4.1 shows that all households can provide their hot water needs completely through SWHSs in the summer months.[22] SWHSs also met a significant part of required heating load in the spring and fall. The proportion of the load supplied by SWHSs depending on household size is estimated during April–May and September–October to be in the range 80–100% and 70–90%, respectively. In contrast, SWHSs if auxiliary electrical heater is used as a back-up, can contribute

[20] The proportion of the load met by SWHSs is estimated using equation (11): F = 4706/7149=0.66 (see row 13).

[21] The proportion of annual heating load supplied by SWHS is estimated to be in the range 56–75%, depending on household size (see appendix A to E).

[22] Households' desired hot water temperature is lower in summer than that in winter in practice. Therefore, we assumed that households using SWHSs do not need auxiliary energy for water heating in the period May-September.

only up to 40% of the heating load, in the winter months when the required heating load is relatively much higher. Therefore, these results highlight importance of source of back-up energy for SWHSs for its overall cost-effectiveness.

Finally, the annual electricity savings for households with one to five members by district are presented in Table 4.4. These energy savings are for the use of an SWHS that is substituting partially for a system of water heating using only electricity.

Table 4.4. Annual electricity savings per dwelling (kWh) by district

	District				
Household size	Nicosia	Famagusta	Kyrenia	Guzelyurt	Iskele
1	754	824	751	800	789
2	952	1,063	949	1,015	1,011
3	1,304	1,458	1,301	1,389	1,389
4	1,494	1,677	1,492	1,593	1,595
5	1,626	1,827	1,624	1,734	1,737

The estimations presented in Table 4.4 indicate that although the country has only a small area, the energy savings differ from one district to another owing to slight differences in solar radiation and in air and cold water temperatures between the districts. It is estimated that annual electricity savings vary significantly, in the range 750–1830 kWh, according to the number of family members in a household, as this will affect the daily load volume. For instance, the energy savings for a household with four members is twice that for a household with one member. This result is consistent with results of studies by Cassard et al. (2011), Gillingham (2009), and Lin et al. (2015).

4.5 The total annual load and auxiliary energy in the case of SWHSs in use

The total annual load for each system and required auxiliary energy in the case of SWHSs in use is estimated, based on meteorological data for Nicosia, and presented in Table 4.5.

Table 4.5. Total annual and auxiliary load in the case of SWHS in use (kWh/year) by household size

Water heating system	Household size				
	1	2	3	4	5
Annual total load if only electricity used	1,006	1,454	1,980	2,439	2,887
Auxiliary (electricity) load with SWHS	252	502	675	945	1,261
Annual total load if only gas heater used	363	726	1,090	1,453	1,816
Auxiliary (LPG) load with SWHS	158	317	475	906	1,130
Auxiliary (electricity) load with SWHS	32	109	134	52	83

Based on the estimates from Table 4.5, the annual heating load when electricity is used alone or as a back-up to an SWHS is considerable greater than that in the case of gas heater usage, partly because of the inclusion of tank heat losses in the heating load. Tank heat losses have a larger impact on heating loads for households with fewer members, even though the proportion of energy supplied by SWHSs for the corresponding households is larger. Tank heat losses occur particularly in the winter season when the ambient temperature is at its lowest level. However, such losses are minimized when gas heaters are used as a back-up to SWHSs in the winter months, although this causes a loss of supplied energy by SWHSs as gas heaters completely replace SWHSs. For this reason, the contribution of SWHS to the heating load is relatively lower when gas heaters are used as a back-up.

4.6 Cost and parameter values for alternative water heating systems

The analysis is carried out in terms of constant prices of 2014, rather than projected nominal prices that would have required us to forecast the rate of inflation.[23] To make the present value calculations in a way that would be consistent with this approach, the projected cash flows are discounted using a real discount rate of 10% (Ozbafli, 2011). In the analysis that follows sensitivity analysis is carried out for additional real interest rates of 5 percent and 15 percent.

4.6.1 Specific data and assumptions for electrical water heaters used alone or as a back-up to SWHSs

It is estimated that the efficiency rate of the electric heater in the hot water tank is 85% (Personal Communication, Department of Mechanical Engineering, Eastern Mediterranean University). A major inefficiency associated with having an electric water heater on the roof is the waste of energy as hot water cools in the pipes from the roof to the places within the house where it is needed. This distance is often 12-25 m, particularly in apartment buildings. This is not a significant problem in the summer months with an SWHS, as there is a surplus of hot water. A major problem arises in the winter months with an SWHS that uses electricity for winter back-up.

In the estimations carried out here, we assume that if an all-season electrical heating system is installed, it will be located close to the place where the water is being used as in the case of LPG water heater. In order to take into account the standby heat loss through pipes in the case of an SWHS with electricity back-up, we assume that a daily average of 10 liters of water and its heat per capita would be wasted during a six-month period when electricity as a source of energy is used to heat water.

[23] We have measured all costs in terms of $US. Average exchange rate was 1 US$=2.20 Turkish Lira (TL) as of November 2014.

4.6.2 Specific data and assumptions for gas heaters used alone or as a back-up to SWHSs

Households using gas heaters alone do not need to install a hot water tank under the cold water tank on the roof because gas heaters are connected to the cold water tank.[24] Owing to the low water pressure a hydrophore unit needs to be installed to pump the water into the gas heater. To estimate the electricity cost of operating the hydrophore unit, a standardized six-minute showering time for a person is mainly considered (Sezai et al., 2005). In this manner, the daily operation duration of the hydrophore unit is assumed to be in the range 0.25-1 hour depending on household size. Finally, the efficiency rate of gas heaters is estimated to be 80% (Personal Communication, Department of Mechanical Engineering, Eastern Mediterranean University).

4.6.3 Financial capital and operating costs (US$) of the water heating systems

The capital cost and the maintenance cost data are obtained by undertaking of a survey of five different local equipment suppliers and maintenance providers in the cities of Nicosia, Famagusta, and Kyrenia in November 2014. Because prices vary slightly across different suppliers and maintenance providers, we use the average cost of such equipment and maintenance. The average financial capital and maintenance costs of the water heating systems under evaluation are shown in Table 4.6.

[24] Likewise gas heaters are connected to the cold water tank in case of SWHS with gas back-up because hot water flowing through the hot water tank potentially harms the heater's thermal performance and also shortens its life.

Table 4.6. Financial capital and maintenance costs (US$) of the water heating systems

	Type of water heater			
	Electrical heater	SWHS with electricity back-up	Gas heater	SWHS with gas heater back-up
Capital cost	273 - 318	637 – 773	205	842 - 978
Electrical element cost	45	45	-	45
Hydrophore cost	-	-	68	68
Installment cost	23	23	114	137
Maintenance cost	-	-	45	45

Gas heaters need to be regularly serviced once a year. Unlike for gas heaters, there is no maintenance service for electrical water heaters and SWHSs. However, households that have an SWHS should clean solar panels periodically, as soiling due to dust, dirt and particularly bird droppings reduces their efficiency.

On average, residents consume 500 kWh of electricity per month (Ozbafli, 2011). An increasing block tariff structure is used for the pricing of electricity for the residential sector in North Cyprus. As of December 2014, residential consumers pay 0.205 US$/kWh for the first 250 kWh, 0.25 US$/kWh for consumption of 251–500 kWh, 0.305 US$/kWh for consumption of 501–750 kWh, and 0.382 US$/kWh for consumption above 750 kWh excluding 10% value added tax (VAT) (Kib-Tek).[25] Therefore, the financial price of electricity is taken as 0.275 US$/kWh. The financial price of an LPG cylinder containing 10 kg gas is 19.50 US$ as of December 2014. In the base case scenario, we assume that the prices of electricity and LPG (in real terms) would be constant throughout 20 years. Other electricity and fuel price scenarios are addressed in the sensitivity analysis.

[25] Source is available at http://www.kibtek.com/Tarifeler/Tarifeler.htm (accessed 8 December 2014).

4.6.4 The various taxes levied on capital items and fuels

In order to estimate economic costs of the capital items, we should take into consideration various taxes levied on them. There are no subsidies on the purchase of the water heating systems. The various taxes levied on the capital items are presented in Table 4.7.

Table 4.7. The various taxes levied on the capital items

Capital items	VAT rate	Withholding tax rate	Custom duty
Solar collectors	10%	--	--
Hot water tank	10%	--	--
Gas heater	16%	--	2.7%
Electrical element	16%	--	--
Hydrophore unit	16%	4%	--

As reported in Table 4.7, locally manufactured SWHSs and electrical water heaters have a 10% VAT levied on their sales price. Imported gas heaters, electrical elements and hydrophore units are subject to a 16% VAT (Personal Communication, Tax Office). In addition, the gas heaters under evaluation have a 2.7% customs duty levied on them as they are imported from out of EU countries or Turkey and the hydrophore units have a 4% withholding tax levied on them (Personal Communication, Customs Office).

Neither the equipment nor heavy fuel oil (HFO) for electricity generation is subject to excise taxes or tariffs. Furthermore, there are currently no subsidies on the purchase of either equipment or fuel. A 10% VAT is only levied on the sales price of electricity. Therefore, the economic price of electricity is taken as 0.25 US$/kWh. In contrast, LPG has a 5% VAT imposed on it when imported, and it also has levies at 0.5% and 18.92% applied to its cost, insurance and freight (CIF) price for the tourism development and promotion fund and the price stabilization fund, respectively. CIF price of an LPG cylinder containing 10 kg gas is 8.57 US$ as of December 2014 (Personal Communication, Customs Office). Its economic price is estimated to be 17.40 US$ as of December 2014.

4.6.5 Lifetime of the water heaters and their miscellaneous parts and lifetime of the analysis

The lifetime of the electrical water heater (hot water tank) is estimated to be 20 years, while the lifetime of the solar panels is estimated to be 10 years owing to the low water quality causing scale formation in the collector system. Furthermore, the lifetime of the gas heaters if used as the exclusive supplier of hot water is estimated to be seven years. The experience in North Cyprus is that gas heaters last 10 years when they are used as a back-up to SWHSs during the winter season. Also, the lifetime of the hydrophore unit is estimated to be five years.

According to the maintenance providers interviewed, the lifetime of the electrical heating element in the hot water tank is shortened as a result of the low water quality. From their experience, the lifetime varies between one and five years depending on water quality supplied by the water utility and the usage of electricity for water heating. Therefore, in the base case scenario, the life expectancy of the heating element when residents use only electricity, SWHS with electricity back-up and SWHS with gas back-up is taken as one year, three years and five years, respectively.[26]

[26] The lifetime of the electrical element may be highly variable from one region to another, depending on water quality. Maintenance providers interviewed stated that residents using an SWHS with electricity back-up in Famagusta, which has the lowest water quality in the country, may potentially need to replace their element every year. In contrast, the lifetime of an element may be up to five years in Nicosia and Kyrenia, which have a relatively higher quality of water.

The lifetime of the analysis is taken as 20 years. During the 20 year period over which the options are compared, some of the equipment for one or more of the options will need to be replaced in order to provide a common time period for the analysis. Using the same project lifetime will improve the accuracy of the comparability of the alternatives (Jenkins et al., 2011a).

4.7 Parameter values for GHG emission estimates

In order to estimate the GHG emissions, we need to take into consideration the efficiency of both the water heaters which is specified in previous section and the electricity generating power plants, as well as the GHG emission factors per unit of energy.

The power plants in North Cyprus are operated with thermal efficiency using HFO of 33% (Atikol et al., 2013). There are also transmission and distribution losses of about 10% in the delivery of the electricity to households (Kib-Tek). Therefore, the required supplementary energy should multiply by a factor of 1.25 in the case of LPG. The adjustment factor is 3.96 of electrical energy needed.[27] This means that 3.96 times as much HFO is required to operate the electrical water heating system than would be needed by a 100% fuel efficient system.

CO_2, NO_x and SO_2 emission factors through HFO use in the power plants are estimated as 0.263kg/kWh, 0.743 g/kWh, and 1.47 g/kWh, respectively (Atikol et al., 2013). Moreover, the CO_2 emission factor through LPG use is taken as 0.211 kg /kWh (United States Environmental Protection Agency, U.S. EPA, 2014).

[27] The factor for LPG is estimated as 1/0.80=1.25 and for electricity as 1/ (0.85*0.33*0.9) =3.96.

The SCC represents the economic damages associated with an incremental increase in CO_2 emissions, conventionally one metric ton, and is currently used in economic cost-benefit analyses. While many estimates have been made of the SCC values (Greenstone et al., 2011), the recent estimates made by U.S. EPA are used in this study. The central value of the SCC is estimated to be \$39 (in 2011 dollars) per ton of CO_2 emissions. A sensitivity analysis is conducted for its value at \$12, \$39 and \$61 per ton (U.S. EPA, 2013).

Chapter 5

FINANCIAL AND ENVIRONMENTAL ANALYSIS OF SWHSs VERSUS ELECTRICAL HEATERS

5.1 Financial feasibility of SWHSs versus electrical heaters

Considering that the efficiency factor of electrical water heaters is 85%, households with solar collectors connected to their hot water tanks are able to save electrical energy of 880–2,150 kWh per annum, depending on family size. At 2014 electricity tariff rates, this is equivalent to annual savings on electricity bills of at least US$ 200 and US$ 485 for families with one and five members, respectively.

Given the additional financial investment cost of the solar panels of between US$ 360 and US$ 445, the payback period of the financial costs of the investment in an SWHS as compared with that for heating water using electricity is estimated to be less than two years.

Considering the short energy payback periods of SWHSs compared to their life expectancy of 10 years, we can safely say that replacing electrical heaters with SWHSs in water heating is a financially very attractive for the North Cypriot households.

5.2 Annual total electricity and GHG emission savings resulting from the replacement of electrical heaters with SWHSs

We estimate the annual total electricity savings using the available data on the number of SWHSs installed by district for 2006, presented in Table 4.1 and data on annual average electricity savings per dwelling by district, presented in Table 4.4. The results are presented in Table 5.1.

Table 5.1. Total electricity savings per district and country-wide (GWh) in 2006

Household size	District					
	Nicosia	Famagusta	Kyrenia	Guzelyurt	Iskele	Country-wide
1	1.19	1.23	1.09	0.49	0.28	4.28
2	3.97	3.34	3.24	1.41	0.85	12.81
3	6.24	4.65	3.59	2.05	1.05	17.58
4	6.99	5.65	3.84	2.34	1.55	20.37
5	1.92	1.98	1.51	0.76	0.80	6.96
Total savings	20.32	16.85	13.26	7.05	4.53	62.00

As shown in Table 5.1, annual total electricity savings potentially reach 62 GWh in 2006 country-wide as a result of replacing electrical heaters with SWHSs. To put it differently, utilization of SWHSs mitigates total electricity consumption in the residential sector by approximately 15%, given a total electricity consumption of 335.8 GWh in 2006 in the residential sector (Kib-Tek).[28]

It is likely that the share of the households employing an SWHS is greater in 2013 than it was in 2006. In the analysis which follows it is assumed that the proportion of households using an SWHS remained the same in 2013 as in 2006. Given the total electricity production of 1,340 GWh in 2013 (Kib-Tek), with one-third of the total

[28] Source is available at http://www.kibtek.com/Santrallar/urt_tuksant97_2008.htm. (accessed 3 March 2015).

generation being undertaken to supply residential households, and if at least 15% of the residential consumption would be saved by the use of SWHSs, then 67 GWh of electricity has potentially been saved by the installed SWHSs in 2013.

In terms of savings in GHG emissions, the use of SWHSs for water heating results in annual savings of at least 70,000 tons of CO_2, 197 tons of NO_x and 390 tons of SO_2 emissions in 2013. It should be noted that this is an underestimate of GHG reduction arising from the installation of the SWHSs because it includes only the direct GHG reduction from the cuts in the use of electricity and hence HFO in water heating. It does not include the reduction in GHG owing to the reduction in the supply of HFO needed to produce electricity.

Chapter 6

FINANCIAL COST-EFFECTIVENESS ANALYSIS OF ALTERNATIVE WATER HEATING SYSTEMS

6.1 Estimated financial costs of hot water consumption for each of the water heating systems

The financial cost-effectiveness of the alternative water heating systems is compared for families with one to five members. This is done by substituting the financial capital expenditure costs reported in Table 4.6 and the corresponding running costs described in section 4.6.3 into equation (1). The results are expressed as the levelized cost of hot water consumption per cubic meter ($\$US/m^3$) for each of the water heating systems, and are presented in Table 6.1. (see appendix F to J).

Table 6.1. Levelized financial costs of hot water consumption ($\$US/m^3$)

Household size	Water heating system			
	Electricity only	Gas heater only	SWHS with electricity back-up*	SWHS with gas heater back-up
1	27.5	13.8	15.1	16.5
2	18.7	9.9	10.9	10.3
3	16.4	8.2	9.2	8.0
4	14.9	7.6	8.9	7.2
5	13.9	7.3	8.8	6.6

* To estimate the cost of heat loss through pipes, we use average variable cost of electricity used to heat water per cubic meter.

Based on the estimations presented above, the cost of electricity usage for the daily purpose of water heating per cubic meter of 13.90–27.50 US$/m^3 is approximately double the cost of heating water by gas water heater alone or with an SWHS with gas back-up. Furthermore, SWHS with electricity back-up is less cost-effective as compared to gas water heater alone or an SWHS with gas back-up for all households. Gas heaters are the most financially cost-effective option for households with one or two members. However, the cost advantage of SWHSs with gas back-up increases as the energy saving accompanied by household size increases, and hence SWHSs with gas back-up become more financially efficient for households with more than two members, even though households need to invest in an SWHS in addition to the gas water heater.

6.2 Sensitivity Analysis

The results from empirical estimations are expected to be sensitive to the parameters including the real prices of fuel oil and LPG, the real discount rate used, the marginal electricity tariff rates paid by households in winter when electricity is used as a back-up to SWHS, and the lifetime of the electrical element. The last two of these variables potentially affect the viability of the SWHS with electricity back-up. The levelized cost estimations for the electrical water heater systems are omitted in the following sections because they are far from being competitive in any situation, as compared to the other systems.

6.2.1 Sensitivity analysis with respect to changes in the real price of fuels

North Cyprus is an oil-importing country and its energy mix relies entirely on imported HFO to generate electricity. Hence, the marginal cost of electricity generation is highly correlated with fuel oil prices. Furthermore, LPG is imported to the country and is widely used for space heating and cooking as well as usage for the purpose of water heating in North Cyprus. Although forecasting energy prices is uncertain, energy prices will undoubtedly change. To assess the effect of this on our estimations, we consider alternative average energy prices (in real terms) over 20 years compared to the base price projections, rather than assuming a specific annual price escalation rate. It is assumed that the movements in HFO and LPG prices are perfectly correlated. In this respect, the sensitivity analysis is conducted based on average changes in the level of prices over the life of the analysis in the range of −10% to 10% of the base prices. The results are presented in Table 6.2.

Table 6.2. Sensitivity analysis of financial levelized cost of hot water ($US/m^3) with respect to average real prices of fuels over 20 years

	Gas heater			SWHS with electricity back-up			SWHS with gas heater back-up		
Average real price of fuels	10% less	Base cost	10% more	10% less	Base cost	10% more	10% less	Base cost	10% more
Household size									
1	13.2	13.8	14.4	14.2	15.1	15.9	16.2	16.5	16.8
2	9.3	9.9	10.5	10.2	10.9	11.7	10.0	10.3	10.7
3	7.6	8.2	8.8	8.6	9.2	9.9	7.6	8.0	8.3
4	7.1	7.6	8.2	8.2	8.9	9.6	6.8	7.2	7.5
5	6.7	7.3	7.9	8.0	8.8	9.5	6.2	6.6	6.9

Changing the average real prices of electricity and LPG for the 20 years of the analysis results in insignificant changes in the relative costs of the three alternatives. The levelized cost of hot water in the case of an SWHS with gas back-up is the least responsive to the fuel prices. Nevertheless, it is estimated to be the most cost-effective system for a household size of more than two even if the real energy prices are 10% lower over 20 years. Furthermore, it becomes more competitive against gas heaters for all households as the energy prices rise. The most remarkable outcome is that an SWHS with electricity back-up, despite the contribution of the SWHS to the heating load, is not an efficient substitute for gas heaters even if the real energy prices are 10% higher throughout the life of the system.

6.2.2 Sensitivity analysis with respect to real discount rate

The size of the real rate of discount has a significant impact on estimating the present values and thereby the levelized costs. The effects of this key parameter for values between 5% and 15% are reported in Table 6.3.

Table 6.3. Sensitivity analysis of financial levelized cost of hot water ($\$US/m^3$) with respect to the real rate of discount

	Gas heater			SWHS with electricity back-up			SWHS with gas heater back-up		
Real discount rate	5%	10%	15%	5%	10%	15%	5%	10%	15%
Household size									
1	13.3	13.8	14.3	13.9	15.1	16.3	14.8	16.5	18.3
2	9.7	9.9	10.2	10.3	10.9	11.5	9.5	10.3	11.2
3	8.0	8.2	8.4	8.8	9.2	9.7	7.4	8.0	8.6
4	7.5	7.6	7.8	8.5	8.9	9.3	6.7	7.2	7.7
5	7.2	7.3	7.4	8.5	8.8	9.1	6.2	6.6	7.0

As can be seen from Table 6.3, higher discount rates lead to gas heaters to be more cost-effective, while lower discount rates ensure SWHS with gas heater back-up to be more cost-effective. Therefore, gas heaters become most cost-effective compared to SWHSs with gas heater back-up for households with size of one to three with discount rates of 15%. Conversely, with 5% discount rates the SWHSs with gas heater back-up become most attractive for households with more than one member. Nonetheless, we find that the relative costs of these alternatives do not vary significantly as the discount rate changes.

