

# Investigating the financial implications of alternative water heating systems

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## **ENGLISH ABSTRACT**

**Keywords:** Alternative water heating systems, conventional geyser, electricity cost increase, investment appraisal methods

**Background:** Electricity tariffs charged by Eskom have sharply increased over the past three years, with a 25% annual increase approved by Nersa until April 2012. There is no indication on what to expect in the future with regard to electricity tariffs. Many South Africans are searching for ways to save on their monthly electricity bills by seeking out alternative water heating systems. Solar geysers became a popular investment option, but this might not be the best options available on the market.

**Purpose:** The purpose of this study is to determine the most financially viable investment option in order to reduce electricity cost when it comes to water heating systems for use in households. This is done by comparing the capital expenditure and operational cost needed with the financial benefits generated by the investment, taking into consideration the size of the household.

**Design and method:** A literature study was done on the different alternative water heating systems in order to obtain a better understanding of how these systems operate and what savings they can generate. Different investment appraisals were identified and a literature review was performed in order to identify the most appropriate investment appraisals for the purpose of this study. It was found that the net present value, equivalent annual annuity, internal rate of return, modified internal rate of return, accounting rate of return, discounted payback period and the economic value added were the best investment appraisal methods to use for the purpose of this study.

**Findings and conclusion:** It was found that the five investment options identified in the literature review would all, to some extent, be financially viable to implement within households with high as well as low volume hot water consumption. All the investment appraisals gave positive outcomes. The conclusion was made that a saving will be generated on the monthly electricity bill no matter what alternative water heating system were to be installed in the place of a conventional geyser.

**Recommendations:** It is recommended that a household with low volume hot water consumption should install a time switch as this investment option renders the highest IRR, MIRR, ARR and discounted payback period. The second best investment option for a household with low volume hot water consumption is a heat pump and the third best option is a gas geyser. For a household with high volume hot water consumption, the best investment options is again a time switch, as this renders the best IRR, MIRR, ARR and

discounted payback period. The second best investment option is a heat pump, with a gas geyser as the third best investment option.

**Value of the research:** This study focuses on five alternative water heating systems for a household within South Africa in times where electricity charges sharply increase. The financial viability of each of the