6.2.3 Sensitivity analysis with respect to households' marginal electricity tariff rates in winter

The contribution of SWHSs to the total required heating load if electricity is used as a back-up is estimated to be around one third in the winter. In other words, households with SWHSs with electricity back-up use mainly electricity as the source of energy for water heating in this period. Total household consumption of electricity is highest during the winter months of December and January, except for the summer peak, as shown in Figure 6.1.[29]

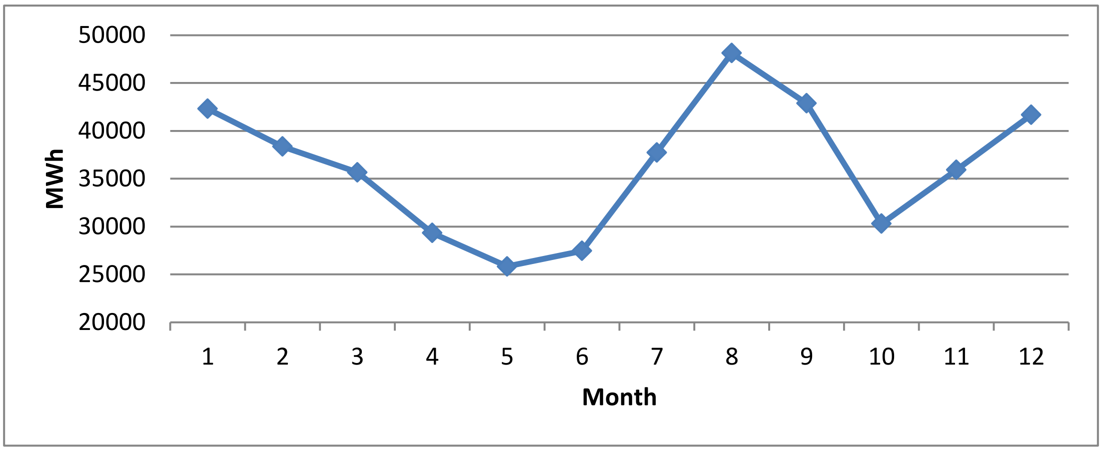

Figure 6.1. Monthly total residential electricity consumption as of 2012 (Kib-Tek).

Therefore, many households when using electricity to heat water will be paying at the third block price of 0.335 US$/kWh during these months. As a result, SWHSs with electricity back-up become further costly compared with alternative water heaters for these households, as shown in Table 6.4.

[29] Source is available at http://www.kibtek.com/Santrallar/uretim_tuketim.htm (accessed 16 March 2015).

Table 6.4. Sensitivity analysis of financial levelized cost of hot water ($\$US/m^3$) with respect to households' marginal electricity tariff rates in winter

	Gas heater[Ŧ]		SWHS with electricity back-up			SWHS with gas heater back-up[Ŧ]	
Electricity tariff rate ($US/kWh)	0.225	0.275	0.225	0.275	0.335	0.225	0.275
Household size							
1	13.6	13.8	13.6	15.1	16.9	16.3	16.5
2	9.7	9.9	9.5	10.9	12.6	10.0	10.3
3	8.0	8.2	8.0	9.2	10.7	7.7	8.0
4	7.5	7.6	7.6	8.9	10.4	7.1	7.2
5	7.1	7.3	7.5	8.8	10.3	6.4	6.6

[Ŧ] The values based on first-second block tariff rates as gas heaters are used for water heating during the winter.

It is important to note that these estimations show that prices of alternative supplementary energy sources for SWHSs have a significant impact. On the one hand, the SWHS with electrical back-up becomes the most cost-effective system for households with size of one or two and using less than electricity of 250 kWh monthly in winter. On the other hand, the cost of the SWHS with electricity back-up becomes potentially 50% more expensive than that of the SWHS with gas heater back-up for households with size of four or five and paying at the third block price tariff in winter.

6.2.4 Sensitivity analysis with respect to lifetime of electrical element

The lifetime of the electrical heating element which depends on largely the quality of water supplied by the water utility might be critical when evaluating the cost-effectiveness of an SWHS with electricity back-up. Therefore, we also conduct a sensitivity analysis on this parameter. We analyze how the SWHS with electricity back-up cost estimations change as the lifetime of the heating element varies between one and five years. No adjustment is made for the case of SWHSs with gas heater back-up as the electrical element is rarely used. The results are presented in Table 6.5.

Table 6.5. Sensitivity analysis of financial levelized cost of hot water ($\$US/m^3$) with respect to lifetime of the electrical element

	Gas heater	SWHS with electricity back-up			SWHS with gas heater back-up
Lifetime of the electrical element (years)	no element	1	3	5	5
Household size					
1	13.8	17.0	15.1	14.7	16.5
2	9.9	11.9	10.9	10.7	10.3
3	8.2	9.9	9.2	9.1	8.0
4	7.6	9.4	8.9	8.8	7.2
5	7.3	9.2	8.8	8.7	6.6

Based on the findings presented above, unlike electricity tariff rates in winter, lifetime of the electrical element has not have a significant impact on the estimations. SWHS with electricity back-up may not be competitive for households even if the element is needed to be replaced each 5 years. Only change in the relative costs is that SWHS with electricity back-up may be least cost-effective system even for households with one member if lifetime of the element is one year.

6.3 Conclusion

To draw a general conclusion based on the estimates and sensitivity analyses presented above, the choice of energy source for SWHS back-up is critical for its financially feasibility. SWHSs with electricity back-up might be the most attractive system under some circumstances only for small sized households. Gas heaters alone may become the most cost-effective alternative for households with one or two members. For these households the additional upfront costs of investing in SWHSs might not be worthwhile. On the other hand, SWHS with gas back-up potentially become the most cost-effective system for households with size of more than two.

Chapter 7

ECONOMIC COST-EFFECTIVENESS ANALYSIS OF ALTERNATIVE WATER HEATING SYSTEMS

7.1 Estimated economic capital costs of the water heating systems

In order to undertake an economic analysis, there is a need to adjust the financial costs for all the fiscal measures that drive a wedge between the financial costs and the economic resources costs. The economic costs of the initial capital and fuels are determined by subtracting from the financial costs the corresponding amount of customs duties, excise taxes and VAT paid. If there were subsidies, then subsidies would be added to their financial costs to arrive at their economic values.

These adjustments are necessary because, while these taxes and subsidies are financial costs and benefits from the point of view of the consumer, they are simply transfers between the consumers and the government. They do not constitute economic resource costs or benefits which are building blocks of an economic analysis.

In this manner, we estimated economic costs of the capital items by taking into account various taxes levied on them given in Table 4.7. Economic costs of the locally manufactured items can be easily calculated as they have only a 10% VAT levied on their sales price.[30] Conversely, in order to estimate economic costs of the imported capital items, we need to estimate their CIF prices, P_{CIF}. This is done by

[30] Economic prices of local manufactured items are equal to their financial prices divided by (1+10%).

considering mark-up ratio of 40% and given tax rates and using the following equation.

$$P_{CIF} = \left[\frac{\frac{P_{fin}}{(1+VAT)} * (1 - mark\ up)}{(1 + VAT + custom\ duty + VAT * custom\ duty + withholding\ tax)} \right] \qquad (12)$$

Once, we estimated the CIF prices, total taxes paid on capital items are accordingly calculated and hence, the economic costs are estimated by subtracting these from their corresponding financial costs (see appendix F to J). The estimated economic costs of capital items are presented in Table 7.1.

Table 7.1. Economic capital costs (US$) of the water heating systems

	Type of water heater			
	Electrical heater	SWHS with electricity back-up	Gas heater	SWHS with gas heater back-up
Capital cost	248 - 289	600 - 724	189	789 – 913
Elect. element cost	42	42	-	42
Hydrophore cost	-	-	62	62

7.2 Economic cost-effectiveness analysis of alternative water heating systems from North Cyprus perspective

An economic analysis of the alternative water heating systems is first conducted from the perspective of North Cyprus. This is done by substituting the economic costs of the capital expenditures and the economic fuel costs into equation (1). The results are presented in Table 7.2. (see appendix F to J).

Table 7.2. Levelized economic costs of hot water consumption ($US/m^3): A North Cyprus perspective

Household size	Water heating system			
	Electricity only	Gas heater only	SWHS with electricity back-up*	SWHS with gas heater back-up
1	25.1	12.9	13.7	15.3
2	17.1	9.2	9.9	9.6
3	15.0	7.5	8.4	7.3
4	13.6	7.0	8.1	6.6
5	12.7	6.7	8.0	6.0

* To estimate the cost of heat loss through pipes, we use average variable cost of electricity used to heat water per cubic meter.

Comparing the results in Table 7.2 with these in Table 6.1, we find that the same pattern holds. The economic cost to North Cyprus for the daily purpose of water heating with electricity is very costly. For households with one or two members, the use of gas heaters alone is the most economically cost-effective option. For larger households, an SWHS with gas back-up is less costly to the economy. It should be noted that an SWHS with electricity back-up is far less economically efficient as compared to an SWHS with gas back-up, particularly for heavy users of water.

For instance, for households with five members, the economic cost of using an SWHS with gas back-up is US$ 6/m^3 while for an SWHS with electricity back-up it is US$ 8/m^3. Hence, the North Cyprus economy potentially saves approximately 25% in terms of total economic resource costs if the corresponding households use an LPG water heater as a back-up rather than electricity. Thus, economic analysis reveals that the choice of energy source for the SWHS back-up is of critical importance for the design of policies for the promotion of the use of SWHSs.

7.3 Economic cost-effectiveness analysis of alternative water heating systems from the global perspective

We also determine the most economically cost-effective technology to heat water from a global perspective. To do this, we combine the environmental impacts of the CO_2 emissions created by each of these alternatives with the economic resource costs as seen from the perspective of North Cyprus. We assess the environmental impact of the water heating systems in terms of their annual CO_2 emissions over their operation stages. Taking into consideration the CO_2 emissions per unit of energy for LPG and electricity and also their adjustment factors given in section 4.7, annual CO_2 emissions from the water heating systems are estimated. The results are presented in Table 7.3.[31]

Table 7.3. Estimated annual CO_2 emissions (kg) from alternative water heating systems

	Household size				
Water heating system	1	2	3	4	5
Electrical heater	1,048	1,514	2,062	2,540	3,007
SWHS with electricity back-up	262	523	703	984	1313
Gas heater	96	192	288	384	480
SWHS with gas back-up	75	197	265	293	385

Based on the estimates reported in Table 7.3, an SWHS with gas heater back-up emits the least CO_2. Conversely, if electricity is used for water heating, it causes substantially higher CO_2 emissions owing to the CO_2 emission factor from thermal electricity generation. This also highlights two important findings from the above estimations. First, SWHSs with electricity back-up release significantly more CO_2 emissions than gas heaters because a significant portion of the heating load is met by

[31] We disregard CO_2 emissions produced in transporting LPG cylinders to retail outlets. However, this fact is unlikely to reverse the conclusions.

electricity in the winter. To put it differently, SWHSs when electricity is used as a back-up system is less environmentally friendly as compared to LPG water heaters. Therefore, this result agrees with results of studies by Taborianski and Prado (2004) and Tsilingiridis et al. (2004). Second, households who have a gas heater in addition to the SWHS and who are not heavy users of water switch from the use of the gas heater to the SWHS in the spring and fall. Therefore, electricity is used only as a supplementary source of energy during this period. For this reason, savings in CO_2 emissions as a result of having an SWHS are very small for those households.

These CO_2 emissions are monetized by using the estimated SCC and included in the estimations of the economic cost of water heating per cubic meter. The results are presented in Table 7.4.

Table 7.4. Levelized economic costs of hot water consumption ($US/m^3): A global perspective

Household size	Water heating system			
	Electricity only	Gas heater only	SWHS with electricity back-up*	SWHS with gas heater back-up
1	28.7	13.2	14.6	15.6
2	19.7	9.5	10.8	9.9
3	17.3	7.8	9.2	7.6
4	15.7	7.3	8.9	6.8
5	14.7	7.0	8.9	6.3

* To estimate the cost of heat loss through pipes, we use average variable cost of electricity used to heat water per cubic meter.

Comparing the estimates in Table 7.2 with those presented above, if electricity is used alone or as a back –up source of energy to SWHS, the costs of hot water consumption from using these systems become further high from the global perspective owing to the CO_2 emissions from the higher HFO consumptions. For instance, the economic cost for heating water using SWHSs with electricity back-up for households with five members is around US$ 2.6/m^3 higher than for those using

SWHSs with gas back-up. On the other hand, including SCC into the economic costs as seen from the perspective of the country does not have a significant impact in the case of gas heater and SWHS with gas back-up so that increases in the corresponding costs are less than 5%.

In the case of North Cyprus, the sizes of the tax and subsidy distortions on the supplies of energy and water heating systems are relatively small. Therefore, they do not significantly favor one or the other technology. In this case the pure market incentives given by the financial costs of the alternative technologies also lead the consumers toward those technologies that are economically cost-effective and environmentally less destructive.

7.4 Sensitivity analysis

Sensitivity analyses for the real economic prices of fuel oil and LPG, and the real social discount rate used are conducted for the same range of values of the real prices and discount rate as in financial analysis case. Also, a sensitivity analysis is conducted for the value of the SCC at $12, $39 and $61 per ton.

The following analyses are based on the results for the economic cost-effective analysis from the global perspective. The levelized cost estimations for a system that uses electricity alone for the purpose of water heating are disregarded in the following sections once again because they are not competitive in any situation, compared to the other systems. The sensitivity results are presented in Table 7.5-7.7.

Table 7.5. Sensitivity analysis of economic levelized cost of hot water ($\$US/m^3$) with respect to average real prices of fuels over 20 years

	Gas heater			SWHS with electricity back-up			SWHS with gas heater back-up		
Average real price of fuels	10% less	Base cost	10% more	10% less	Base cost	10% more	10% less	Base cost	10% More
Household size									
1	12.7	13.2	13.8	13.9	14.6	15.4	15.3	15.6	15.9
2	8.9	9.5	10.0	10.1	10.8	11.5	9.5	9.9	10.2
3	7.3	7.8	8.3	8.6	9.2	9.8	7.3	7.6	7.9
4	6.8	7.3	7.8	8.3	8.9	9.6	6.5	6.8	7.2
5	6.5	7.0	7.5	8.2	8.9	9.5	5.9	6.3	6.6

Table 7.6. Sensitivity analysis of economic levelized cost of hot water ($\$US/m^3$) with respect to the real social rate of discount

	Gas heater			SWHS with electricity back-up			SWHS with gas heater back-up		
Real discount rate	5%	10%	15%	5%	10%	15%	5%	10%	15%
Household size									
1	12.8	13.2	13.7	13.6	14.6	15.7	14.0	15.6	17.2
2	9.2	9.5	9.7	10.3	10.8	11.4	9.1	9.9	10.7
3	7.7	7.8	8.0	8.8	9.2	9.6	7.1	7.6	8.2
4	7.2	7.3	7.4	8.6	8.9	9.2	6.4	6.8	7.3
5	6.9	7.0	7.1	8.6	8.9	9.1	5.9	6.3	6.6

As can be seen in Table 7.5 and 7.6, variations in the average economic prices and discount rates adopted results in small changes in the relative economic levelized costs of hot water so that no reversals of the ranking of the alternatives are created. An SWHS with gas heater back-up is most economical for households with more than two members, while a gas heater is the most economical system for households consuming a low daily volume of water. The sensitivity of the results at the given SCC range of values is presented in Table 7.7.

Table 7.7. Sensitivity analysis of economic levelized cost of hot water ($\$US/m^3$) with respect to SCC

	Gas heater			SWHS with electricity back-up			SWHS with gas heater back-up		
SCC (US$)	12	39	61	12	39	61	12	39	61
Household size									
1	13.0	13.2	13.4	14.0	14.6	15.1	15.4	15.6	15.7
2	9.2	9.5	9.7	10.2	10.8	11.3	9.7	9.9	10.1
3	7.6	7.8	8.0	8.7	9.2	9.7	7.4	7.6	7.8
4	7.1	7.3	7.5	8.4	8.9	9.4	6.7	6.8	7.0
5	6.8	7.0	7.2	8.2	8.9	9.4	6.1	6.3	6.4

As shown in Table 7.7, the value of the SCC affects mainly the economic levelized cost of hot water consumption in the case of an SWHS with electricity back-up owing to the CO_2 emission factor from thermal electricity generation. Therefore, the higher prospective CO_2 costs lead to higher social externalities and hence to higher economic costs, and vice versa. The impact of the SCC on the levelized costs in the case of an SWHS with gas back-up and a gas heater is similar as the proportion of LPG usage to heat water is relatively low during the summer.

Chapter 8

COST-EFFECTIVENESS ANALYSIS OF ALTERNATIVE WATER HEATING SYSTEMS WITH PRESSURIZED POTABLE WATER SUPPLY

8.1 Introduction

In this chapter, we investigate how a continuously pressurized potable water supply would affect the relative cost-effectiveness of the alternative water heating systems. If the water utility were to supply pressurized potable water, households using gas heaters (either alone or as a back-up with an SWHS) would not have to buy a hydrophore unit to pressurize the water supply. Therefore, cost of water heating by gas water heater would decrease and also these households would have access to reliable hot water on demand no matter whether they have an SWHS.

Furthermore, a high level of water quality would increase the lifetime of solar panels and electrical elements. Therefore, it would enhance the financially viability of SWHSs either. In this respect, it is assumed that the lifetime of the element in the case of the SWHS with electricity back-up would be five years and in the case of the SWHS with gas heater back-up it would be 10 years. In addition, we assumed that the lifetime of the solar panels would increase to 20 years.[32]

[32]Our assumptions based on information obtained from maintenance providers interviewed from Nicosia and Kyrenia on the lifetime of the electrical element, and solar panels under different conditions.

8.2 Levelized costs of hot water consumption ($US/m^3) with pressurized potable water supply

Based on these parameter values, we estimate the financial and economic levelized costs of the three alternative water heaters.[33] We find that real prices of electricity and LPG throughout the lifetime of the project have an insignificant effect on the estimations. The results for discount rates in the range 5–15% are presented in Table 8.1.-8.2. (see appendix F to J).[34]

Table 8.1. Levelized financial costs of hot water consumption ($US/m^3) with pressurized potable water supply

	Gas heater			SWHS with electricity back-up[Ŧ]			SWHS with gas heater back-up		
Real discount rate	5%	10%	15%	5%	10%	15%	5%	10%	15%
Household size									
1	11.0	11.4	11.8	12.2	13.6	15.0	11.8	13.6	15.5
2	7.9	8.1	8.3	9.5	10.2	10.9	7.8	8.7	9.6
3	6.8	7.0	7.1	8.2	8.7	9.2	6.2	6.8	7.5
4	6.3	6.4	6.5	8.1	8.5	8.9	5.7	6.2	6.7
5	6.0	6.1	6.2	8.1	8.4	8.8	5.3	5.7	6.1

Ŧ The estimations based on second block electricity price of 0.275 US$/kWh.

Table 8.2. Levelized economic costs of hot water consumption ($US/m^3) with pressurized potable water supply

	Gas heater			SWHS with electricity back-up[Ŧ]			SWHS with gas heater back-up		
Real discount rate	5%	10%	15%	5%	10%	15%	5%	10%	15%
Household size									
1	10.7	11.0	11.4	12.1	13.2	14.5	11.3	12.9	14.7
2	7.6	7.8	8.0	9.6	10.1	10.8	7.6	8.4	9.2
3	6.6	6.7	6.8	8.3	8.7	9.2	6.0	6.6	7.2
4	6.1	6.2	6.3	8.2	8.5	8.9	5.5	5.9	6.4
5	5.8	5.8	5.9	8.3	8.5	8.8	5.1	5.4	5.8

Ŧ The estimations based on second block electricity price of 0.250 US$/kWh.

[33] The cost estimations for the electrical water heater systems are disregarded because it is obvious that they are far from being competitive.

[34] It is important to note that residents will not need to install cold water tanks or replace their old tanks on the roof once there is a reliable pressurized supply of water. Therefore, our estimations in the case of SWHSs presented in Table 8.1-8.2 would rise slightly for the residents of houses that will be constructed, owing to the additional cost of connecting an SWHS on the roof to the mains.

Based on the estimations presented above, the continuous supply of pressurized potable water by the water utility makes SWHSs with electricity back-up both financially and economically further less competitive than using either gas heaters alone or SWHSs with gas heater back-up. The SWHS with gas heater back-up would potentially be again the best choice of technology both for financially and economically for water heating for households having more than two members. Likewise, gas heaters would be the most cost-effective option for families with lower sized families. Finally, it should be pointed out that it is estimated that the cost of heating water is reduced approximately by 15% for the SWHS with LPG back-up and for the heating of water by the LPG heater alone when a pressurized supply of water is available.

Chapter 9

CONCLUSION AND POLICY IMPLICATION

9.1 Conclusions

There is no doubt that when solar collectors are substituted for electricity in water heating, enormous amounts of energy and hence GHG emissions are saved. Furthermore, replacing electrical heaters with SWHSs is financially as well as economically feasible for all households in North Cyprus. However, an SWHS with electricity back-up is not a good option for water heating from an economic or environmental point of view compared with the use of gas heaters or SWHSs with gas back-up depending on the household size. Gas heaters alone are the most cost-effective system for households with one or two members, while an SWHS with gas back-up is the most financial, most economic, and most environmentally friendly system for water heating by households with more than two members.

A major finding that emerges from this study is that in climates where SWHSs are not able to deliver adequate energy throughout the year, it is very important to take into consideration what is to be used as the source of back-up energy. In most cases, electricity is assumed to be the default supplier of the supplementary energy for an SWHS. In this study, we found that even in Cyprus, with its relative abundance of sunshine and mild (above freezing) winters, this is not the best solution.

In the vast majority of cases an SWHS with gas back-up is superior to an SWHS that uses electricity as a supplement for winter water heating. In addition to the financial and economic savings in the costs of the SWHS with LPG gas back-up; there is the added convenience of having almost instant hot water in the winter months, and also the advantage of almost eliminating the wastage of hot water through cooling in the distribution pipes that are located outside the building. Owing to the GHG emissions from thermal electricity generation, an SWHS with LPG back-up will also result in a substantially lower amount of GHG emissions than is the case for the SWHS with electricity back-up.

As in the case of many developing countries, bottled LPG is readily available in North Cyprus. Therefore, the readily accessible LPG supplies combined with the relatively inexpensive and reliable gas water heaters is an option that needs to be considered. LPG is largely used across Cyprus for cooking and space heating, and hence there is already a commercial distribution system in place.

Finally, we find that a continuously pressurized potable water supply would not significantly affect the relative cost-effectiveness of the alternative water heating systems. The SWHS with gas heater back-up would potentially be again the best choice both for financially and economically for water heating for households having more than two members. Likewise, gas heaters would be the most cost-effective option for families with one or two members. However, it should be pointed out that the cost of heating water is reduced approximately by 15% for the heating of water by the LPG heater alone or the SWHS with LPG back-up when a pressurized supply of water is available.

9.2 Policy Implications

The results of this study have a number of implications for the design of prospective energy policies with regard to water heating. These implications are important for any country where the seasonal variation in temperature or solar radiation requires significant supplementary energy from a non-solar source.

The analysis in this study points to the critical importance of having a policy for SWHSs that does not simply promote the installation of SWHSs, but that also promotes the appropriate auxiliary source of energy for supplementing the SWHS. A policy promoting SWHSs that requires a mandatory installation of SWHSs with electricity back-up is not a good economic or environmental policy. For most situations, an SWHS with gas back-up is the most cost-effective option, both financially and economically.

The disadvantage of the SWHS with gas back-up is its initial capital costs. These capital costs, including the installation costs, are approximately 40% higher than the capital cost of an SWHS using electricity as the supplementary energy source. Government should consider policies that would make credit facilities available to poor families who might find the greater capital outlays a barrier to purchasing such a system. Poor families tend to be larger in terms of number of children, and hence they tend to be larger consumers of hot water. Furthermore, using SWHSs with gas heater as a back-up reduces the waste of water that is a characteristic of SWHSs with electricity back-up.

In the design of water heating policies to reduce the level of CO_2 emissions, the government should first observe what financial incentives are required that would yield the best results. Policies should not be designed to just promote SWHSs, while ignoring the sources of the supplementary energies that the alternative technologies require.

REFERENCES

Allen, S. R., Hammond, G. P., Harajli, H. A., McManus, M. C., & Winnett, A. B. (2010). Integrated appraisal of a solar hot water system. *Energy*, 35(3), 1351-1362.

Ardente, F., Beccali, G., Cellura, M., & Brano, V. L. (2005). Life cycle assessment of a solar thermal collector. *Renewable Energy*, 30(7), 1031-1054.

Atikol, U., Abbasoğlu, S., & Nowzari, R. (2013). A feasibility integrated approach in the promotion of solar house design. *International Journal of Energy Research*, 37(5), 378-388.

Atikol, U., & Güven, H. (2003). Feasibility of DSM-technology transfer to developing countries. *Applied energy*, 76(1), 197-210.

Battisti, R., & Corrado, A. (2005).Environmental assessment of solar thermal collectors with integrated water storage. *Journal of Cleaner Production*, 13(13), 1295-1300.

Cassard, H., Denholm, P., & Ong, S. (2011). Technical and economic performance of residential solar water heating in the United States. *Renewable and Sustainable Energy Reviews*, 15(8), 3789-3800.

Crawford, R. H., & Treloar, G. J. (2004). Net energy analysis of solar and conventional domestic hot water systems in Melbourne, Australia. *Solar Energy*, 76(1), 159-163.

Cyprus Institute of Energy. Nicosia, South Cyprus.

Cyprus Turkish Electricity Authority, Kib-Tek. Nicosia, North Cyprus.

Diakoulaki, D., Zervos, A., Sarafidis, J., & Mirasgedis, S. (2001). Cost benefit analysis for solar water heating systems. *Energy Conversion and Management*, 42(14), 1727-1739.

Duffie, J.A., Beckman, W.A. (2006). Solar Engineering of Thermal Processes, third ed. John Wiley & Sons, New Jersey.

Duffie, J. A., & Mitchell, J. W. (1983). f-Chart: predictions and measurements. *Journal of Solar Energy Engineering*, 105(1), 3-9.

Fanney, A. H., & Klein, S. A. (1983). Performance of solar domestic hot water systems at the National Bureau of Standard—measurements and predictions. *Journal of Solar Energy Engineering*, 105(3), 311-321.

Fraisse, G., Bai, Y., Le Pierrès, N., & Letz, T. (2009). Comparative study of various optimization criteria for SDHWS and a suggestion for a new global evaluation. *Solar Energy*, 83(2), 232-245.

Gastli, A., & Charabi, Y. (2011). Solar water heating initiative in Oman energy saving and carbon credits. *Renewable and Sustainable Energy Reviews*, 15(4), 1851-1856.

Giglio, T., Lamberts, R., Barbosa, M., & Urbano, M. (2014). A procedure for analysing energy savings in multiple small solar water heaters installed in low-income housing in Brazil. *Energy Policy*, 72, 43-55.

Gillingham, K. (2009). Economic efficiency of solar hot water policy in New Zealand. *Energy Policy*, 37(9), 3336-3347.

Greenstone, M., Kopits, E., & Wolverton, A. (2011). Estimating the social cost of carbon for use in us federal rulemakings: A summary and interpretation (No. w16913).National Bureau of Economic Research. Available at http://www.nber.org/papers/w16913.pdf (accessed 30 December 2014).

Han, J., Mol, A. P., & Lu, Y. (2010). Solar water heaters in China: a new day dawning. *Energy Policy*, 38(1), 383-391.

Hang, Y., Qu, M., & Zhao, F. (2012). Economic and environmental life cycle analysis of solar hot water systems in the United States. *Energy and Buildings*, 45, 181-188.

Hernandez, P., & Kenny, P. (2012). Net energy analysis of domestic solar water heating installations in operation. *Renewable and Sustainable Energy Reviews*, 16(1), 170-177.

Ilkan, M., Erdil, E., & Egelioğlu, F. (2005). Renewable energy resources as an alternative to modify the load curve in Northern Cyprus. *Energy*, 30(5), 555-572.

International Energy Agency, IEA, (2014). CO_2 emissions from fuel combustion: Highlights. Available at http://www.iea.org/publications/freepublications/publication/CO2EmissionsFromFuelCombustionHighlights2014.pdf (accessed 15 January 2015).

Jenkins, G., Kuo, C., & Harberger, A. C. (2011a). Cost-benefit analysis for investment decisions: Chapter 5 (Scale, Timing, Length and Inter-Dependencies in Project Selection). (No. 2011-05). John Deutsch International - Development Discussion Papers. Available at http://www.queensjdiexec.org/publications/qed_dp_198.pdf (accessed 15 October 2014).

Jenkins, G., Kuo, C., & Harberger, A. C. (2011b). Cost-benefit analysis for investment decisions: Chapter 15 (Cost-Effectiveness and Cost Utility Analysis). (No. 2011-15). John Deutsch International - Development Discussion Papers. Available at http://www.queensjdiexec.org/publications/qed_dp_208.pdf (accessed 5 October 2014).

Kablan, M. M. (2004). Techno-economic analysis of the Jordanian solar water heating system. *Energy*, 29(7), 1069-1079.

Kaldellis, J. K., El-Samani, K., & Koronakis, P. (2005). Feasibility analysis of domestic solar water heating systems in Greece. *Renewable Energy*, 30(5), 659-682.

Kalogirou, S. A. (1997). Solar water heating in Cyprus: current status of technology and problems. *Renewable Energy*, 10(1), 107-112.

Kalogirou, S. A. (2003). The energy subsidisation policies of Cyprus and their effect on renewable energy systems economics. *Renewable Energy*, 28(11), 1711-1728.

Kalogirou, S. A. (2004). Environmental benefits of domestic solar energy systems. *Energy conversion and management*, 45(18), 3075-3092.

Kalogirou, S. A. (2009a). Solar Energy Engineering: Processes and Systems, first ed. Elsevier, London.

Kalogirou, S. A. (2009b). Thermal performance, economic and environmental life cycle analysis of thermosiphon solar water heaters. *Solar Energy*, 83(1), 39-48.

Koroneos, C. J., & Nanaki, E. A. (2012). Life cycle environmental impact assessment of a solar water heater. *Journal of Cleaner Production*, 37, 154-161.

Li, W., Song, G., Beresford, M., & Ma, B. (2011). China's transition to green energy systems: The economics of home solar water heaters and their popularization in Dezhou city. *Energy Policy*, 39(10), 5909-5919.

Lin, W. M., Chang, K. C., & Chung, K. M. (2015). Payback period for residential solar water heaters in Taiwan. *Renewable and Sustainable Energy Reviews*, 41, 901-906.

Ma, B., Song, G., Smardon, R. C., & Chen, J. (2014). Diffusion of solar water heaters in regional China: Economic feasibility and policy effectiveness evaluation. *Energy Policy*, 72, 23-34.

Martinopoulos, G., Tsilingiridis, G., & Kyriakis, N. (2013). Identification of the environmental impact from the use of different materials in domestic solar hot water systems. *Applied Energy*, 102, 545-555.

Mutch, J. J. (1974). Residential Water Heating, Fuel Consumption, Economics and Public Policy, RAND Corp., R-1498-NSF.

Naspolini, H. F., & Rüther, R. (2012). Assessing the technical and economic viability of low-cost domestic solar hot water systems (DSHWS) in low-income residential dwellings in Brazil. *Renewable Energy*, 48, 92-99.

Ozbafli, A. (2011). Estimating the willingness to pay for a reliable electricity supply in the Turkish Republic of Northern Cyprus. PhD Thesis. The University of Birmingham, UK.

Ozbafli, A., & Jenkins, G. (2015). The willingness to pay by households for improved reliability of electricity service in North Cyprus. *Energy Policy*, 87, 359-369.

Ozsabuncuoglu, I. H. (1995). Economic analysis of flat plate collectors of solar energy. *Energy Policy*, 23(9), 755-763.

Raisul Islam, M., Sumathy, K., & Khan, S. U. (2013). Solar water heating systems and their market trends. *Renewable and Sustainable Energy Reviews*, 17, 1-25.

REN21, (2013). Renewables 2013: Global Status Report. Available at http://www.ren21.net/Portals/0/documents/Resources/GSR/2013/GSR2013_lowres.pdf (accessed 20 March 2014).

RETScreen: Renewable Energy Project Analysis Software. RETScreen online user manual. Available at http://www.retscreen.net/ang/d_t_guide.php(accessed 10 October 2013).

Roulleau, T., & Lloyd, C. R. (2008). International policy issues regarding solar water heating, with a focus on New Zealand. *Energy Policy*, 36(6), 1843-1857.

Secretariat-General of The National Security Council, Republic of Turkey. Available at http://www.mgk.gov.tr/calismalar/calismalar/014_kktc_su_temini_elektrik_nakli_projeleri.pdf (accessed 15 July 2014).

Sezai, I., Aldabbagh, L. B. Y., Atikol, U., & Hacısevki, H. (2005). Performance improvement by using dual heaters in a storage-type domestic electric water-heater. *Applied Energy*, 81(3), 291-305.

Shariah, A. M., & Löf, G. O. G. (1997). Effects of auxiliary heater on annual performance of thermosyphon solar water heater simulated under variable operating conditions. *Solar Energy*, 60(2), 119-126.

Short, W., Packey, D. J., & Holt, T. (2005). A manual for the economic evaluation of energy efficiency and renewable energy technologies. University Press of the Pacific.

Solar Rating and Certification Corporation (SRCC).Available at http://solar-rating.org/ (accessed 10 January 2014).

Srinivas, M. (2011). Domestic solar hot water systems: Developments, evaluations and essentials for "viability" with a special reference to India. *Renewable and Sustainable Energy Reviews*, 15(8), 3850-3861.

Stackhouse, P.W., & Whitlock, C.H., (2008). Surface meteorology and Solar Energy (SSE) release 6.0, NASA SSE 6.0. Earth Science Enterprise Program, National Aeronautic and Space Administration (NASA), Langley. Available at http://eosweb. larc. nasa. gov/sse/ (accessed 16 February 2014).

State Planning Organization, Nicosia, North Cyprus.

Taborianski, V. M., & Prado, R. T. (2004). Comparative evaluation of the contribution of residential water heating systems to the variation of greenhouse gases stock in the atmosphere. *Building and environment*, 39(6), 645-652.

Tsilingiridis, G., & Martinopoulos, G. (2010). Thirty years of domestic solar hot water systems use in Greece–energy and environmental benefits–future perspectives. *Renewable Energy*, 35(2), 490-497.

Tsilingiridis, G., Martinopoulos, G., & Kyriakis, N. (2004). Life cycle environmental impact of a thermosyphonic domestic solar hot water system in comparison with electrical and gas water heating. *Renewable Energy*, 29(8), 1277-1288.

United Nations Environment Programme, (2014). Integrating solar thermal in buildings- a quick guide for architects and builders. Available at http://www.estif.org/fileadmin/estif/content/publications/downloads/unep_report_final_v04_lowres.pdf (accessed 20 June 2014).

U.S. EPA, (2014). Emission factors for greenhouse gas inventories. Available at http://www.epa.gov/climateleadership/documents/emission-factors.pdf(accessed 20 November 2014).

U.S. EPA, (2013). Fact sheet: social cost of carbon. Available at http://www.epa.gov/climatechange/Downloads/EPAactivities/scc-fact-sheet.pdf(accessed 25 December 2014).

APPENDICES

Appendix A: Monthly and Annual Energy Contribution by SWHSs for Household Size of 1 with Hot Water Consumption of 40 liters/day

F-CHART PARAMETERS

City	Nicosia	**Household size**	1

Collector parameters

A	1.62	net collector area (m²)
F_RU_L	4.005	W/m² °C
$F_R(\tau\alpha)$	0.711	
F'_R/F_R	1	
$(\tau\alpha)/(\tau\alpha)$	0.96	

Storage tank parameters

Radius of tank	0.27	m
Height of tank	0.997	m
Volume of tank	120	litres
Area of tank	2.15	m²
Loss coef. of tank	1	W/m² °C

Conversion parameters

1 MJ	0.277	kWh
1 MJ	1000000	J
ΔT	86400	total second per day
1 kWh	3.6	MJ

Other parameters

$T_{desired}$	50	°C
Specific heat of water	4190	J/lt°C
Daily hot water demand	40	litres
T_{ref}	100	°C

MONTHLY AVERAGE DAILY AMBIENT AND COLD WATER TEMPERATURES AND GLOBAL RADIATION

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
Tamb (°C)	12.2	11.9	13.9	17.5	21.6	25.9	29.3	29.4	26.8	22.7	17.7	13.7
Tcoldwater (°C)	14.8	14.9	16.9	20.7	25.4	29.8	33.3	33.4	30.6	25.8	20.3	16.3
Radiation (kWh/m²)	2.49	3.44	4.83	5.98	7.24	8.12	7.93	7.08	5.88	4.26	2.87	2.2
Radiation (MJ/m²)	8.96	12.38	17.39	21.53	26.06	29.23	28.55	25.49	21.17	15.34	10.33	7.92

MONTHLY AND ANNUAL TOTAL HEATING LOAD

		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	
Energy required to heat water up to desired temp.	Load (J)	1.83E+08	164717280	1.7E+08	147320400	1.3E+08	1.02E+08	8.7E+07	8.6E+07	97543200	1.3E+08	149331600	1.8E+08	
	Load (MJ)	182.89	164.72	171.97	147.32	127.81	101.57	86.77	86.25	97.54	125.73	149.33	175.09	Total
	Load (kWh)	50.66	45.63	47.64	40.81	35.40	28.13	24.03	23.89	27.02	34.83	41.36	48.50	448
Tank loss	Load$_{loss}$ (W)	81.25	81.89	77.59	69.85	61.04	51.80	44.49	44.28	49.86	58.68	69.42	78.02	
	Load$_{loss}$ (J)	2.18E+08	198108992	2.1E+08	181061368	1.6E+08	1.34E+08	1.2E+08	1.2E+08	1.29E+08	1.6E+08	179947144	2.1E+08	
	Load$_{loss}$ (MJ)	217.61	198.11	207.82	181.06	163.49	134.26	119.17	118.59	129.25	157.16	179.95	208.97	
														Total
Total heating load	Total Load (MJ)	400.49	362.83	379.80	328.38	291.31	235.83	205.93	204.84	226.79	282.89	329.28	384.06	3632
	Total Load (kWh)	110.94	100.50	105.20	90.96	80.69	65.32	57.04	56.74	62.82	78.36	91.21	106.39	1006

TWO DIMENSIONLESS PARAMETERS OF THE F-CHART METHOD

X: ratio of collector losses to heating loads	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
$X = [F_R U_L * F'_R / F_R * (T_{ref} - T_{amb}) * \Delta T * A] /$ Load	3.810	3.811	3.940	4.225	4.677	5.284	5.966	5.989	5.428	4.748	4.203	3.905

The f-chart method was developed with a standard tank capacity of 75 litres per square meter of collector area. So X has to be multiplied by a correction factor:

Xc/X= (actual tank capacity/75)^-0.25

Xc/X= 1.003

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Corrected X, Xc=X*Xc/X	3.822	3.823	3.952	4.238	4.691	5.301	5.985	6.008	5.445	4.763	4.216	3.917

What is more, to account for fluctuation of cold water temp and min acceptable temp X has to be multipled by another correction fator:

Xcc/X= (11.6+1.18Ts+3.86Tcw-2.32Ta)/(100-Ta)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Xcc/X	1.132	1.141	1.203	1.332	1.512	1.694	1.855	1.860	1.729	1.520	1.311	1.179
Updated X, Xu= Xc*Xcc/X	4.328	4.361	4.754	5.646	7.093	8.980	11.103	11.175	9.412	7.242	5.528	4.617

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Y: ratio of absorbed solar radiation to heating loads	0.767	1.057	1.569	2.175	3.067	4.112	4.752	4.265	3.096	1.858	1.041	0.707

$Y = [F_R(\tau\alpha) * F'_R / F_R * (\tau\alpha) / (\tau\alpha) * H_T * N * A] /$ Load

MONTHLY AND ANNUAL PROPORTION OF THE LOAD SUPPLIED BY SOLAR ENERGY

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	Total
$f = 1.029Y - 0.065X - 0.245Y^2 + 0.0018X^2 + 0.0215Y^3$	0.41	0.59	0.83	0.99	1.10	1.14	1.16	1.10	1.02	0.83	0.53	0.35	
Corrected f for summer months , f`	0.41	0.59	0.83	0.99	1.00	1.00	1.00	1.00	1.00	0.83	0.53	0.35	
Monthly energy contribution by solar energy (MJ)	163	214	314	325	291	236	206	205	227	234	173	135	2723
Monthly energy contribution by solar energy (kWh)	45	59	87	90	81	65	57	57	63	65	48	37	754

Annual saving of energy (kWh)	754
Annual solar fraction, F	0.75

Appendix B: Monthly and Annual Energy Contribution by SWHSs for Household Size of 2 with Hot Water Consumption of 80 liters/day

F-CHART PARAMETERS

City Nicosia **Household size** 2

Collector parameters

A	1.62	net collector area (m²)
F_RU_L	4.005	W/m² °C
$F_R(\tau\alpha)$	0.711	
F'_R/F_R	1	
$(\tau\alpha)/(\tau\alpha)$	0.96	

Storage tank parameters

Radius of tank	0.27	m
Height of tank	0.997	m
Volume of tank	120	litres
Area of tank	2.15	m²
Loss coef. of tank	1	W/m² °C

Conversion parameters

1 MJ	0.277	kWh
1 MJ	1000000	J
ΔT	86400	total second per day
1 kWh	3.6	MJ

Other parameters

$T_{desired}$	50	°C
Specific heat of water	4190	J/lt°C
Daily hot water demand	80	litres
T_{ref}	100	°C

MONTHLY AVERAGE DAILY AMBIENT AND COLD WATER TEMPERATURES AND GLOBAL RADIATION

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
Tamb (°C)	12.2	11.9	13.9	17.5	21.6	25.9	29.3	29.4	26.8	22.7	17.7	13.7
Tcoldwater (°C)	14.8	14.9	16.9	20.7	25.4	29.8	33.3	33.4	30.6	25.8	20.3	16.3
Radiation (kWh/m²)	2.49	3.44	4.83	5.98	7.24	8.12	7.93	7.08	5.88	4.26	2.87	2.2
Radiation (MJ/m²)	8.96	12.38	17.39	21.53	26.06	29.23	28.55	25.49	21.17	15.34	10.33	7.92

MONTHLY AND ANNUAL TOTAL HEATING LOAD

		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	
Energy required to heat water up to desired temp.	Load (J)	365770240	3.29E+08	3.44E+08	2.95E+08	2.6E+08	203131200	1.74E+08	1.7E+08	1.95E+08	2.5E+08	298663200	3.5E+08	
	Load (MJ)	365.77	329.43	343.95	294.64	255.62	203.13	173.53	172.49	195.09	251.47	298.66	350.18	Total
	Load (kWh)	101.32	91.25	95.27	81.62	70.81	56.27	48.07	47.78	54.04	69.66	82.73	97.00	896
Tank loss	Load $_{loss}$ (W)	81.25	81.89	77.59	69.85	61.04	51.80	44.49	44.28	49.86	58.68	69.42	78.02	
	Load $_{loss}$ (J)	217607909	1.98E+08	2.08E+08	1.81E+08	1.6E+08	134263968	1.19E+08	1.2E+08	1.29E+08	1.6E+08	179947144	2.1E+08	
	Load $_{loss}$ (MJ)	217.61	198.11	207.82	181.06	163.49	134.26	119.17	118.59	129.25	157.16	179.95	208.97	
														Total
Total heating load	Total Load (MJ)	583.38	527.54	551.77	475.70	419.12	337.40	292.70	291.08	324.34	408.63	478.61	559.16	5249
	Total Load (kWh)	161.60	146.13	152.84	131.77	116.10	93.46	81.08	80.63	89.84	113.19	132.58	154.89	1454

TWO DIMENSIONLESS PARAMETERS OF THE F-CHART METHOD

<u>X: ratio of collector losses to heating loads</u>	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
$X = [F_R U_L * F`_R / F_R * (T_{ref} - T_{amb}) * \Delta T * A] /$ Load	2.615	2.621	2.712	2.917	3.251	3.693	4.198	4.215	3.795	3.287	2.892	2.682

The f-chart method was developed with a standard tank capacity of 75 litres per square meter of collector area. So X has to be multiplied by a correction factor:

Xc/X= (actual tank capacity/75)^-0.25

Xc/X= 1.003

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
<u>Corrected X, Xc=X*Xc/X</u>	2.624	2.629	2.720	2.926	3.261	3.705	4.211	4.228	3.807	3.298	2.901	2.690

What is more, to account for fluctuation of cold water temp and min acceptable temp X has to be multipled by another correction fator:

Xcc/X= (11.6+1.18Ts+3.86Tcw-2.32Ta)/(100-Ta)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Xcc/X	1.132	1.141	1.203	1.332	1.512	1.694	1.855	1.860	1.729	1.520	1.311	1.179
<u>Updated X, Xu= Xc*Xcc/X</u>	2.971	3.000	3.273	3.897	4.930	6.277	7.811	7.864	6.582	5.013	3.803	3.172

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
<u>Y: ratio of absorbed solar radiation to heating loads</u>	0.527	0.727	1.080	1.501	2.132	2.874	3.343	3.001	2.165	1.286	0.716	0.486

$Y = [\, F_R(\tau\alpha) * F`_R / F_R * (\tau\alpha) / (\tau\alpha) * H_T * N * A] /$ Load

MONTHLY AND ANNUAL PROPORTION OF THE LOAD SUPPLIED BY SOLAR ENERGY

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	Total
$f = 1.029Y - 0.065X - 0.245Y^2 + 0.0018X^2 + 0.0215Y^3$	0.30	0.45	0.66	0.84	1.01	1.11	1.11	1.06	0.95	0.68	0.40	0.26	
Corrected f for summer months , f`	0.30	0.45	0.66	0.84	1.00	1.00	1.00	1.00	0.95	0.68	0.40	0.26	
Monthly energy contribution by solar energy (MJ)	175	236	364	399	419	337	293	291	307	279	190	143	3435
Monthly energy contribution by solar energy (kWh)	48	65	101	111	116	93	81	81	85	77	53	40	952
Annual saving of energy (kWh)	952												
Annual solar fraction, F	0.65												

Appendix C: Monthly and Annual Energy Contribution by SWHSs for Household Size of 3 with Hot Water Consumption of 120 liters/day

F-CHART PARAMETERS

City	Nicosia	**Household size**	3

Collector parameters

A	2.11	net collector area (m²)
F_RU_L	3.79	W/m² °C
$F_R(\tau\alpha)$	0.73	
F'_R/F_R	1	
$(\tau\alpha)/(\tau\alpha)$	0.96	

Storage tank parameters

Radius of tank	0.3	m
Height of tank	1	m
Volume of tank	150	litres
Area of tank	2.45	m²
Loss coef. of tank	1	W/m² °C

Conversion parameters

1 MJ	0.277	kWh
1 MJ	1000000	J
ΔT	86400	total second per day
1 kWh	3.6	MJ

Other parameters

$T_{desired}$	50	°C
Specific heat of water	4190	J/lt°C
Daily hot water demand	120	litres
T_{ref}	100	°C

MONTHLY AVERAGE DAILY AMBIENT AND COLD WATER TEMPERATURES AND GLOBAL RADIATION

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
Tamb (°C)	12.2	11.9	13.9	17.5	21.6	25.9	29.3	29.4	26.8	22.7	17.7	13.7
Tcoldwater (°C)	14.8	14.9	16.9	20.7	25.4	29.8	33.3	33.4	30.6	25.8	20.3	16.3
Radiation (kWh/m²)	2.49	3.44	4.83	5.98	7.24	8.12	7.93	7.08	5.88	4.26	2.87	2.2
Radiation (MJ/m²)	8.96	12.38	17.39	21.53	26.06	29.23	28.55	25.49	21.17	15.34	10.33	7.92

MONTHLY AND ANNUAL TOTAL HEATING LOAD

		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	
Energy required to heat	Load (J)	548655360	4.94E+08	5.2E+08	441961200	383435280	3.05E+08	2.6E+08	258740880	2.93E+08	377200560	447994800	525275160	
water up to desired temp.	Load (MJ)	548.66	494.15	515.92	441.96	383.44	304.70	260.30	258.74	292.63	377.20	447.99	525.28	Total
	Load (kWh)	151.98	136.88	142.91	122.42	106.21	84.40	72.10	71.67	81.06	104.48	124.09	145.50	1344
Tank loss	$Load_{loss}$ (W)	92.62	93.36	88.46	79.64	69.59	59.05	50.72	50.48	56.85	66.90	79.15	88.95	
	$Load_{loss}$ (J)	248084084	2.26E+08	2.4E+08	206419169	186391217	1.53E+08	1.36E+08	135199263	1.47E+08	179171839	205148897	238239478	
	$Load_{loss}$ (MJ)	248.08	225.85	236.93	206.42	186.39	153.07	135.86	135.20	147.35	179.17	205.15	238.24	
														Total
Total heating load	Total Load (MJ)	796.74	720.01	752.85	648.38	569.83	457.76	396.16	393.94	439.98	556.37	653.14	763.51	7149
	Total Load (kWh)	220.70	199.44	208.54	179.60	157.84	126.80	109.73	109.12	121.87	154.12	180.92	211.49	1980

TWO DIMENSIONLESS PARAMETERS OF THE F-CHART METHOD

X: ratio of collector losses to heating loads	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
$X = [F_R U_L * F'_R / F_R * (T_{ref} - T_{amb}) * \Delta T * A] / Load$	2.360	2.367	2.450	2.637	2.947	3.355	3.823	3.839	3.449	2.976	2.612	2.421

The f-chart method was developed with a standard tank capacity of 75 litres per square meter of collector area. So X has to be multiplied by a correction factor:

X_c/X= (actual tank capacity/75)^-0.25

X_c/X= 1.013

Corrected X, $X_c = X * X_c/X$	2.392	2.399	2.483	2.673	2.987	3.401	3.874	3.890	3.495	3.016	2.647	2.454

What is more, to account for fluctuation of cold water temp and min acceptable temp, X has to be multiplied by another correction fator:

$X_{cc}/X = (11.6+1.18T_w+3.86T_m-2.32T_a)/(100-T_a)$

X_{cc}/X	1.132	1.141	1.203	1.332	1.512	1.694	1.855	1.860	1.729	1.520	1.311	1.179
Updated X, $X_u = X_c * X_{cc}/X$	2.709	2.737	2.987	3.561	4.515	5.761	7.187	7.236	6.042	4.585	3.470	2.892

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Y: ratio of absorbed solar radiation to heating loads	0.516	0.712	1.059	1.473	2.097	2.833	3.303	2.966	2.134	1.264	0.702	0.475

$Y = [F_R(\tau\alpha) * F'_R / F_R * (\tau\alpha) / (\tau\alpha) * H_T * N * A] / Load$

MONTHLY AND ANNUAL PROPORTION OF THE LOAD SUPPLIED BY SOLAR ENERGY

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	Total
$f = 1.029Y - 0.065X - 0.245Y^2 + 0.0018X^2 + 0.0215Y^3$	0.31	0.45	0.66	0.84	1.02	1.12	1.13	1.08	0.96	0.69	0.40	0.26	
Corrected f for summer months , f`	0.31	0.45	0.66	0.84	1.00	1.00	1.00	1.00	0.96	0.69	0.40	0.26	
Monthly energy contribution by solar energy (MJ)	243	325	499	547	570	458	396	394	423	385	265	201	4706
Monthly energy contribution by solar energy (kWh)	67	90	138	152	158	127	110	109	117	107	73	56	1304

Annual saving of energy (kWh)	1304
Annual solar fraction, F	0.66

Appendix D: Monthly and Annual Energy Contribution by SWHSs for Household Size of 4 with Hot Water Consumption of 160 liters/day

F-CHART PARAMETERS

City	Nicosia	**Household size**	4

Collector parameters

A	2.23	net collector area (m²)
$F_R U_L$	3.64	W/m² °C
$F_R(\tau\alpha)$	0.705	
F'_R/F_R	1	
$(\tau\alpha)/(\tau\alpha)$	0.96	

Storage tank parameters

Radius of tank	0.27	m
Height of tank	1.2	m
Volume of tank	200	litres
Area of tank	2.5	m²
Loss coef. of tank	1	W/m² °C

Conversion parameters

1 MJ	0.277	kWh
1 MJ	1000000	J
ΔT	86400	total second per day
1 kWh	3.6	MJ

Other parameters

$T_{desired}$	50	°C
Specific heat of water	4190	J/lt°C
Daily hot water demand	160	litres
T_{ref}	100	°C

MONTHLY AVERAGE DAILY AMBIENT AND COLD WATER TEMPERATURES AND GLOBAL RADIATION

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
Tamb (°C)	12.2	11.9	13.9	17.5	21.6	25.9	29.3	29.4	26.8	22.7	17.7	13.7
Tcoldwater (°C)	14.8	14.9	16.9	20.7	25.4	29.8	33.3	33.4	30.6	25.8	20.3	16.3
Radiation (kWh/m²)	2.49	3.44	4.83	5.98	7.24	8.12	7.93	7.08	5.88	4.26	2.87	2.2
Radiation (MJ/m²)	8.96	12.38	17.39	21.53	26.06	29.23	28.55	25.49	21.17	15.34	10.33	7.92

MONTHLY AND ANNUAL TOTAL HEATING LOAD

		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	
Energy required to heat	Load (J)	731540480	658869120	6.9E+08	589281600	5.1E+08	4.06E+08	3.47E+08	3.4E+08	3.9E+08	5E+08	597326400	7E+08	
water up to desired temp.	Load (MJ)	731.54	658.87	687.90	589.28	511.25	406.26	347.07	344.99	390.17	502.93	597.33	700.37	Total
	Load (kWh)	202.64	182.51	190.55	163.23	141.62	112.53	96.14	95.56	108.08	139.31	165.46	194.00	1792
Tank loss	Load $_{loss}$ (W)	94.26	95.01	90.02	81.05	70.82	60.10	51.62	51.37	57.85	68.08	80.55	90.52	
	Load $_{loss}$ (J)	252473264	229850212	2.4E+08	210071200	1.9E+08	1.56E+08	1.38E+08	1.4E+08	1.5E+08	1.8E+08	208778454	2.4E+08	
	Load $_{loss}$ (MJ)	252.47	229.85	241.12	210.07	189.69	155.78	138.26	137.59	149.96	182.34	208.78	242.45	
														Total
Total heating load	Total Load (MJ)	984.01	888.72	929.02	799.35	700.94	562.04	485.33	482.58	540.13	685.28	806.10	942.82	8806
	Total Load (kWh)	272.6	246.2	257.3	221.4	194.2	155.7	134.4	133.7	149.6	189.8	223.3	261.2	2439

TWO DIMENSIONLESS PARAMETERS OF THE F-CHART METHOD

X: ratio of collector losses to heating loads	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
X= [$F_R U_L$*F\`$_R$/F_R*(T_{ref}-T_{amb})*ΔT*A]/ Load	1.940	1.947	2.015	2.171	2.432	2.774	3.167	3.181	2.851	2.452	2.148	1.990

The f-chart method was developed with a standard tank capacity of 75 litres per square meter of collector area. So X has to be multiplied by a correction factor:

Xc/X= (actual tank capacity/75)^-0.25

Xc/X= 0.956

Corrected X, Xc=X*Xc/X	1.855	1.862	1.927	2.077	2.325	2.653	3.029	3.042	2.727	2.345	2.054	1.903

What is more, to account for fluctuation of cold water temp and min acceptable temp X has to be multipled by another correction fator:

Xcc/X= (11.6+1.18Ts+3.86Tcw-2.32Ta)/(100-Ta)

Xcc/X	1.132	1.141	1.203	1.332	1.512	1.694	1.855	1.860	1.729	1.520	1.311	1.179
Updated X, Xu= Xc*Xcc/X	2.101	2.124	2.318	2.766	3.516	4.494	5.619	5.657	4.714	3.566	2.693	2.243

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Y: ratio of absorbed solar radiation to heating loads	0.426	0.589	0.876	1.219	1.740	2.355	2.752	2.471	1.774	1.047	0.580	0.393

Y= [F_R(τα)*F\`$_R$/ F_R*(τα)/ (τα)*H_T*N*A]/ Load

MONTHLY AND ANNUAL PROPORTION OF THE LOAD SUPPLIED BY SOLAR ENERGY

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	Total
f= 1.029Y-0.065X-0.245Y^2 + 0.0018X^2 + 0.0215Y^3	0.27	0.40	0.59	0.76	0.96	1.09	1.12	1.06	0.91	0.62	0.36	0.23	
Corrected f for summer months , f\`	0.27	0.40	0.59	0.76	0.96	1.00	1.00	1.00	0.91	0.62	0.36	0.23	
Monthly energy contribution by solar energy (MJ)	263	351	545	610	670	562	485	483	491	428	288	218	5393
Monthly energy contribution by solar energy (kWh)	73	97	151	169	186	156	134	134	136	119	80	60	1494

Annual saving of energy (kWh)	1494
Annual solar fraction, F	0.61

Appendix E: Monthly and Annual Energy Contribution by SWHSs for Household Size of 5 with Hot Water Consumption of 200 liters/day

F-CHART PARAMETERS

City	Nicosia	**Household size**	5

Collector parameters

A	2.23	net collector area (m²)
$F_R U_L$	3.64	W/m² °C
$F_R(\tau\alpha)$	0.705	
F'_R / F_R	1	
$(\tau\alpha)/(\tau\alpha)$	0.96	

Storage tank parameters

Radius of tank	0.27	m
Height of tank	1.2	m
Volume of tank	200	litres
Area of tank	2.5	m²
Loss coef. of tank	1	W/m² °C

Conversion parameters

1 MJ	0.277	kWh
1 MJ	1000000	J
ΔT	86400	total second per day
1 kWh	3.6	MJ

Other parameters

$T_{desired}$	50	°C
Specific heat of water	4190	J/lt°C
Daily hot water demand	200	litres
T_{ref}	100	°C

MONTHLY AVERAGE DAILY AMBIENT AND COLD WATER TEMPERATURES AND GLOBAL RADIATION

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
Tamb (°C)	12.2	11.9	13.9	17.5	21.6	25.9	29.3	29.4	26.8	22.7	17.7	13.7
Tcoldwater (°C)	14.8	14.9	16.9	20.7	25.4	29.8	33.3	33.4	30.6	25.8	20.3	16.3
Radiation (kWh/m²)	2.49	3.44	4.83	5.98	7.24	8.12	7.93	7.08	5.88	4.26	2.87	2.2
Radiation (MJ/m²)	8.96	12.38	17.39	21.53	26.06	29.23	28.55	25.49	21.17	15.34	10.33	7.92

MONTHLY AND ANNUAL TOTAL HEATING LOAD

		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	
Energy required to heat	Load (J)	914425600	823586400	8.6E+08	736602000	6.4E+08	507828000	4.34E+08	4.3E+08	4.88E+08	6.3E+08	746658000	8.8E+08	
water up to desired temp.	Load (MJ)	914.43	823.59	859.87	736.60	639.06	507.83	433.83	431.23	487.72	628.67	746.66	875.46	Total
	Load (kWh)	253.30	228.13	238.18	204.04	177.02	140.67	120.17	119.45	135.10	174.14	206.82	242.50	2240
Tank loss	$Load_{loss}$ (W)	94.26	95.01	90.02	81.05	70.82	60.10	51.62	51.37	57.85	68.08	80.55	90.52	
	$Load_{loss}$ (J)	252473264	229850212	2.41E+08	210071200	1.9E+08	155775875	1.38E+08	1.4E+08	1.5E+08	1.8E+08	208778454	2.4E+08	
	$Load_{loss}$ (MJ)	252.47	229.85	241.12	210.07	189.69	155.78	138.26	137.59	149.96	182.34	208.78	242.45	
														Total
Total heating load	Total Load (MJ)	1166.90	1053.44	1100.99	946.67	828.75	663.60	572.09	568.83	637.67	811.01	955.44	1117.91	10423
	Total Load (kWh)	323.23	291.80	304.97	262.23	229.56	183.82	158.47	157.56	176.64	224.65	264.66	309.66	2887

TWO DIMENSIONLESS PARAMETERS OF THE F-CHART METHOD

X: ratio of collector losses to heating loads	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
$X = [F_R U_L * F'_R / F_R * (T_{ref} - T_{amb}) * \Delta T * A] / \text{Load}$	1.636	1.642	1.700	1.834	2.057	2.349	2.687	2.698	2.415	2.072	1.812	1.678

The f-chart method was developed with a standard tank capacity of 75 litres per square meter of collector area. So X has to be multiplied by a correction factor:

$X_c/X = (\text{actual tank capacity}/75)^{-0.25}$

$X_c/X =$ 0.956

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Corrected X, Xc=X*Xc/X	1.564	1.570	1.626	1.753	1.967	2.247	2.569	2.580	2.310	1.982	1.733	1.605

What is more, to account for fluctuation of cold water temp and min acceptable temp X has to be multiplied by another correction fator:

$X_{cc}/X = (11.6 + 1.18T_s + 3.86T_{cw} - 2.32T_a)/(100 - T_a)$

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Xcc/X	1.132	1.141	1.203	1.332	1.512	1.694	1.855	1.860	1.729	1.520	1.311	1.179
Updated X, Xu= Xc*Xcc/X	1.771	1.792	1.956	2.336	2.974	3.806	4.767	4.800	3.993	3.013	2.272	1.892

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Y: ratio of absorbed solar radiation to heating loads	0.359	0.497	0.739	1.030	1.471	1.995	2.335	2.096	1.503	0.885	0.490	0.331

$Y = [F_R(\tau\alpha) * F'_R / F_R * (\tau\alpha)/(\tau\alpha) * H_T * N * A] / \text{Load}$

MONTHLY AND ANNUAL PROPORTION OF THE LOAD SUPPLIED BY SOLAR ENERGY

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	Total
$f = 1.029Y - 0.065X - 0.245Y^2 + 0.0018X^2 + 0.0215Y^3$	0.23	0.34	0.51	0.68	0.87	1.03	1.07	1.01	0.84	0.55	0.31	0.20	
Corrected f for summer months , f`	0.23	0.34	0.51	0.68	0.87	1.00	1.00	1.00	0.84	0.55	0.31	0.20	
Monthly energy contribution by solar energy (MJ)	268	361	567	645	725	664	572	569	533	449	295	222	5870
Monthly energy contribution by solar energy (kWh)	74	100	157	179	201	184	158	158	148	124	82	61	1626

Annual saving of energy (kWh)	1626
Annual solar fraction, F	0.56

Appendix F: Results from Cost-Effectiveness Analysis for Household Size of 1 with Hot Water Consumption of 40 liters/day

TABLE OF PARAMETERS

CAPITAL COSTS:

SWHSs:			***Gas heaters:***		
Price of solar panels:	364	US $	Price of gas heaters:	205	US $
Price of hot water tank:	273	US $	Set up price:	114	US $ // labor included
Set up price:	23	US $	Price of hydrophore:	68	US $ // labor included

MAINTENANCE COSTS:

				Daily working hr of pump:	0.25	hr
				1 horse power	0.746	kWh
Maintenance cost of gas heaters:	45	US $ // labor included				
Cost of electrical element:	45	US $ // labor included	Lifetime of element	3		

VARIABLE COSTS:

Electricity price:	0.275	US $/kWh	Heating value of LPG gas	46.15	MJ/kg	1 MJ	0.2777	kWh
LPG cylinder price:	19.5	US $/ 10 kg	Total heating value:	461.5	MJ	Total heating valu	128.2	kWh

ESTIMATIONS:

Daily hot water consumption:	40	liters				
Est. lifetime of panels:	10	years		Est. lifetime of gas heater:	7-10	years
Est. lifetime of hot water tank:	20	years		Est. lifetime of hydrophore:	5	years

			Proportion of heating load by season		Proportion of heating load by season by gas heater		
Est. annual heating load for storage tank models:	1006	kWh	Heating load during May-Sep	323	Heating load during Nov-Feb	158	kWh
Est. annual heating load for tankless models (gas heat.):	363	kWh	Heating load March-April-Oct	274	Load supplied by solar:	242	kWh
Est. annual heating load supplied by solar energy:	754	kWh	Heating load during Nov-Feb	409			

Est. efficiency rate of electrical element:	85%
Est. efficiency rate of gas heater:	80%

Real discount rate:	10%
Change in average real prices:	0%

FINANCIAL COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	660	0	0	0	0	0	0	0	0	0	387	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006
Load supplied by solar panels per annum (kWh):	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754
Auxiliary electric energy (kWh) per annum @100% efficiency:	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252
Auxiliary electric energy (kWh) per annum @85% efficiency	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296
Cost of auxiliary energy:	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Cost of energy lost in pipes:	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Cost of elelctrical element:	0	0	0	45	0	0	45	0	0	45	0	0	45	0	0	45	0	0	45	0
Total Costs:	**782**	**122**	**122**	**167**	**122**	**122**	**167**	**122**	**122**	**167**	**509**	**122**	**167**	**122**	**122**	**167**	**122**	**122**	**167**	**122**

NPV @10%: **2060**

FINANCIAL COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006
Load supplied by solar panels per annum (kWh):	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754
Auxiliary electric energy (kWh) per annum @100% efficiency:	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252
Auxiliary electric energy (kWh) per annum @85% efficiency	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296
Cost of auxiliary energy:	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Cost of energy lost in pipes:	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Cost of elelctrical element:	0	0	0	0	0	45	0	0	0	0	45	0	0	0	0	45	0	0	0	0
Total Costs:	782	122	122	122	122	167	122	122	122	122	167	122	122	122	122	167	122	122	122	122

NPV @10%: **1855**

FINANCIAL COST ANALYSIS OF ELECTRICAL WATER HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20	PV of electricity usage	Levelized cost per tonne
Capital Costs:	296	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Variable Costs:																						
Estimated annual heating load (kWh):	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006		
Electric energy per annum @85% efficiency (kWh):	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184		
Cost of electricity:	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	325	3048	22.3
Cost of electrical element:	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45		
Total Costs:	**666**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**	**370**		

NPV @10%: **3765**

FINANCIAL COST ANALYSIS OF GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	319	0	0	0	0	0	319	0	0	0	0	0	0
Cost of hydrophore:	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363
Required annual heating load @80% efficiency (kWh):	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Cost of LPG cylinder:	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69
Electricity cost of hydrophore:	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	**475**	**133**	**133**	**133**	**133**	**201**	**133**	**407**	**133**	**133**	**201**	**133**	**133**	**407**	**133**	**201**	**133**	**133**	**133**	**133**

NPV @10%: **1890**

FINANCIAL COST ANALYSIS OF GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	319	0	0	0	0	0	0	319	0	0	0	0	0	319	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363
Required annual heating load @80% efficiency (kWh):	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Cost of LPG cylinder:	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	388	114	114	114	114	114	114	388	114	114	114	114	114	388	114	114	114	114	114	114

NPV @10%: **1562**

FINANCIAL COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Cost of hydrophore:	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0
Cost of solar system:	660	0	0	0	0	0	0	0	0	0	387	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1047	0	0	0	0	68	0	0	0	0	774	0	0	0	0	68	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158
Required annual heating load @80% efficiency (kWh):	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cost of LPG cylinder:	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Electricity cost of hydrophore:	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Auxiliary electricity energy @85% efficiency (kWh):	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
Cost of auxiliary electricity energy:	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Cost of electrical element:	0	0	0	0	0	45	0	0	0	0	45	0	0	0	0	45	0	0	0	0
Total Variable Costs:	47	47	47	47	47	92	47	47	47	47	92	47	47	47	47	92	47	47	47	47
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	1094	92	92	92	92	205	92	92	92	92	866	92	92	92	92	205	92	92	92	92

NPV @10%: **2255**

FINANCIAL COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Cost of solar system:	660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Costs:	979	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158
Required annual heating load @80% efficiency (kWh):	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cost of LPG cylinder:	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Auxiliary electricity energy @85% efficiency (kWh):	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
Cost of auxiliary electricity energy:	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Cost of electrical element:	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0
Total Variable Costs:	40	40	40	40	40	40	40	40	40	40	85	40	40	40	40	40	40	40	40	40
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	**1019**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**404**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**

NPV @10%: 1857

PARAMETERS FOR ESTIMATION OF ECONOMIC PRICES

TAXES ON CAPITAL COSTS

	VAT rates	Stopaj tax rates	Customs duties		
Local solar panels:	10%	0%	0%	Econ price:	352
Imported solar panels:	16%	4%	0%		
Gas heaters:	16%	0%	2.7%		
Local hot water tank:	10%	0%	0%	Econ price:	248
Hydrophore:	16%	4%	0%		
Electrical Element:	16%	0%	0%		

	VAT rates	FIF rates	TGTF rates
LPG:	5%	18.92%	0.5%
Electricity:	10%	// only VAT is levied on electricity.	
Econ price of elec	0.25	US $/kWh	

Mark up ratio:	40%

CIF price of gas heaters:	89	US $
Paid stopaj taxes:	0	US $
Paid custom duties:	2	US $
VAT credit:	15	US $
VAT paid on financial pri	28	US $
Total tax payments:	16	US $
Econ price of gas heaters:	189	US $

CIF price of hydrophore:	29	US $
Paid stopaj taxes:	1	US $
Paid custom duties:	0	US $
VAT credit:	5	US $
VAT paid on financial price:	9	US $
Total tax payments:	6	US $
Econ price of hydrophore:	62	US $

CIF price of electrical element:	20	US $
Paid stopaj taxes:	0	US $
Paid custom duties:	0	US $
VAT credit:	3	US $
VAT paid on financial price:	6	US $
Total tax payments:	3	US $
Econ price of electrical element:	42	US $

CIF price of LPG:	8.57	US $ per 10 kg
Paid FIF	1.62	US $
Paid TGTF	0.05	US $
VAT credit:	0.51	US $
VAT paid on fin pr	0.93	US $
Total tax payments:	2.09	US $
Econ price of LPG:	17.41	US $

	Gas heaters	Hydrophore	Electrical element	LPG
CONVERSION FACTORS:	0.922	0.914	0.933	0.89

Social real discount rate:	10%

PARAMETERS FOR ESTIMATION OF SOCIAL COST OF CARBON

Stationary combustion emission factors:

	CO2 factor:		CO2 factor:	
LPG:	61.9638	kg CO2 per mmBTU	0.211	kg CO2 per kWH
HFO:	75.3538	kg CO2 per mmBTU	0.263	kg CO2 per kWH

	Electrical heater:	SWHS with electricity	SWHS with gas heater	Gas heater
Annual estimated heating load (kWh):				
Electricity:	1006	252	32	0
LPG:	0	0	158	363

Adjusted factor for electricity:	3.96
Adjusted factor for LPG:	1.25

Annual CO2 emissions (kg):	1048	262	75	96
Annual CO2 emissions (ton):	1.048	0.262	0.075	0.096

			2015	2016	2017	2018	2019	2020	2021	2022
Annual average growth rate of SCC:			3.30%	3.30%	3.30%	3.30%	3.30%	2.10%	2.10%	2.10%
Est. SCC in 2015 per metric tonnes	39	US $ in 2011 Dol								
	41.4	US $ in 2015 Dol	41.4	42.8	44.2	45.7	47.2	48.7	49.7	50.8

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Annual average growth rate of SCC:	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	1.90%	1.90%	1.90%	1.90%	1.90%
Est. SCC in 2015 per metric tonnes												
	51.9	52.9	54.1	55.2	56.3	57.5	58.7	60.0	61.1	62.3	63.5	64.7

ECONOMIC COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	600	0	0	0	0	0	0	0	0	0	352	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006
Load supplied by solar panels per annum (kWh):	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754
Auxiliary electric energy per annum @100% efficiency (kWh):	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252
Auxiliary electric energy per annum @85% efficiency (kWh):	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296
Cost of auxiliary energy:	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74
Cost of energy lost in pipes:	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
Cost of electrical element:	0	0	0	42	0	0	42	0	0	42	0	0	42	0	0	42	0	0	42	0
Social cost of carbon:	11	11	12	12	12	13	13	13	14	14	14	14	15	15	15	16	16	16	17	17
Total Costs:	721	122	122	165	123	123	166	124	124	166	477	125	167	126	126	168	127	127	169	128

NPV @10%: **1998**

ECONOMIC COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006
Load supplied by solar panels per annum (kWh):	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754	754
Auxiliary electric energy per annum @100% efficiency (kWh):	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252	252
Auxiliary electric energy per annum @85% efficiency (kWh):	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296
Cost of auxiliary energy:	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74	74
Cost of energy lost in pipes:	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36
Cost of electrical element:	0	0	0	0	0	42	0	0	0	0	42	0	0	0	0	42	0	0	0	0
Social cost of carbon:	11	11	12	12	12	13	13	13	14	14	14	14	15	15	15	16	16	16	17	17
Total Costs:	721	122	122	123	123	165	124	124	124	124	167	125	125	126	126	168	127	127	127	128

NPV @10%: **1811**

ECONOMIC COST ANALYSIS OF ELECTRICAL WATER HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20	PV of electricity usage	Levelized cost per tonne
Capital Costs:	269	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Variable Costs:																						
Estimated annual heating load (kWh):	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006	1006		
Electric energy per annum @85% efficiency (kWh):	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184	1184		
Cost of electricity:	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	296	2771	20.3
Cost of electrical element:	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42		
Social cost of carbon:	43	45	46	48	49	51	52	53	54	55	57	58	59	60	62	63	64	65	66	68		
Total Costs:	650	383	384	386	387	389	390	391	392	393	395	396	397	398	399	401	402	403	404	406		

NPV @10%: **3922**

ECONOMIC COST ANALYSIS OF GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	303	0	0	0	0	0	303	0	0	0	0	0	0
Cost of hydrophore:	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363
Required annual heating load @80% efficiency (kWh):	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Cost of LPG cylinder:	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
Electricity cost of hydrophore:	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Social cost of carbon:	4	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	448	128	128	128	128	190	128	386	129	129	191	129	129	387	129	192	130	130	130	130

NPV @10%: **1807**

ECONOMIC COST ANALYSIS OF GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	303	0	0	0	0	0	0	303	0	0	0	0	0	303	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363	363
Required annual heating load @80% efficiency (kWh):	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454	454
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Cost of LPG cylinder:	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
Social cost of carbon:	4	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	369	111	111	111	111	111	111	369	112	112	112	112	112	370	112	112	113	113	113	113

NPV @10%: 1509

ECONOMIC COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Cost of hydrophore:	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0
Cost of solar system:	600	0	0	0	0	0	0	0	0	0	352	0	0	0	0	0	0	0	0	0
Total Capital Costs:	965	0	0	0	0	62	0	0	0	0	717	0	0	0	0	62	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158
Required annual heating load @80% efficiency (kWh):	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cost of LPG cylinder:	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Electricity cost of hydrophore:	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Auxiliary electricity energy @85% efficiency (kWh):	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
Cost of auxiliary electricity energy:	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Cost of electrical element:	0	0	0	0	0	42	0	0	0	0	42	0	0	0	0	42	0	0	0	0
Total Variable Costs:	42	42	42	42	42	84	42	42	42	42	84	42	42	42	42	84	42	42	42	42
Social cost of carbon:	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	1010	90	90	90	90	195	91	91	91	91	805	91	91	91	91	195	91	92	92	92

NPV @10%: 2133

ECONOMIC COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Cost of solar system:	600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Costs:	903	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158
Required annual heating load @80% efficiency (kWh):	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198	198
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Cost of LPG cylinder:	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Auxiliary electricity energy @85% efficiency (kWh):	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
Cost of auxiliary electricity energy:	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Cost of electrical element:	0	0	0	0	0	0	0	0	0	0	42	0	0	0	0	0	0	0	0	0
Total Variable Costs:	36	36	36	36	36	36	36	36	36	36	78	36	36	36	36	36	36	36	36	36
Social cost of carbon:	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	**942**	**84**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**85**	**385**	**85**	**85**	**86**	**86**	**86**	**86**	**86**	**86**	**86**

NPV @10%: **1769**

LEVELIZED COST OF HOT WATER CONSUMPTION PER CUBIC METER

Total daily hot water consumption:	40	liter
Annual hot water con. (liters):	14600	
Annual hot water con. (cubic meter)	14.6	

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Annual hot water consumption (cubic meter):	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6

PV of hot water consumption @10%: 137

Fin levelized cost of SWHS with elect back-up:	15.1	US $	**Econ levelized cost of SWHS with elect back-up:**	14.6	US $
Fin levelized cost of electrical heater:	27.5	US $	**Econ levelized cost of electrical heater:**	28.7	US $
Fin levelized cost of gas heater:	13.8	US $	**Econ levelized cost of gas heater:**	13.2	US $
Fin levelized cost of gas heater with project:	11.4	US $	**Econ levelized cost of gas heater with project:**	11.0	US $
Fin levelized cost of SWHS combined gas heater:	16.5	US $	**Econ levelized cost of SWHS combined gas heater:**	15.6	US $
Fin levelized cost of SWHS combined gas with projec	13.6	US $	**Econ levelized cost of SWHS combined gas with project:**	12.9	US $
Fin levelized cost of SWHS with elect with project:	13.6	US $	**Econ levelized cost of SWHS with elect with project:**	13.2	US $

SENSITIVITY ANALYSIS FOR FINANCIAL COSTS

		BEFORE WATER SUPPLY PROJECT			AFTER WATER SUPPLY PROJECT		
		SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Changes in real prices of electricity and gas:		**15.1**	**13.8**	**16.5**	**13.6**	**11.4**	**13.6**
	-10%	14.2	13.2	16.2	12.7	11.0	13.3
	-5%	14.6	13.5	16.3	13.2	11.2	13.4
	-3%	14.8	13.6	16.4	13.3	11.3	13.5
	0%	**15.1**	**13.8**	**16.5**	**13.6**	**11.4**	**13.6**
	3%	15.3	14.0	16.6	13.8	11.6	13.7
	5%	15.5	14.1	16.7	14.0	11.7	13.7
	10%	15.9	14.4	16.8	14.4	11.9	13.9
		SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Real discount rate:		**15.1**	**13.8**	**16.5**	**13.6**	**11.4**	**13.6**
	5%	13.9	13.3	14.8	12.2	11.0	11.8
	10%	**15.1**	**13.8**	**16.5**	**13.6**	**11.4**	**13.6**
	15%	16.3	14.3	18.3	15.0	11.8	15.5
		SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Electricity price:		**15.1**	**13.8**	**16.5**	**13.6**	**11.4**	**13.6**
	0.225	13.6	13.6	16.3	12.1	11.4	13.5
	0.275	**15.1**	**13.8**	**16.5**	**13.6**	**11.4**	**13.6**
	0.335	16.9	14.1	16.7	15.4	11.4	13.7
		SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Lifetime of electrical element:		**15.1**	**13.8**	**16.5**	**13.6**	**11.4**	**13.6**
	1	17.0	13.8	16.5	13.6	11.4	13.6
	3	**15.1**	**13.8**	**16.5**	**13.6**	**11.4**	**13.6**
	5	14.7	13.8	16.5	13.6	11.4	13.6

SENSITIVITY ANALYSIS FOR ECONOMIC COSTS

	BEFORE WATER SUPPLY PROJECT			AFTER WATER SUPPLY PROJECT		
	SWHS with elect	Gas	SWHS with gas	SWHS with elect	Gas	SWHS with gas
Changes in real prices of electricity and gas:	**14.6**	**13.2**	**15.6**	**13.2**	**11.0**	**12.9**
-10%	13.9	12.7	15.3	12.5	10.6	12.7
-5%	14.2	12.9	15.5	12.9	10.8	12.8
-3%	14.4	13.1	15.5	13.0	10.9	12.9
0%	**14.6**	**13.2**	**15.6**	**13.2**	**11.0**	**12.9**
3%	14.8	13.4	15.7	13.5	11.2	13.0
5%	15.0	13.5	15.7	13.6	11.2	13.1
10%	15.4	13.8	15.9	14.0	11.5	13.2
	SWHS with elect	Gas	SWHS with gas	SWHS with elect	Gas	SWHS with gas
Real discount rate:	**14.6**	**13.2**	**15.6**	**13.2**	**11.0**	**12.9**
5%	13.6	12.8	14.0	12.1	10.7	11.3
10%	**14.6**	**13.2**	**15.6**	**13.2**	**11.0**	**12.9**
15%	15.7	13.7	17.2	14.5	11.4	14.7
	SWHS with elect	Gas	SWHS with gas	SWHS with elect	Gas	SWHS with gas
Social cost of carbon:	**14.6**	**13.2**	**15.6**	**13.2**	**11.0**	**12.9**
12	14.0	13.0	15.4	12.6	10.8	12.8
39	**14.6**	**13.2**	**15.6**	**13.2**	**11.0**	**12.9**
61	15.1	13.4	15.7	13.7	11.2	13.1

Appendix G: Results from Cost-Effectiveness Analysis for Household Size of 2 with Hot Water Consumption of 80 liters/day

TABLE OF PARAMETERS

CAPITAL COSTS:

SWHSs:			***Gas heaters:***		
Price of solar panels:	364	US $	Price of gas heaters:	205	US $
Price of hot water tank:	273	US $	Set up price:	114	US $ // labor included
Set up price:	23	US $	Price of hydrophore:	68	US $ // labor included
			Daily working hr of pump:	0.5	hr
			1 horse power	0.746	kWh

MAINTENANCE COSTS:

Maintenance cost of gas heaters:	45	US $ // labor included		
Cost of electrical element:	45	US $ // labor included	Lifetime of element	3

VARIABLE COSTS:

Electricity price:	0.275	US $/kWh	Heating value of LPG gas	46.15	MJ/kg	1 MJ	0.2777	kWh
LPG cylinder price:	19.5	US $/ 10 kg	Total heating value:	461.5	MJ	Total heating valu	128.2	kWh

ESTIMATIONS:

Daily hot water consumption:	80	liters			
Est. lifetime of panels:	10	years	Est. lifetime of gas heater:	7-10	years
Est. lifetime of hot water tank:	20	years	Est. lifetime of hydrophore:	5	years

			Proportion of heating load by season		Proportion of heating load by season by gas heater		
Est. annual heating load for storage tank models:	1454	kWh	Heating load during May-Sep	461	Heating load during Nov-Feb	317	kWh
Est. annual heating load for tankless models (gas heat.):	726	kWh	Heating load March-April-Oct	398	Load supplied by solar:	289	kWh
Est. annual heating load supplied by solar energy:	952	kWh	Heating load during Nov-Feb	595			

Est. efficiency rate of electrical element:	85%
Est. efficiency rate of gas heater:	80%

Real discount rate:	10%
Change in average real prices:	0%

FINANCIAL COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	660	0	0	0	0	0	0	0	0	0	387	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454
Load supplied by solar panels per annum (kWh):	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952
Auxiliary electric energy (kWh) per annum @100% efficiency:	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502
Auxiliary electric energy (kWh) per annum @85% efficiency	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591
Cost of auxiliary energy:	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162
Cost of energy lost in pipes:	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58
Cost of elelctrical element:	0	0	0	45	0	0	45	0	0	45	0	0	45	0	0	45	0	0	45	0
Total Costs:	**880**	**220**	**220**	**265**	**220**	**220**	**265**	**220**	**220**	**265**	**607**	**220**	**265**	**220**	**220**	**265**	**220**	**220**	**265**	**220**

NPV @10%: **2985**

FINANCIAL COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454
Load supplied by solar panels per annum (kWh):	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952
Auxiliary electric energy (kWh) per annum @100% efficiency:	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502
Auxiliary electric energy (kWh) per annum @85% efficiency	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591
Cost of auxiliary energy:	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162	162
Cost of energy lost in pipes:	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58
Cost of elelctrical element:	0	0	0	0	0	45	0	0	0	0	45	0	0	0	0	45	0	0	0	0
Total Costs:	880	220	220	220	220	265	220	220	220	220	265	220	220	220	220	265	220	220	220	220

NPV @10%: **2780**

FINANCIAL COST ANALYSIS OF ELECTRICAL WATER HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20	PV of electricity usage	Levelized cost per tonne
Capital Costs:	296	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Variable Costs:																						
Estimated annual heating load (kWh):	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454		
Electric energy per annum @85% efficiency (kWh):	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711		
Cost of electricity:	470	470	470	470	470	470	470	470	470	470	470	470	470	470	470	470	470	470	470	470	4405	16.1
Cost of electrical element:	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45		
Total Costs:	**811**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**	**515**		

NPV @10%: 5123

FINANCIAL COST ANALYSIS OF GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	319	0	0	0	0	0	319	0	0	0	0	0	0
Cost of hydrophore:	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726
Required annual heating load @80% efficiency (kWh):	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Cost of LPG cylinder:	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
Electricity cost of hydrophore:	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	**563**	**221**	**221**	**221**	**221**	**289**	**221**	**495**	**221**	**221**	**289**	**221**	**221**	**495**	**221**	**289**	**221**	**221**	**221**	**221**

NPV @10%: 2712

FINANCIAL COST ANALYSIS OF GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	319	0	0	0	0	0	0	319	0	0	0	0	0	319	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726
Required annual heating load @80% efficiency (kWh):	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Cost of LPG cylinder:	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138	138
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	457	183	183	183	183	183	183	457	183	183	183	183	183	457	183	183	183	183	183	183

NPV @10%: **2209**

FINANCIAL COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Cost of hydrophore:	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0
Cost of solar system:	660	0	0	0	0	0	0	0	0	0	387	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1047	0	0	0	0	68	0	0	0	0	774	0	0	0	0	68	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317
Required annual heating load @80% efficiency (kWh):	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Cost of LPG cylinder:	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Electricity cost of hydrophore:	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109
Auxiliary electricity energy @85% efficiency (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Cost of auxiliary electricity energy:	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Cost of electrical element:	0	0	0	0	0	45	0	0	0	0	45	0	0	0	0	45	0	0	0	0
Total Variable Costs:	108	108	108	108	108	153	108	108	108	108	153	108	108	108	108	153	108	108	108	108
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	1155	153	153	153	153	266	153	153	153	153	927	153	153	153	153	266	153	153	153	153

NPV @10%: **2829**

FINANCIAL COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Cost of solar system:	660	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Costs:	979	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317
Required annual heating load @80% efficiency (kWh):	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Cost of LPG cylinder:	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109
Auxiliary electricity energy @85% efficiency (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Cost of auxiliary electricity energy:	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Cost of electrical element:	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0
Total Variable Costs:	96	96	96	96	96	96	96	96	96	96	141	96	96	96	96	96	96	96	96	96
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	**1075**	**141**	**141**	**141**	**141**	**141**	**141**	**141**	**141**	**141**	**460**	**141**	**141**	**141**	**141**	**141**	**141**	**141**	**141**	**141**

NPV @10%: **2373**

PARAMETERS FOR ESTIMATION OF ECONOMIC PRICES

TAXES ON CAPITAL COSTS

	VAT rates	Stopaj tax rates	Customs duties		
Local solar panels:	10%	0%	0%	Econ price:	352
Imported solar panels:	16%	4%	0%		
Gas heaters:	16%	0%	2.7%		
Local hot water tank:	10%	0%	0%	Econ price:	248
Hydrophore:	16%	4%	0%		
Electrical Element:	16%	0%	0%		

	VAT rates	FIF rates	TGTF rates
LPG:	5%	18.92%	0.5%
Electricity:	10%	'/ only VAT is levied on electricity.	
Econ price of elec	0.25	US $/kWh	

Mark up ratio: 40%

CIF price of gas heaters:	89	US $
Paid stopaj taxes:	0	US $
Paid custom duties:	2	US $
VAT credit:	15	US $
VAT paid on financial pri	28	US $
Total tax payments:	16	US $
Econ price of gas heaters:	189	US $

CIF price of hydrophore:	29	US $
Paid stopaj taxes:	1	US $
Paid custom duties:	0	US $
VAT credit:	5	US $
VAT paid on financial price:	9	US $
Total tax payments:	6	US $
Econ price of hydrophore:	62	US $

CIF price of electrical element:	20	US $
Paid stopaj taxes:	0	US $
Paid custom duties:	0	US $
VAT credit:	3	US $
VAT paid on financial price:	6	US $
Total tax payments:	3	US $
Econ price of electrical element:	42	US $

CIF price of LPG:	8.57	US $ per 10 kg
Paid FIF	1.62	US $
Paid TGTF	0.05	US $
VAT credit:	0.51	US $
VAT paid on fin pr	0.93	US $
Total tax payments:	2.09	US $
Econ price of LPG:	17.41	US $

CONVERSION FACTORS: 0.922 | 0.914 | 0.933 | 0.89

Social real discount rate: 10%

PARAMETERS FOR ESTIMATION OF SOCIAL COST OF CARBON

Stationary combustion emission factors:

	CO2 factor:		CO2 factor:	
LPG:	61.9638	kg CO2 per mmBTU	0.211	kg CO2 per kWH
HFO:	75.3538	kg CO2 per mmBTU	0.263	kg CO2 per kWH

	Electrical heater:	SWHS with electricity	SWHS with gas heater	Gas heater
Annual estimated heating load (kWh):				
Electricity:	1454	502	109	0
LPG:	0	0	317	726

Adjusted factor for electricity: 3.96
Adjusted factor for LPG: 1.25

	Electrical heater	SWHS with electricity	SWHS with gas heater	Gas heater
Annual CO2 emissions (kg):	1514	523	197	192
Annual CO2 emissions (ton):	1.514	0.523	0.197	0.192

			2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Annual average growth rate of SCC:			3.30%	3.30%	3.30%	3.30%	3.30%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	1.90%	1.90%	1.90%	1.90%	1.90%
Est. SCC in 2015 per metric tonnes	39	US $ in 2011 Dol																				
	41.4	US $ in 2015 Dol	41.4	42.8	44.2	45.7	47.2	48.7	49.7	50.8	51.9	52.9	54.1	55.2	56.3	57.5	58.7	60.0	61.1	62.3	63.5	64.7

ECONOMIC COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	600	0	0	0	0	0	0	0	0	0	352	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454
Load supplied by solar panels per annum (kWh):	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952
Auxiliary electric energy per annum @100% efficiency (kWh):	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502
Auxiliary electric energy per annum @85% efficiency (kWh):	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591
Cost of auxiliary energy:	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148
Cost of energy lost in pipes:	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
Cost of electrical element:	0	0	0	42	0	0	42	0	0	42	0	0	42	0	0	42	0	0	42	0
Social cost of carbon:	22	22	23	24	25	25	26	27	27	28	28	29	29	30	31	31	32	33	33	34
Total Costs:	822	223	223	266	225	226	268	227	227	270	580	229	272	230	231	274	232	233	276	234

NPV @10%: **2960**

ECONOMIC COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454
Load supplied by solar panels per annum (kWh):	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952	952
Auxiliary electric energy per annum @100% efficiency (kWh):	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502	502
Auxiliary electric energy per annum @85% efficiency (kWh):	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591	591
Cost of auxiliary energy:	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148
Cost of energy lost in pipes:	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53
Cost of electrical element:	0	0	0	0	0	42	0	0	0	0	42	0	0	0	0	42	0	0	0	0
Social cost of carbon:	22	22	23	24	25	25	26	27	27	28	28	29	29	30	31	31	32	33	33	34
Total Costs:	822	223	223	224	225	268	226	227	227	228	271	229	230	230	231	274	232	233	234	234

NPV @10%: **2773**

ECONOMIC COST ANALYSIS OF ELECTRICAL WATER HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20	PV of electricity usage	Levelized cost per to
Capital Costs:	269	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Variable Costs:																						
Estimated annual heating load (kWh):	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454	1454		
Electric energy per annum @85% efficiency (kWh):	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711	1711		
Cost of electricity:	428	428	428	428	428	428	428	428	428	428	428	428	428	428	428	428	428	428	428	428	4005	14.6
Cost of electrical element:	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42		
Social cost of carbon:	63	65	67	69	71	74	75	77	79	80	82	84	85	87	89	91	93	94	96	98		
Total Costs:	801	534	537	539	541	543	545	547	548	550	552	553	555	557	559	560	562	564	566	568		

NPV @10%: 5374

ECONOMIC COST ANALYSIS OF GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	303	0	0	0	0	0	303	0	0	0	0	0	0
Cost of hydrophore:	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726
Required annual heating load @80% efficiency (kWh):	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Cost of LPG cylinder:	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123
Electricity cost of hydrophore:	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
Social cost of carbon:	8	8	8	9	9	9	10	10	10	10	10	11	11	11	11	11	12	12	12	12
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	530	211	211	211	211	274	212	470	212	212	275	213	213	471	214	276	214	214	214	215

NPV @10%: 2589

ECONOMIC COST ANALYSIS OF GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	303	0	0	0	0	0	0	303	0	0	0	0	0	303	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726	726
Required annual heating load @80% efficiency (kWh):	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908	908
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Cost of LPG cylinder:	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123
Social cost of carbon:	8	8	8	9	9	9	10	10	10	10	10	11	11	11	11	11	12	12	12	12
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	434	176	177	177	177	178	178	436	178	178	179	179	179	437	180	180	180	180	180	181

NPV @10%: 2131

ECONOMIC COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Cost of hydrophore:	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0
Cost of solar system:	600	0	0	0	0	0	0	0	0	0	352	0	0	0	0	0	0	0	0	0
Total Capital Costs:	965	0	0	0	0	62	0	0	0	0	717	0	0	0	0	62	0	0	0	0
Variable Costs:																				
<u>During the November- February period:</u>																				
Est. heating load that will be met by gas heater (kWh):	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317
Required annual heating load @80% efficiency (kWh):	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Cost of LPG cylinder:	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
Electricity cost of hydrophore:	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
<u>During March- April and October:</u>																				
Est. heating load that will be met by electrical heater (kWh):	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109
Auxiliary electricity energy @85% efficiency (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Cost of auxiliary electricity energy:	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Cost of electrical element:	0	0	0	0	0	42	0	0	0	0	42	0	0	0	0	42	0	0	0	0
Total Variable Costs:	97	97	97	97	97	139	97	97	97	97	139	97	97	97	97	139	97	97	97	97
Social cost of carbon:	8	8	9	9	9	10	10	10	10	10	11	11	11	11	12	12	12	12	13	13
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	1070	151	151	151	151	256	152	152	152	153	867	153	153	153	154	258	154	154	155	155

NPV @10%: 2708

ECONOMIC COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Cost of solar system:	600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Costs:	903	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317	317
Required annual heating load @80% efficiency (kWh):	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396	396
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Cost of LPG cylinder:	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54	54
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109	109
Auxiliary electricity energy @85% efficiency (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Cost of auxiliary electricity energy:	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
Cost of electrical element:	0	0	0	0	0	0	0	0	0	0	42	0	0	0	0	0	0	0	0	0
Total Variable Costs:	86	86	86	86	86	86	86	86	86	86	128	86	86	86	86	86	86	86	86	86
Social cost of carbon:	8	8	9	9	9	10	10	10	10	10	11	11	11	11	12	12	12	12	13	13
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	**997**	**139**	**140**	**140**	**140**	**141**	**141**	**141**	**141**	**141**	**442**	**142**	**142**	**142**	**142**	**143**	**143**	**143**	**143**	**144**

NPV @10%: 2291

LEVELIZED COST OF HOT WATER CONSUMPTION PER CUBIC METER

Total daily hot water consumption:	80	liter
Annual hot water con. (liters):	29200	
Annual hot water con. (cubic meter)	29.2	

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Annual hot water consumption (cubic meter):	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2	29.2

PV of hot water consumption @10%: 273

Fin levelized cost of SWHS with elect back-up:	10.9	US $	**Econ levelized cost of SWHS with elect back-up:**	10.8	US $
Fin levelized cost of electrical heater:	18.7	US $	**Econ levelized cost of electrical heater:**	19.7	US $
Fin levelized cost of gas heater:	9.9	US $	**Econ levelized cost of gas heater:**	9.5	US $
Fin levelized cost of gas heater with project:	8.1	US $	**Econ levelized cost of gas heater with project:**	7.8	US $
Fin levelized cost of SWHS combined gas heater:	10.3	US $	**Econ levelized cost of SWHS combined gas heater:**	9.9	US $
Fin levelized cost of SWHS combined gas with projec	8.7	US $	**Econ levelized cost of SWHS combined gas with project:**	8.4	US $
Fin levelized cost of SWHS with elect with project:	10.2	US $	**Econ levelized cost of SWHS with elect with project:**	10.1	US $

SENSITIVITY ANALYSIS FOR FINANCIAL COSTS

	BEFORE WATER SUPPLY PROJECT			AFTER WATER SUPPLY PROJECT		
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Changes in real prices of electricity and gas:	**10.9**	**9.9**	**10.3**	**10.2**	**8.1**	**8.7**
-10%	10.2	9.3	10.0	9.4	7.6	8.4
-5%	10.5	9.6	10.2	9.8	7.8	8.5
-3%	10.7	9.7	10.2	9.9	7.9	8.6
0%	**10.9**	**9.9**	**10.3**	**10.2**	**8.1**	**8.7**
3%	11.1	10.1	10.5	10.4	8.2	8.8
5%	11.3	10.2	10.5	10.5	8.3	8.8
10%	11.7	10.5	10.7	10.9	8.5	9.0
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Real discount rate:	**10.9**	**9.9**	**10.3**	**10.2**	**8.1**	**8.7**
5%	10.3	9.7	9.5	9.5	7.9	7.8
10%	**10.9**	**9.9**	**10.3**	**10.2**	**8.1**	**8.7**
15%	11.5	10.2	11.2	10.9	8.3	9.6
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Electricity price:	**10.9**	**9.9**	**10.3**	**10.2**	**8.1**	**8.7**
0.225	9.5	9.7	10.0	8.8	8.1	8.5
0.275	**10.9**	**9.9**	**10.3**	**10.2**	**8.1**	**8.7**
0.335	12.6	10.2	10.7	11.8	8.1	8.9
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Lifetime of electrical element:	**10.9**	**9.9**	**10.3**	**10.2**	**8.1**	**8.7**
1	11.9	9.9	10.3	10.2	8.1	8.7
3	**10.9**	**9.9**	**10.3**	**10.2**	**8.1**	**8.7**
5	10.7	9.9	10.3	10.2	8.1	8.7

SENSITIVITY ANALYSIS FOR ECONOMIC COSTS

	BEFORE WATER SUPPLY PROJECT			AFTER WATER SUPPLY PROJECT		
	SWHS with elect	Gas	SWHS with gas	SWHS with elect	Gas	SWHS with gas
Changes in real prices of electricity and gas:	**10.8**	**9.5**	**9.9**	**10.1**	**7.8**	**8.4**
-10%	10.1	8.9	9.6	9.5	7.4	8.1
-5%	10.5	9.2	9.7	9.8	7.6	8.2
-3%	10.6	9.3	9.8	9.9	7.7	8.3
0%	**10.8**	**9.5**	**9.9**	**10.1**	**7.8**	**8.4**
3%	11.0	9.6	10.0	10.3	7.9	8.5
5%	11.2	9.7	10.1	10.5	8.0	8.5
10%	11.5	10.0	10.2	10.8	8.2	8.7
	SWHS with elect	Gas	SWHS with gas	SWHS with elect	Gas	SWHS with gas
Real discount rate:	**10.8**	**9.5**	**9.9**	**10.1**	**7.8**	**8.4**
5%	10.3	9.2	9.1	9.6	7.6	7.6
10%	**10.8**	**9.5**	**9.9**	**10.1**	**7.8**	**8.4**
15%	11.4	9.7	10.7	10.8	8.0	9.2
	SWHS with elect	Gas	SWHS with gas	SWHS with elect	Gas	SWHS with gas
Social cost of carbon:	**10.8**	**9.5**	**9.9**	**10.1**	**7.8**	**8.4**
12	10.2	9.2	9.7	9.5	7.6	8.1
39	**10.8**	**9.5**	**9.9**	**10.1**	**7.8**	**8.4**
61	11.3	9.7	10.1	10.6	8.0	8.6

Appendix H: Results from Cost-Effectiveness Analysis for Household Size of 3 with Hot Water Consumption of 120 liters/day

TABLE OF PARAMETERS

CAPITAL COSTS:

SWHSs:			***Gas heaters:***		
Price of solar panels:	409	US $	Price of gas heaters:	205	US $
Price of hot water tank:	295	US $	Set up price:	114	US $ // labor included
Set up price:	23	US $	Price of hydrophore:	68	US $ // labor included

MAINTENANCE COSTS:

			Daily working hr of pump:	0.5	hr
			1 horse power	0.746	kWh
Maintenance cost of gas heaters:	45	US $ // labor included			
Cost of electrical element:	45	US $ // labor included	Lifetime of element	3	

VARIABLE COSTS:

Electricity price:	0.275	US $/kWh	Heating value of LPG gas	46.15	MJ/kg	1 MJ	0.2777	kWh
LPG cylinder price:	19.5	US $/ 10 kg	Total heating value:	461.5	MJ	Total heating valu	128.2	kWh

ESTIMATIONS:

Daily hot water consumption:	120	liters			
Est. lifetime of panels:	10	years	Est. lifetime of gas heater:	7-10	years
Est. lifetime of hot water tank:	20	years	Est. lifetime of hydrophore:	5	years

			Proportion of heating load by season		Proportion of heating load by season by gas heater		
Est. annual heating load for storage tank models:	1980	kWh	Heating load during May-Sep	625	Heating load during Nov-Feb	475	kWh
Est. annual heating load for tankless models (gas heat.):	1090	kWh	Heating load March-April-Oct	542	Load supplied by solar:	408	kWh
Est. annual heating load supplied by solar energy:	1305	kWh	Heating load during Nov-Feb	813			

Est. efficiency rate of electrical element:	85%
Est. efficiency rate of gas heater:	80%
Real discount rate:	10%
Change in average real prices:	0%

FINANCIAL COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	727	0	0	0	0	0	0	0	0	0	432	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980
Load supplied by solar panels per annum (kWh):	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305
Auxiliary electric energy (kWh) per annum @100% efficiency:	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675
Auxiliary electric energy (kWh) per annum @85% efficiency	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794
Cost of auxiliary energy:	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218
Cost of energy lost in pipes:	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Cost of elelctrical element:	0	0	0	45	0	0	45	0	0	45	0	0	45	0	0	45	0	0	45	0
Total Costs:	**1024**	**297**	**297**	**342**	**297**	**297**	**342**	**297**	**297**	**342**	**729**	**297**	**342**	**297**	**297**	**342**	**297**	**297**	**342**	**297**

NPV @10%: **3790**

FINANCIAL COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	727	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980
Load supplied by solar panels per annum (kWh):	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305
Auxiliary electric energy (kWh) per annum @100% efficiency:	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675
Auxiliary electric energy (kWh) per annum @85% efficiency	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794
Cost of auxiliary energy:	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218
Cost of energy lost in pipes:	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Cost of elelctrical element:	0	0	0	0	0	45	0	0	0	0	45	0	0	0	0	45	0	0	0	0
Total Costs:	1024	297	297	297	297	342	297	297	297	297	342	297	297	297	297	342	297	297	297	297

NPV @10%: **3568**

FINANCIAL COST ANALYSIS OF ELECTRICAL WATER HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980
Electric energy per annum @85% efficiency (kWh):	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329
Cost of electricity:	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641	641
Cost of electrical element:	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Total Costs:	**1004**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**	**686**

PV of electricity usage	Levelized cost per tonne
5999	14.6

NPV @10%: 6738

FINANCIAL COST ANALYSIS OF GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	319	0	0	0	0	0	319	0	0	0	0	0	0
Cost of hydrophore:	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090
Required annual heating load @80% efficiency (kWh):	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Cost of LPG cylinder:	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207
Electricity cost of hydrophore:	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37	37
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	**632**	**290**	**290**	**290**	**290**	**358**	**290**	**564**	**290**	**290**	**358**	**290**	**290**	**564**	**290**	**358**	**290**	**290**	**290**	**290**

NPV @10%: 3360

FINANCIAL COST ANALYSIS OF GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	319	0	0	0	0	0	0	319	0	0	0	0	0	319	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090
Required annual heating load @80% efficiency (kWh):	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Cost of LPG cylinder:	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207	207
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	526	252	252	252	252	252	252	526	252	252	252	252	252	526	252	252	252	252	252	252

NPV @10%: **2857**

FINANCIAL COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Cost of hydrophore:	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0
Cost of solar system:	727	0	0	0	0	0	0	0	0	0	432	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1114	0	0	0	0	68	0	0	0	0	819	0	0	0	0	68	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Required annual heating load @80% efficiency (kWh):	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Cost of LPG cylinder:	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
Electricity cost of hydrophore:	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Auxiliary electricity energy @85% efficiency (kWh):	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158
Cost of auxiliary electricity energy:	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
Cost of electrical element:	0	0	0	0	0	45	0	0	0	0	45	0	0	0	0	45	0	0	0	0
Total Variable Costs:	146	146	146	146	146	191	146	146	146	146	191	146	146	146	146	191	146	146	146	146
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	1260	191	191	191	191	304	191	191	191	191	1010	191	191	191	191	304	191	191	191	191

NPV @10%: **3271**

FINANCIAL COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Cost of solar system:	727	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1046	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Required annual heating load @80% efficiency (kWh):	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Cost of LPG cylinder:	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Auxiliary electricity energy @85% efficiency (kWh):	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158
Cost of auxiliary electricity energy:	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
Cost of electrical element:	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0
Total Variable Costs:	134	134	134	134	134	134	134	134	134	134	179	134	134	134	134	134	134	134	134	134
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	**1180**	**179**	**179**	**179**	**179**	**179**	**179**	**179**	**179**	**179**	**498**	**179**	**179**	**179**	**179**	**179**	**179**	**179**	**179**	**179**

NPV @10%: **2797**

PARAMETERS FOR ESTIMATION OF ECONOMIC PRICES

TAXES ON CAPITAL COSTS

	VAT rates	Stopaj tax rates	Customs duties		
Local solar panels:	10%	0%	0%	Econ price:	393
Imported solar panels:	16%	4%	0%		
Gas heaters:	16%	0%	2.7%		
Local hot water tank:	10%	0%	0%	Econ price:	268
Hydrophore:	16%	4%	0%		
Electrical Element:	16%	0%	0%		

	VAT rates	FIF rates	TGTF rates
LPG:	5%	18.92%	0.5%
Electricity:	10%	// only VAT is levied on electricity.	
Econ price of elect	0.25	US $/kWh	

Mark up ratio: 40%

CIF price of gas heaters:	89	US $	CIF price of hydrophore:	29	US $	CIF price of electrical element:	20	US $	CIF price of LPG:	8.57	US $ per 10 kg
Paid stopaj taxes:	0	US $	Paid stopaj taxes:	1	US $	Paid stopaj taxes:	0	US $	Paid FIF	1.62	US $
Paid custom duties:	2	US $	Paid custom duties:	0	US $	Paid custom duties:	0	US $	Paid TGTF	0.05	US $
VAT credit:	15	US $	VAT credit:	5	US $	VAT credit:	3	US $	VAT credit:	0.51	US $
VAT paid on financial pri	28	US $	VAT paid on financial price:	9	US $	VAT paid on financial price:	6	US $	VAT paid on fin pr	0.93	US $
Total tax payments:	16	US $	Total tax payments:	6	US $	Total tax payments:	3	US $	Total tax payments:	2.09	US $
Econ price of gas heaters:	189	US $	Econ price of hydrophore:	62	US $	Econ price of electrical element:	42	US $	Econ price of LPG:	17.41	US $
CONVERSION FACTORS:	0.922			0.914			0.933			0.89	

Social real discount rate: 10%

PARAMETERS FOR ESTIMATION OF SOCIAL COST OF CARBON

Stationary combustion emission factors:

	CO2 factor:		CO2 factor:	
LPG:	61.9638	kg CO2 per mmBTU	0.211	kg CO2 per kWH
HFO:	75.3538	kg CO2 per mmBTU	0.263	kg CO2 per kWH

	Electrical heater:	SWHS with electricity	SWHS with gas heater	Gas heater
Annual estimated heating load (kWh):				
Electricity:	1980	675	134	0
LPG:	0	0	475	1090

Adjusted factor for electricity:	3.96
Adjusted factor for LPG:	1.25

Annual CO2 emissions (kg):	2062	703	265	288
Annual CO2 emissions (ton):	2.062	0.703	0.265	0.288

			2015	2016	2017	2018	2019	2020	2021	2022
Annual average growth rate of SCC:			3.30%	3.30%	3.30%	3.30%	3.30%	2.10%	2.10%	2.10%
Est. SCC in 2015 per metric tonnes	39	US $ in 2011 Dol								
	41.4	US $ in 2015 Dol	41.4	42.8	44.2	45.7	47.2	48.7	49.7	50.8

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Annual average growth rate of SCC:	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	1.90%	1.90%	1.90%	1.90%	1.90%
Est. SCC in 2015 per metric tonnes	51.9	52.9	54.1	55.2	56.3	57.5	58.7	60.0	61.1	62.3	63.5	64.7

ECONOMIC COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	661	0	0	0	0	0	0	0	0	0	393	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980
Load supplied by solar panels per annum (kWh):	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305
Auxiliary electric energy per annum @100% efficiency (kWh):	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675
Auxiliary electric energy per annum @85% efficiency (kWh):	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794
Cost of auxiliary energy:	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199
Cost of energy lost in pipes:	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
Cost of electrical element:	0	0	0	42	0	0	42	0	0	42	0	0	42	0	0	42	0	0	42	0
Social cost of carbon:	29	30	31	32	33	34	35	36	36	37	38	39	40	40	41	42	43	44	45	45
Total Costs:	960	300	301	344	303	305	347	306	307	350	701	309	352	311	312	354	313	314	357	316

NPV @10%: 3776

ECONOMIC COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	661	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980
Load supplied by solar panels per annum (kWh):	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305	1305
Auxiliary electric energy per annum @100% efficiency (kWh):	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675	675
Auxiliary electric energy per annum @85% efficiency (kWh):	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794	794
Cost of auxiliary energy:	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199	199
Cost of energy lost in pipes:	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
Cost of electrical element:	0	0	0	0	0	42	0	0	0	0	42	0	0	0	0	42	0	0	0	0
Social cost of carbon:	29	30	31	32	33	34	35	36	36	37	38	39	40	40	41	42	43	44	45	45
Total Costs:	960	300	301	302	303	347	305	306	307	308	350	309	310	311	312	354	313	314	315	316

NPV @10%: 3573

ECONOMIC COST ANALYSIS OF ELECTRICAL WATER HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	289	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980
Electric energy per annum @85% efficiency (kWh):	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329	2329
Cost of electricity:	582	582	582	582	582	582	582	582	582	582	582	582	582	582	582	582	582	582	582	582
Cost of electrical element:	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
Social cost of carbon:	85	88	91	94	97	100	103	105	107	109	111	114	116	119	121	124	126	128	131	133
Total Costs:	999	713	715	719	722	725	727	729	731	734	736	738	741	743	745	748	750	753	755	758

PV of electricity usage	Levelized cost per tonne
5454	13.3

NPV @10%: 7098

ECONOMIC COST ANALYSIS OF GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	303	0	0	0	0	0	303	0	0	0	0	0	0
Cost of hydrophore:	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090
Required annual heating load @80% efficiency (kWh):	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Cost of LPG cylinder:	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185
Electricity cost of hydrophore:	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34
Social cost of carbon:	12	12	13	13	14	14	14	15	15	15	16	16	16	17	17	17	18	18	18	19
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	596	276	277	277	278	340	278	537	279	279	342	280	280	539	281	344	282	282	282	283

NPV @10%: 3213

ECONOMIC COST ANALYSIS OF GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	303	0	0	0	0	0	0	303	0	0	0	0	0	303	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090	1090
Required annual heating load @80% efficiency (kWh):	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363	1363
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Cost of LPG cylinder:	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185	185
Social cost of carbon:	12	12	13	13	14	14	14	15	15	15	16	16	16	17	17	17	18	18	18	19
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	500	242	243	243	244	244	244	503	245	245	246	246	246	505	247	247	248	248	248	249

NPV @10%: 2754

ECONOMIC COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Cost of hydrophore:	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0
Cost of solar system:	661	0	0	0	0	0	0	0	0	0	393	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1026	0	0	0	0	62	0	0	0	0	758	0	0	0	0	62	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Required annual heating load @80% efficiency (kWh):	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Cost of LPG cylinder:	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81
Electricity cost of hydrophore:	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Auxiliary electricity energy @85% efficiency (kWh):	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158
Cost of auxiliary electricity energy:	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
Cost of electrical element:	0	0	0	0	0	42	0	0	0	0	42	0	0	0	0	42	0	0	0	0
Total Variable Costs:	131	131	131	131	131	173	131	131	131	131	173	131	131	131	131	173	131	131	131	131
Social cost of carbon:	11	11	12	12	12	13	13	13	14	14	14	15	15	15	16	16	16	17	17	17
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	1168	188	188	188	189	293	189	190	190	190	945	191	191	192	192	296	192	193	193	193

NPV @10%: 3136

ECONOMIC COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Cost of solar system:	661	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Costs:	964	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Variable Costs:																				
During the November- February period:																				
Est. heating load that will be met by gas heater (kWh):	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Required annual heating load @80% efficiency (kWh):	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594	594
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Cost of LPG cylinder:	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81
During March- April and October:																				
Est. heating load that will be met by electrical heater (kWh):	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Auxiliary electricity energy @85% efficiency (kWh):	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158	158
Cost of auxiliary electricity energy:	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
Cost of electrical element:	0	0	0	0	0	0	0	0	0	0	42	0	0	0	0	0	0	0	0	0
Total Variable Costs:	120	120	120	120	120	120	120	120	120	120	162	120	120	120	120	120	120	120	120	120
Social cost of carbon:	11	11	12	12	12	13	13	13	14	14	14	15	15	15	16	16	16	17	17	17
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	**1095**	**176**	**177**	**177**	**178**	**178**	**178**	**179**	**179**	**179**	**479**	**180**	**180**	**180**	**181**	**181**	**181**	**182**	**182**	**182**

NPV @10%: **2704**

LEVELIZED COST OF HOT WATER CONSUMPTION PER CUBIC METER

Total daily hot water consumption:	120	liter
Annual hot water con. (liters):	43800	
Annual hot water con. (cubic meter)	43.8	

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Annual hot water consumption (cubic meter):	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8	43.8

PV of hot water consumption @10%: 410

Fin levelized cost of SWHS with elect back-up:	9.2	US $	**Econ levelized cost of SWHS with elect back-up:**	9.2	US $
Fin levelized cost of electrical heater:	16.4	US $	**Econ levelized cost of electrical heater:**	17.3	US $
Fin levelized cost of gas heater:	8.2	US $	**Econ levelized cost of gas heater:**	7.8	US $
Fin levelized cost of gas heater with project:	7.0	US $	**Econ levelized cost of gas heater with project:**	6.7	US $
Fin levelized cost of SWHS combined gas heater:	8.0	US $	**Econ levelized cost of SWHS combined gas heater:**	7.6	US $
Fin levelized cost of SWHS combined gas with projec	6.8	US $	**Econ levelized cost of SWHS combined gas with project:**	6.6	US $
Fin levelized cost of SWHS with elect with project:	8.7	US $	**Econ levelized cost of SWHS with elect with project:**	8.7	US $

SENSITIVITY ANALYSIS FOR FINANCIAL COSTS

	BEFORE WATER SUPPLY PROJECT			AFTER WATER SUPPLY PROJECT		
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Changes in real prices of electricity and gas:	**9.2**	**8.2**	**8.0**	**8.7**	**7.0**	**6.8**
-10%	8.6	7.6	7.6	8.0	6.5	6.5
-5%	8.9	7.9	7.8	8.4	6.7	6.7
-3%	9.0	8.0	7.9	8.5	6.8	6.7
0%	**9.2**	**8.2**	**8.0**	**8.7**	**7.0**	**6.8**
3%	9.4	8.4	8.1	8.9	7.1	6.9
5%	9.6	8.5	8.1	9.0	7.2	7.0
10%	9.9	8.8	8.3	9.4	7.4	7.1
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Real discount rate:	**9.2**	**8.2**	**8.0**	**8.7**	**7.0**	**6.8**
5%	8.8	8.0	7.4	8.2	6.8	6.2
10%	**9.2**	**8.2**	**8.0**	**8.7**	**7.0**	**6.8**
15%	9.7	8.4	8.6	9.2	7.1	7.5
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Electricity price:	**9.2**	**8.2**	**8.0**	**8.7**	**7.0**	**6.8**
0.225	8.0	8.0	7.7	7.5	7.0	6.6
0.275	**9.2**	**8.2**	**8.0**	**8.7**	**7.0**	**6.8**
0.335	10.7	8.4	8.3	10.2	7.0	7.0
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Lifetime of electrical element:	**9.2**	**8.2**	**8.0**	**8.7**	**7.0**	**6.8**
1	9.9	8.2	8.0	8.7	7.0	6.8
3	**9.2**	**8.2**	**8.0**	**8.7**	**7.0**	**6.8**
5	9.1	8.2	8.0	8.7	7.0	6.8

SENSITIVITY ANALYSIS FOR ECONOMIC COSTS

	BEFORE WATER SUPPLY PROJECT			AFTER WATER SUPPLY PROJECT		
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Changes in real prices of electricity and gas:	**9.2**	**7.8**	**7.6**	**8.7**	**6.7**	**6.6**
-10%	8.6	7.3	7.3	8.1	6.3	6.3
-5%	8.9	7.6	7.5	8.4	6.5	6.5
-3%	9.0	7.7	7.6	8.5	6.6	6.5
0%	**9.2**	**7.8**	**7.6**	**8.7**	**6.7**	**6.6**
3%	9.4	8.0	7.7	8.9	6.8	6.7
5%	9.5	8.1	7.8	9.0	6.9	6.7
10%	9.8	8.3	7.9	9.3	7.1	6.9
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Real discount rate:	**9.2**	**7.8**	**7.6**	**8.7**	**6.7**	**6.6**
5%	8.8	7.7	7.1	8.3	6.6	6.0
10%	**9.2**	**7.8**	**7.6**	**8.7**	**6.7**	**6.6**
15%	9.6	8.0	8.2	9.2	6.8	7.2
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Social cost of carbon:	**9.2**	**7.8**	**7.6**	**8.7**	**6.7**	**6.6**
12	8.7	7.6	7.4	8.2	6.5	6.4
39	**9.2**	**7.8**	**7.6**	**8.7**	**6.7**	**6.6**
61	9.7	8.0	7.8	9.2	6.9	6.8

Appendix I: Results from Cost-Effectiveness Analysis for Household Size of 4 with Hot Water Consumption of 160 liters/day

TABLE OF PARAMETERS

CAPITAL COSTS:

SWHSs:								***Gas heaters:***		
Price of solar panels:	455	US $						Price of gas heaters:	205	US $
Price of hot water tank:	318	US $						Set up price:	114	US $ // labor included
Set up price:	23	US $						Price of hydrophore:	68	US $ // labor included

MAINTENANCE COSTS:

					Daily working hr of pump:	0.75	hr
					1 horse power	0.746	kWh
Maintenance cost of gas heaters:	45	US $ // labor included					
Cost of electrical element:	45	US $ // labor included	Lifetime of element	3			

VARIABLE COSTS:

Electricity price:	0.275	US $/kWh	Heating value of LPG gas	46.15	MJ/kg	1 MJ	0.2777	kWh
LPG cylinder price:	19.5	US $/ 10 kg	Total heating value:	461.5	MJ	Total heating valu	128.2	kWh

ESTIMATIONS:

Daily hot water consumption:	160	liters			
Est. lifetime of panels:	10	years	Est. lifetime of gas heater:	7-10	years
Est. lifetime of hot water tank:	20	years	Est. lifetime of hydrophore:	5	years

			Proportion of heating load by season		Proportion of heating load by season by gas heater		
Est. annual heating load for storage tank models:	2439	kWh	Heating load during May-Sep	768	Heating load during Oct-Marc	906	kWh
Est. annual heating load for tankless models (gas heat.):	1453	kWh	Heating load April	221	Load supplied by solar:	169	kWh
Est. annual heating load supplied by solar energy:	1494	kWh	Heating load during Oct-March	1450			

Est. efficiency rate of electrical element:	85%
Est. efficiency rate of gas heater:	80%

Real discount rate:	10%
Change in average real prices:	0%

FINANCIAL COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	796	0	0	0	0	0	0	0	0	0	478	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439
Load supplied by solar panels per annum (kWh):	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494
Auxiliary electric energy (kWh) per annum @100% efficiency:	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945
Auxiliary electric energy (kWh) per annum @85% efficiency	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112
Cost of auxiliary energy:	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306
Cost of energy lost in pipes:	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Cost of elelctrical element:	0	0	0	45	0	0	45	0	0	45	0	0	45	0	0	45	0	0	45	0
Total Costs:	**1199**	**403**	**403**	**448**	**403**	**403**	**448**	**403**	**403**	**448**	**881**	**403**	**448**	**403**	**403**	**448**	**403**	**403**	**448**	**403**

NPV @10%: **4866**

FINANCIAL COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	796	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439
Load supplied by solar panels per annum (kWh):	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494
Auxiliary electric energy (kWh) per annum @100% efficiency:	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945
Auxiliary electric energy (kWh) per annum @85% efficiency	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112
Cost of auxiliary energy:	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306	306
Cost of energy lost in pipes:	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97	97
Cost of elelctrical element:	0	0	0	0	0	45	0	0	0	0	45	0	0	0	0	45	0	0	0	0
Total Costs:	1199	403	403	403	403	448	403	403	403	403	448	403	403	403	403	448	403	403	403	403

NPV @10%: **4626**

FINANCIAL COST ANALYSIS OF ELECTRICAL WATER HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20	PV of electricity usage	Levelized cost per tonne
Capital Costs:	341	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Variable Costs:																						
Estimated annual heating load (kWh):	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439		
Electric energy per annum @85% efficiency (kWh):	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869		
Cost of electricity:	789	789	789	789	789	789	789	789	789	789	789	789	789	789	789	789	789	789	789	789	7390	13.5
Cost of electrical element:	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45		
Total Costs:	**1175**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**	**834**		

NPV @10%: 8152

FINANCIAL COST ANALYSIS OF GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	319	0	0	0	0	0	319	0	0	0	0	0	0
Cost of hydrophore:	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453
Required annual heating load @80% efficiency (kWh):	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
Cost of LPG cylinder:	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276
Electricity cost of hydrophore:	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56	56
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	**720**	**378**	**378**	**378**	**378**	**446**	**378**	**652**	**378**	**378**	**446**	**378**	**378**	**652**	**378**	**446**	**378**	**378**	**378**	**378**

NPV @10%: 4182

FINANCIAL COST ANALYSIS OF GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	319	0	0	0	0	0	0	319	0	0	0	0	0	319	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453
Required annual heating load @80% efficiency (kWh):	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
Cost of LPG cylinder:	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276	276
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	595	321	321	321	321	321	321	595	321	321	321	321	321	595	321	321	321	321	321	321

NPV @10%: **3503**

FINANCIAL COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Cost of hydrophore:	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0
Cost of solar system:	796	0	0	0	0	0	0	0	0	0	478	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1183	0	0	0	0	68	0	0	0	0	865	0	0	0	0	68	0	0	0	0
Variable Costs:																				
During the October- March period:																				
Est. heating load that will be met by gas heater (kWh):	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906
Required annual heating load @80% efficiency (kWh):	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Cost of LPG cylinder:	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172
Electricity cost of hydrophore:	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
During April:																				
Est. heating load that will be met by electrical heater (kWh):	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
Auxiliary electricity energy @85% efficiency (kWh):	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
Cost of auxiliary electricity energy:	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Cost of electrical element:	0	0	0	0	0	45	0	0	0	0	45	0	0	0	0	45	0	0	0	0
Total Variable Costs:	208	208	208	208	208	253	208	208	208	208	253	208	208	208	208	253	208	208	208	208
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	1391	253	253	253	253	366	253	253	253	253	1118	253	253	253	253	366	253	253	253	253

NPV @10%: **3934**

FINANCIAL COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Cost of solar system:	796	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1115	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Variable Costs:																				
During the October- March period:																				
Est. heating load that will be met by gas heater (kWh):	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906
Required annual heating load @80% efficiency (kWh):	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Cost of LPG cylinder:	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172
During April:																				
Est. heating load that will be met by electrical heater (kWh):	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
Auxiliary electricity energy @85% efficiency (kWh):	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
Cost of auxiliary electricity energy:	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Cost of electrical element:	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0
Total Variable Costs:	189	189	189	189	189	189	189	189	189	189	234	189	189	189	189	189	189	189	189	189
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	**1304**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**553**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**

NPV @10%: 3386

PARAMETERS FOR ESTIMATION OF ECONOMIC PRICES

TAXES ON CAPITAL COSTS

	VAT rates	Stopaj tax rates	Customs duties		
Local solar panels:	10%	0%	0%	Econ price:	435
Imported solar panels:	16%	4%	0%		
Gas heaters:	16%	0%	2.7%		
Local hot water tank:	10%	0%	0%	Econ price:	289
Hydrophore:	16%	4%	0%		
Electrical Element:	16%	0%	0%		

	VAT rates	FIF rates	TGTF rates
LPG:	5%	18.92%	0.5%
Electricity:	10%	/ only VAT is levied on electricity.	
Econ price of elec	0.25	US $/kWh	

Mark up ratio: 40%

CIF price of gas heaters:	89	US $	CIF price of hydrophore:	29	US $	CIF price of electrical element:	20	US $	CIF price of LPG:	8.57	US $ per 10 kg
Paid stopaj taxes:	0	US $	Paid stopaj taxes:	1	US $	Paid stopaj taxes:	0	US $	Paid FIF	1.62	US $
Paid custom duties:	2	US $	Paid custom duties:	0	US $	Paid custom duties:	0	US $	Paid TGTF	0.05	US $
VAT credit:	15	US $	VAT credit:	5	US $	VAT credit:	3	US $	VAT credit:	0.51	US $
VAT paid on financial pri	28	US $	VAT paid on financial price:	9	US $	VAT paid on financial price:	6	US $	VAT paid on fin pr:	0.93	US $
Total tax payments:	16	US $	Total tax payments:	6	US $	Total tax payments:	3	US $	Total tax payments:	2.09	US $
Econ price of gas heaters:	189	US $	Econ price of hydrophore:	62	US $	Econ price of electrical element:	42	US $	Econ price of LPG:	17.41	US $
CONVERSION FACTORS:	0.922			0.914			0.933			0.89	

Social real discount rate: 10%

PARAMETERS FOR ESTIMATION OF SOCIAL COST OF CARBON

Stationary combustion emission factors:

	CO2 factor:		CO2 factor:	
LPG:	61.9638	kg CO2 per mmBTU	0.211	kg CO2 per kWH
HFO:	75.3538	kg CO2 per mmBTU	0.263	kg CO2 per kWH

		Electrical heater:	SWHS with electricity	SWHS with gas heater	Gas heater
Annual estimated heating load (kWh):					
Electricity:		2439	945	52	0
LPG:		0	0	906	1453
Adjusted factor for electricity:	3.96				
Adjusted factor for LPG:	1.25				
Annual CO2 emissions (kg):		2540	984	293	384
Annual CO2 emissions (ton):		2.540	0.984	0.293	0.384

			2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Annual average growth rate of SCC:			3.30%	3.30%	3.30%	3.30%	3.30%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	2.10%	1.90%	1.90%	1.90%	1.90%	1.90%
Est. SCC in 2015 per metric tonnes	39	US $ in 2011 Dol																				
	41.4	US $ in 2015 Dol	41.4	42.8	44.2	45.7	47.2	48.7	49.7	50.8	51.9	52.9	54.1	55.2	56.3	57.5	58.7	60.0	61.1	62.3	63.5	64.7

ECONOMIC COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	724	0	0	0	0	0	0	0	0	0	435	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439
Load supplied by solar panels per annum (kWh):	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494
Auxiliary electric energy per annum @100% efficiency (kWh):	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945
Auxiliary electric energy per annum @85% efficiency (kWh):	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112
Cost of auxiliary energy:	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278
Cost of energy lost in pipes:	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88
Cost of electrical element:	0	0	0	42	0	0	42	0	0	42	0	0	42	0	0	42	0	0	42	0
Social cost of carbon:	41	42	43	45	46	48	49	50	51	52	53	54	55	57	58	59	60	61	62	64
Total Costs:	1131	408	410	453	413	414	457	416	417	460	854	421	464	423	424	467	427	428	471	430

NPV @10%: **4886**

ECONOMIC COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	724	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439
Load supplied by solar panels per annum (kWh):	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494	1494
Auxiliary electric energy per annum @100% efficiency (kWh):	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945	945
Auxiliary electric energy per annum @85% efficiency (kWh):	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112
Cost of auxiliary energy:	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278	278
Cost of energy lost in pipes:	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88	88
Cost of electrical element:	0	0	0	0	0	42	0	0	0	0	42	0	0	0	0	42	0	0	0	0
Social cost of carbon:	41	42	43	45	46	48	49	50	51	52	53	54	55	57	58	59	60	61	62	64
Total Costs:	1131	408	410	411	413	456	415	416	417	418	462	421	422	423	424	467	427	428	429	430

NPV @10%: **4666**

ECONOMIC COST ANALYSIS OF ELECTRICAL WATER HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	310	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439	2439
Electric energy per annum @85% efficiency (kWh):	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869	2869
Cost of electricity:	717	717	717	717	717	717	717	717	717	717	717	717	717	717	717	717	717	717	717	717
Cost of electrical element:	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
Social cost of carbon:	105	109	112	116	120	124	126	129	132	134	137	140	143	146	149	152	155	158	161	164
Total Costs:	1175	868	872	875	879	883	886	888	891	894	897	900	902	905	909	912	915	918	921	924

PV of electricity usage	Levelized cost per tonne
6718	12.3

NPV @10%: 8607

ECONOMIC COST ANALYSIS OF GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	303	0	0	0	0	0	303	0	0	0	0	0	0
Cost of hydrophore:	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453
Required annual heating load @80% efficiency (kWh):	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
Cost of LPG cylinder:	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247
Electricity cost of hydrophore:	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51	51
Social cost of carbon:	16	16	17	18	18	19	19	19	20	20	21	21	22	22	23	23	23	24	24	25
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	679	359	360	360	361	424	362	620	363	363	426	364	364	623	365	428	366	367	367	368

NPV @10%: 3994

ECONOMIC COST ANALYSIS OF GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	303	0	0	0	0	0	0	303	0	0	0	0	0	303	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453	1453
Required annual heating load @80% efficiency (kWh):	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
Cost of LPG cylinder:	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247	247
Social cost of carbon:	16	16	17	18	18	19	19	19	20	20	21	21	22	22	23	23	23	24	24	25
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	566	308	309	309	310	310	311	569	312	312	313	313	313	572	314	315	315	316	316	317

NPV @10%: **3376**

ECONOMIC COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Cost of hydrophore:	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0
Cost of solar system:	724	0	0	0	0	0	0	0	0	0	435	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1089	0	0	0	0	62	0	0	0	0	800	0	0	0	0	62	0	0	0	0
Variable Costs:																				
During the October- March period:																				
Est. heating load that will be met by gas heater (kWh):	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906
Required annual heating load @80% efficiency (kWh):	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Cost of LPG cylinder:	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154
Electricity cost of hydrophore:	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
During April:																				
Est. heating load that will be met by electrical heater (kWh):	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
Auxiliary electricity energy @85% efficiency (kWh):	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
Cost of auxiliary electricity energy:	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Cost of electrical element:	0	0	0	0	0	42	0	0	0	0	42	0	0	0	0	42	0	0	0	0
Total Variable Costs:	186	186	186	186	186	228	186	186	186	186	228	186	186	186	186	228	186	186	186	186
Social cost of carbon:	12	13	13	13	14	14	15	15	15	16	16	16	17	17	17	18	18	18	19	19
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	1287	243	244	244	245	349	246	246	246	246	1043	247	247	248	248	353	249	249	250	250

NPV @10%: **3740**

ECONOMIC COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Cost of solar system:	724	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1027	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Variable Costs:																				
During the October- March period:																				
Est. heating load that will be met by gas heater (kWh):	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906	906
Required annual heating load @80% efficiency (kWh):	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133	1133
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Cost of LPG cylinder:	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154	154
During April:																				
Est. heating load that will be met by electrical heater (kWh):	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52	52
Auxiliary electricity energy @85% efficiency (kWh):	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
Cost of auxiliary electricity energy:	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Cost of electrical element:	0	0	0	0	0	0	0	0	0	0	42	0	0	0	0	0	0	0	0	0
Total Variable Costs:	169	169	169	169	169	169	169	169	169	169	211	169	169	169	169	169	169	169	169	169
Social cost of carbon:	12	13	13	13	14	14	15	15	15	16	16	16	17	17	17	18	18	18	19	19
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	**1208**	**227**	**227**	**228**	**228**	**228**	**229**	**229**	**229**	**230**	**530**	**230**	**231**	**231**	**231**	**232**	**232**	**232**	**233**	**233**

NPV @10%: **3240**

LEVELIZED COST OF HOT WATER CONSUMPTION PER CUBIC METER

Total daily hot water consumption:	160	liter
Annual hot water con. (liters):	58400	
Annual hot water con. (cubic meter)	58.4	

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Annual hot water consumption (cubic meter):	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4	58.4

PV of hot water consumption @10%: 547

Fin levelized cost of SWHS with elect back-up:	8.9	US $	**Econ levelized cost of SWHS with elect back-up:**	8.9	US $
Fin levelized cost of electrical heater:	14.9	US $	**Econ levelized cost of electrical heater:**	15.7	US $
Fin levelized cost of gas heater:	7.6	US $	**Econ levelized cost of gas heater:**	7.3	US $
Fin levelized cost of gas heater with project:	6.4	US $	**Econ levelized cost of gas heater with project:**	6.2	US $
Fin levelized cost of SWHS combined gas heater:	7.2	US $	**Econ levelized cost of SWHS combined gas heater:**	6.8	US $
Fin levelized cost of SWHS combined gas with projec	6.2	US $	**Econ levelized cost of SWHS combined gas with project:**	5.9	US $
Fin levelized cost of SWHS with elect with project:	8.5	US $	**Econ levelized cost of SWHS with elect with project:**	8.5	US $

SENSITIVITY ANALYSIS FOR FINANCIAL COSTS

	BEFORE WATER SUPPLY PROJECT			AFTER WATER SUPPLY PROJECT		
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Changes in real prices of electricity and gas:	**8.9**	**7.6**	**7.2**	**8.5**	**6.4**	**6.2**
-10%	8.2	7.1	6.8	7.8	5.9	5.9
-5%	8.6	7.4	7.0	8.1	6.2	6.0
-3%	8.7	7.5	7.1	8.3	6.3	6.1
0%	**8.9**	**7.6**	**7.2**	**8.5**	**6.4**	**6.2**
3%	9.1	7.8	7.3	8.7	6.5	6.3
5%	9.2	7.9	7.4	8.8	6.6	6.4
10%	9.6	8.2	7.5	9.1	6.9	6.5
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Real discount rate:	**8.9**	**7.6**	**7.2**	**8.5**	**6.4**	**6.2**
5%	8.5	7.5	6.7	8.1	6.3	5.7
10%	**8.9**	**7.6**	**7.2**	**8.5**	**6.4**	**6.2**
15%	9.3	7.8	7.7	8.9	6.5	6.7
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Electricity price:	**8.9**	**7.6**	**7.2**	**8.5**	**6.4**	**6.2**
0.225	7.6	7.5	7.1	7.2	6.4	6.1
0.275	**8.9**	**7.6**	**7.2**	**8.5**	**6.4**	**6.2**
0.335	10.4	7.9	7.3	10.0	6.4	6.3
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Lifetime of electrical element:	**8.9**	**7.6**	**7.2**	**8.5**	**6.4**	**6.2**
1	9.4	7.6	7.2	8.5	6.4	6.2
3	**8.9**	**7.6**	**7.2**	**8.5**	**6.4**	**6.2**
5	8.8	7.6	7.2	8.5	6.4	6.2

SENSITIVITY ANALYSIS FOR ECONOMIC COSTS

	BEFORE WATER SUPPLY PROJECT			AFTER WATER SUPPLY PROJECT		
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Changes in real prices of electricity and gas:	**8.9**	**7.3**	**6.8**	**8.5**	**6.2**	**5.9**
-10%	8.3	6.8	6.5	7.9	5.8	5.6
-5%	8.6	7.0	6.7	8.2	6.0	5.8
-3%	8.7	7.2	6.7	8.3	6.0	5.8
0%	**8.9**	**7.3**	**6.8**	**8.5**	**6.2**	**5.9**
3%	9.1	7.5	6.9	8.7	6.3	6.0
5%	9.2	7.6	7.0	8.8	6.4	6.1
10%	9.6	7.8	7.2	9.2	6.6	6.2
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Real discount rate:	**8.9**	**7.3**	**6.8**	**8.5**	**6.2**	**5.9**
5%	8.6	7.2	6.4	8.2	6.1	5.5
10%	**8.9**	**7.3**	**6.8**	**8.5**	**6.2**	**5.9**
15%	9.2	7.4	7.3	8.9	6.3	6.4
	SWHS with elect	**Gas**	**SWHS with gas**	**SWHS with elect**	**Gas**	**SWHS with gas**
Social cost of carbon:	**8.9**	**7.3**	**6.8**	**8.5**	**6.2**	**5.9**
12	8.4	7.1	6.7	8.0	5.9	5.8
39	**8.9**	**7.3**	**6.8**	**8.5**	**6.2**	**5.9**
61	9.4	7.5	7.0	9.0	6.4	6.1

Appendix J: Results from Cost-Effectiveness Analysis for Household Size of 5 with Hot Water Consumption of 200 liters/day

TABLE OF PARAMETERS

CAPITAL COSTS:

SWHSs:

Price of solar panels:	455	US $
Price of hot water tank:	318	US $
Set up price:	23	US $

Gas heaters:

Price of gas heaters:	205	US $
Set up price:	114	US $ // labor included
Price of hydrophore:	68	US $ // labor included
Daily working hr of pump	1	hr
1 horse power	0.746	kWh

MAINTENANCE COSTS:

Maintenance cost of gas heaters:	45	US $ // labor included		
Cost of electrical element:	45	US $ // labor include	Lifetime of element	3

VARIABLE COSTS:

Electricity price:	0.275	US $/kWh	Heating value of LPG	46.15	MJ/kg	1 MJ	0.2777	kWh
LPG cylinder price:	19.5	US $/ 10 kg	Total heating value:	461.5	MJ	Total heating va	128.2	kWh

ESTIMATIONS:

Daily hot water consumption:	200	liters
Est. lifetime of panels:	10	years
Est. lifetime of hot water tank:	20	years
Est. lifetime of gas heater	7-10	years
Est. lifetime of hydrophor	5	years

Est. annual heating load for storage tank models:	2887	kWh
Est. annual heating load for tankless models (gas heat.):	1816	kWh
Est. annual heating load supplied by solar energy:	1626	kWh

Proportion of heating load by season

Heating load during May-Sep	906
Heating load April	262
Heating load during Oct-March	1719

Proportion of heating load by season by gas heater

Heating load during Oct-M	1130	kWh
Load supplied by solar:	179	kWh

Est. efficiency rate of electrical element:	85%
Est. efficiency rate of gas heater:	80%

Real discount rate:	10%
Change in average real prices:	0%

FINANCIAL COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	796	0	0	0	0	0	0	0	0	0	478	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887
Load supplied by solar panels per annum (kWh):	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626
Auxiliary electric energy (kWh) per annum @100% efficiency:	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261
Auxiliary electric energy (kWh) per annum @85% efficiency	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484
Cost of auxiliary energy:	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408
Cost of energy lost in pipes:	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115
Cost of elelctrical element:	0	0	0	45	0	0	45	0	0	45	0	0	45	0	0	45	0	0	45	0
Total Costs:	**1319**	**523**	**523**	**568**	**523**	**523**	**568**	**523**	**523**	**568**	**1001**	**523**	**568**	**523**	**523**	**568**	**523**	**523**	**568**	**523**

NPV @10%: **5991**

FINANCIAL COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	796	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887
Load supplied by solar panels per annum (kWh):	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626
Auxiliary electric energy (kWh) per annum @100% efficiency:	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261
Auxiliary electric energy (kWh) per annum @85% efficiency	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484
Cost of auxiliary energy:	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408	408
Cost of energy lost in pipes:	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115	115
Cost of elelctrical element:	0	0	0	0	0	45	0	0	0	0	45	0	0	0	0	45	0	0	0	0
Total Costs:	1319	523	523	523	523	568	523	523	523	523	568	523	523	523	523	568	523	523	523	523

NPV @10%: **5751**

FINANCIAL COST ANALYSIS OF ELECTRICAL WATER HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20	PV of electricity usage	Levelized cost per tonne
Capital Costs:	341	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Variable Costs:																						
Estimated annual heating load (kWh):	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887		
Electric energy per annum @85% efficiency (kWh):	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396		
Cost of electricity:	934	934	934	934	934	934	934	934	934	934	934	934	934	934	934	934	934	934	934	934	8747	12.8
Cost of electrical element:	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45		
Total Costs:	**1320**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**	**979**		

NPV @10%: **9510**

FINANCIAL COST ANALYSIS OF GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	319	0	0	0	0	0	319	0	0	0	0	0	0
Cost of hydrophore:	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816
Required annual heating load @80% efficiency (kWh):	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
Cost of LPG cylinder:	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345
Electricity cost of hydrophore:	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	**807**	**465**	**465**	**465**	**465**	**533**	**465**	**739**	**465**	**465**	**533**	**465**	**465**	**739**	**465**	**533**	**465**	**465**	**465**	**465**

NPV @10%: **5004**

FINANCIAL COST ANALYSIS OF GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	319	0	0	0	0	0	0	319	0	0	0	0	0	319	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816
Required annual heating load @80% efficiency (kWh):	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
Cost of LPG cylinder:	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	664	390	390	390	390	390	390	664	390	390	390	390	390	664	390	390	390	390	390	390

NPV @10%: **4150**

FINANCIAL COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Cost of hydrophore:	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0	68	0	0	0	0
Cost of solar system:	796	0	0	0	0	0	0	0	0	0	478	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1183	0	0	0	0	68	0	0	0	0	865	0	0	0	0	68	0	0	0	0
Variable Costs:																				
During the October- March period:																				
Est. heating load that will be met by gas heater (kWh):	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130
Required annual heating load @80% efficiency (kWh):	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Cost of LPG cylinder:	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215
Electricity cost of hydrophore:	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
During April:																				
Est. heating load that will be met by electrical heater (kWh):	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
Auxiliary electricity energy @85% efficiency (kWh):	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98
Cost of auxiliary electricity energy:	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Cost of electrical element:	0	0	0	0	0	45	0	0	0	0	45	0	0	0	0	45	0	0	0	0
Total Variable Costs:	266	266	266	266	266	311	266	266	266	266	311	266	266	266	266	311	266	266	266	266
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	1449	311	311	311	311	424	311	311	311	311	1176	311	311	311	311	424	311	311	311	311

NPV @10%: **4485**

FINANCIAL COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	319	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Cost of solar system:	796	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1115	0	0	0	0	0	0	0	0	0	319	0	0	0	0	0	0	0	0	0
Variable Costs:																				
During the October- March period:																				
Est. heating load that will be met by gas heater (kWh):	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130
Required annual heating load @80% efficiency (kWh):	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Cost of LPG cylinder:	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215
During April:																				
Est. heating load that will be met by electrical heater (kWh):	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
Auxiliary electricity energy @85% efficiency (kWh):	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98
Cost of auxiliary electricity energy:	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Cost of electrical element:	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0	0
Total Variable Costs:	242	242	242	242	242	242	242	242	242	242	287	242	242	242	242	242	242	242	242	242
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	**1357**	**287**	**287**	**287**	**287**	**287**	**287**	**287**	**287**	**287**	**606**	**287**	**287**	**287**	**287**	**287**	**287**	**287**	**287**	**287**

NPV @10%: **3879**

PARAMETERS FOR ESTIMATION OF ECONOMIC PRICES

TAXES ON CAPITAL COSTS

	VAT rates	Stopaj tax rates	Customs duties		
Local solar panels:	10%	0%	0%	Econ price:	435
Imported solar panels:	16%	4%	0%		
Gas heaters:	16%	0%	2.7%		
Local hot water tank:	10%	0%	0%	Econ price:	289
Hydrophore:	16%	4%	0%		
Electrical Element:	16%	0%	0%		

	VAT rates	FIF rates	TGTF rates
LPG:	5%	18.92%	0.5%
Electricity:	10%	›nly VAT is levied on electricity.	
Econ price of el	0.25	US $/kWh	

Mark up ratio:	40%

CIF price of gas heaters	89	US $	CIF price of hydrophore:	29	US $	CIF price of electrical element:	20	US $	ĈIF price of LPG	8.57	ĴS $ per 10 kg
Paid stopaj taxes:	0	US $	Paid stopaj taxes:	1	US $	Paid stopaj taxes:	0	US $	Paid FIF	1.62	US $
Paid custom duties:	2	US $	Paid custom duties:	0	US $	Paid custom duties:	0	US $	Paid TGTF	0.05	US $
VAT credit:	15	US $	VAT credit:	5	US $	VAT credit:	3	US $	VAT credit:	0.51	US $
VAT paid on financia	28	US $	VAT paid on financial price:	9	US $	VAT paid on financial price:	6	US $	VAT paid on fin	0.93	US $
Total tax payments:	16	US $	Total tax payments:	6	US $	Total tax payments:	3	US $	Total tax paymer	2.09	US $
Econ price of gas heater	189	US $	Econ price of hydrophore:	62	US $	Econ price of electrical element	42	US $	Econ price of LP	17.41	US $
CONVERSION FACTORS:	0.922			0.914			0.933			0.89	

Social real discount rate:	10%

PARAMETERS FOR ESTIMATION OF SOCIAL COST OF CARBON

Stationary combustion emission factors:

	CO2 factor:		CO2 factor:	
LPG:	61.9638	kg CO2 per mmBTU	0.211	‹g CO2 per kWH
HFO:	75.3538	kg CO2 per mmBTU	0.263	‹g CO2 per kWH

	Electrical heate	SWHS with electricity	SWHS with gas heater	Gas heater
Annual estimated heating load (kWh):				
Electricity:	2887	1261	83	0
LPG:	0	0	1130	1816

Adjusted factor for electricity:	3.96
Adjusted factor for LPG:	1.25

Annual CO2 emissions (kg):	3007	1313	385	480
Annual CO2 emissions (ton):	3.007	1.313	0.385	0.480

			2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Annual average growth rate of SCC:			3.30%	3.30%	3.30%	3.30%	3.30%	2.10%	2.10%	2.10%	2.10%	2.10%
Est. SCC in 2015 per metric to	39	US $ in 2011 Dol										
	41.4	US $ in 2015 D	41.4	42.8	44.2	45.7	47.2	48.7	49.7	50.8	51.9	52.9

	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Annual average growth rate of SCC:	2.10%	2.10%	2.10%	2.10%	2.10%	1.90%	1.90%	1.90%	1.90%	1.90%
	54.1	55.2	56.3	57.5	58.7	60.0	61.1	62.3	63.5	64.7

ECONOMIC COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	724	0	0	0	0	0	0	0	0	0	435	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887
Load supplied by solar panels per annum (kWh):	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626
Auxiliary electric energy per annum @100% efficiency (kWh):	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261
Auxiliary electric energy per annum @85% efficiency (kWh):	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484
Cost of auxiliary energy:	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371
Cost of energy lost in pipes:	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105
Cost of electrical element:	0	0	0	42	0	0	42	0	0	42	0	0	42	0	0	42	0	0	42	0
Social cost of carbon:	54	56	58	60	62	64	65	67	68	70	71	72	74	76	77	79	80	82	83	85
Total Costs:	1254	532	534	578	538	540	583	542	544	587	981	548	592	551	553	596	556	557	601	560

NPV @10%: **6062**

ECONOMIC COST ANALYSIS OF SWHS WITH ELECTRICITY BACK UP WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	724	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887
Load supplied by solar panels per annum (kWh):	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626	1626
Auxiliary electric energy per annum @100% efficiency (kWh):	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261	1261
Auxiliary electric energy per annum @85% efficiency (kWh):	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484
Cost of auxiliary energy:	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371	371
Cost of energy lost in pipes:	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105	105
Cost of electrical element:	0	0	0	0	0	42	0	0	0	0	42	0	0	0	0	42	0	0	0	0
Social cost of carbon:	54	56	58	60	62	64	65	67	68	70	71	72	74	76	77	79	80	82	83	85
Total Costs:	1254	532	534	536	538	582	541	542	544	545	589	548	550	551	553	596	556	557	559	560

NPV @10%: **5842**

ECONOMIC COST ANALYSIS OF ELECTRICAL WATER HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	310	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887	2887
Electric energy per annum @85% efficiency (kWh):	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396	3396
Cost of electricity:	849	849	849	849	849	849	849	849	849	849	849	849	849	849	849	849	849	849	849	849
Cost of electrical element:	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
Social cost of carbon:	125	129	133	137	142	146	150	153	156	159	163	166	169	173	177	180	184	187	191	194
Total Costs:	1326	1020	1024	1028	1033	1038	1041	1044	1047	1050	1054	1057	1061	1064	1068	1071	1075	1078	1082	1086

PV of electricity usage	Levelized cost per tonne
7952	11.6

NPV @10%: **10058**

ECONOMIC COST ANALYSIS OF GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	303	0	0	0	0	0	303	0	0	0	0	0	0
Cost of hydrophore:	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816
Required annual heating load @80% efficiency (kWh):	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
Cost of LPG cylinder:	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308
Electricity cost of hydrophore:	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68	68
Social cost of carbon:	20	21	21	22	23	23	24	24	25	25	26	26	27	28	28	29	29	30	30	31
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	761	442	443	443	444	507	445	704	446	447	510	448	449	707	450	512	451	451	452	452

NPV @10%: **4776**

ECONOMIC COST ANALYSIS OF GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:	303	0	0	0	0	0	0	303	0	0	0	0	0	303	0	0	0	0	0	0
Variable Costs:																				
Estimated annual heating load (kWh):	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816	1816
Required annual heating load @80% efficiency (kWh):	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270	2270
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
Cost of LPG cylinder:	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308	308
Social cost of carbon:	20	21	21	22	23	23	24	24	25	25	26	26	27	28	28	29	29	30	30	31
Maintenance Costs:	0	45	45	45	45	45	45	0	45	45	45	45	45	0	45	45	45	45	45	45
Total Costs:	631	374	375	375	376	377	377	636	378	379	379	380	380	639	382	382	383	383	384	384

NPV @10%: **3998**

ECONOMIC COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Cost of hydrophore:	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0	62	0	0	0	0
Cost of solar system:	724	0	0	0	0	0	0	0	0	0	435	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1089	0	0	0	0	62	0	0	0	0	800	0	0	0	0	62	0	0	0	0
Variable Costs:																				
During the October- March period:																				
Est. heating load that will be met by gas heater (kWh):	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130
Required annual heating load @80% efficiency (kWh):	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Cost of LPG cylinder:	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192
Electricity cost of hydrophore:	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22
During April:																				
Est. heating load that will be met by electrical heater (kWh):	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
Auxiliary electricity energy @85% efficiency (kWh):	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98
Cost of auxiliary electricity energy:	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Cost of electrical element:	0	0	0	0	0	42	0	0	0	0	42	0	0	0	0	42	0	0	0	0
Total Variable Costs:	239	239	239	239	239	281	239	239	239	239	281	239	239	239	239	281	239	239	239	239
Social cost of carbon:	16	16	17	18	18	19	19	20	20	20	21	21	22	22	23	23	24	24	24	25
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	1343	300	301	301	302	407	303	303	304	304	1101	305	305	306	306	411	307	308	308	309

NPV @10%: **4277**

ECONOMIC COST ANALYSIS OF SWHS COMBINED WITH GAS HEATER WITH RELIABLE WATER SUPPLY

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Capital Costs:																				
Cost of gas heater:	303	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Cost of solar system:	724	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Capital Costs:	1027	0	0	0	0	0	0	0	0	0	303	0	0	0	0	0	0	0	0	0
Variable Costs:																				
During the October- March period:																				
Est. heating load that will be met by gas heater (kWh):	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130	1130
Required annual heating load @80% efficiency (kWh):	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413	1413
Heating value of one LPG cylinder (kWh):	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
Consumption of LPG cylinder per annum (unit):	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Cost of LPG cylinder:	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192
During April:																				
Est. heating load that will be met by electrical heater (kWh):	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83	83
Auxiliary electricity energy @85% efficiency (kWh):	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98
Cost of auxiliary electricity energy:	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Cost of electrical element:	0	0	0	0	0	0	0	0	0	0	42	0	0	0	0	0	0	0	0	0
Total Variable Costs:	216	216	216	216	216	216	216	216	216	216	258	216	216	216	216	216	216	216	216	216
Social cost of carbon:	16	16	17	18	18	19	19	20	20	20	21	21	22	22	23	23	24	24	24	25
Maintenance Costs:	0	45	45	45	45	45	45	45	45	45	0	45	45	45	45	45	45	45	45	45
Total Costs:	**1259**	**278**	**278**	**279**	**279**	**280**	**280**	**281**	**281**	**282**	**582**	**283**	**283**	**283**	**284**	**284**	**285**	**285**	**286**	**286**

NPV @10%: **3724**

LEVELIZED COST OF HOT WATER CONSUMPTION PER CUBIC METER

Total daily hot water consump	200	liter
Annual hot water con. (liters):	73000	
Annual hot water con. (cubic r	73	

	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	YR 9	YR 10	YR 11	YR 12	YR 13	YR 14	YR 15	YR 16	YR 17	YR 18	YR 19	YR 20
Annual hot water consumption (cubic meter):	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73

PV of hot water consumption @10%: 684

Fin levelized cost of SWHS with elect back-u	8.8	US $	**Econ levelized cost of SWHS with elect back-up:**	8.9	US $
Fin levelized cost of electrical heater:	13.9	US $	**Econ levelized cost of electrical heater:**	14.7	US $
Fin levelized cost of gas heater:	7.3	US $	**Econ levelized cost of gas heater:**	7.0	US $
Fin levelized cost of gas heater with project:	6.1	US $	**Econ levelized cost of gas heater with project:**	5.8	US $
Fin levelized cost of SWHS combined gas hea	6.6	US $	**Econ levelized cost of SWHS combined gas heater:**	6.3	US $
Fin levelized cost of SWHS combined gas wit	5.7	US $	**Econ levelized cost of SWHS combined gas with project:**	5.4	US $
Fin levelized cost of SWHS with elect with p	8.4	US $	**Econ levelized cost of SWHS with elect with project:**	8.5	US $

SENSITIVITY ANALYSIS FOR FINANCIAL COSTS

	BEFORE WATER SUPPLY PROJECT			AFTER WATER SUPPLY PROJECT		
	SWHS with elec	**Gas**	**SWHS with gas**	**SWHS with elec**	**Gas**	**SWHS with gas**
Changes in real prices of electricity and gas:	**8.8**	**7.3**	**6.6**	**8.4**	**6.1**	**5.7**
-10%	8.0	6.7	6.2	7.7	5.6	5.3
-5%	8.4	7.0	6.4	8.1	5.8	5.5
-3%	8.5	7.1	6.5	8.2	5.9	5.6
0%	**8.8**	**7.3**	**6.6**	**8.4**	**6.1**	**5.7**
3%	9.0	7.5	6.7	8.6	6.2	5.8
5%	9.1	7.6	6.7	8.8	6.3	5.8
10%	9.5	7.9	6.9	9.1	6.5	6.0
	SWHS with elec	**Gas**	**SWHS with gas**	**SWHS with elec**	**Gas**	**SWHS with gas**
Real discount rate:	**8.8**	**7.3**	**6.6**	**8.4**	**6.1**	**5.7**
5%	8.5	7.2	6.2	8.1	6.0	5.3
10%	**8.8**	**7.3**	**6.6**	**8.4**	**6.1**	**5.7**
15%	9.1	7.4	7.0	8.8	6.2	6.1
	SWHS with elec	**Gas**	**SWHS with gas**	**SWHS with elec**	**Gas**	**SWHS with gas**
Electricity price:	**8.8**	**7.3**	**6.6**	**8.4**	**6.1**	**5.7**
0.225	7.5	7.1	6.4	7.1	6.1	5.6
0.275	**8.8**	**7.3**	**6.6**	**8.4**	**6.1**	**5.7**
0.335	10.3	7.5	6.7	10.0	6.1	5.8
	SWHS with elec	**Gas**	**SWHS with gas**	**SWHS with elec**	**Gas**	**SWHS with gas**
Lifetime of electrical element:	**8.8**	**7.3**	**6.6**	**8.4**	**6.1**	**5.7**
1	9.2	7.3	6.6	8.4	6.1	5.7
3	**8.8**	**7.3**	**6.6**	**8.4**	**6.1**	**5.7**
5	8.7	7.3	6.6	8.4	6.1	5.7

SENSITIVITY ANALYSIS FOR ECONOMIC COSTS

	BEFORE WATER SUPPLY PROJECT			AFTER WATER SUPPLY PROJECT		
	SWHS with elec	**Gas**	**SWHS with gas**	**SWHS with elec**	**Gas**	**SWHS with gas**
Changes in real prices of electricity and gas:	**8.9**	**7.0**	**6.3**	**8.5**	**5.8**	**5.4**
-10%	8.2	6.5	5.9	7.9	5.4	5.2
-5%	8.5	6.7	6.1	8.2	5.6	5.3
-3%	8.7	6.8	6.2	8.4	5.7	5.4
0%	**8.9**	**7.0**	**6.3**	**8.5**	**5.8**	**5.4**
3%	9.1	7.1	6.4	8.7	6.0	5.5
5%	9.2	7.2	6.4	8.9	6.1	5.6
10%	9.5	7.5	6.6	9.2	6.3	5.7
	SWHS with elec	**Gas**	**SWHS with gas**	**SWHS with elec**	**Gas**	**SWHS with gas**
Real discount rate:	**8.9**	**7.0**	**6.3**	**8.5**	**5.8**	**5.4**
5%	8.6	6.9	5.9	8.3	5.8	5.1
10%	**8.9**	**7.0**	**6.3**	**8.5**	**5.8**	**5.4**
15%	9.1	7.1	6.6	8.8	5.9	5.8
	SWHS with elec	**Gas**	**SWHS with gas**	**SWHS with elec**	**Gas**	**SWHS with gas**
Social cost of carbon:	**8.9**	**7.0**	**6.3**	**8.5**	**5.8**	**5.4**
12	8.2	6.8	6.1	7.9	5.6	5.3
39	**8.9**	**7.0**	**6.3**	**8.5**	**5.8**	**5.4**
61	9.4	7.2	6.4	9.1	6.0	5.6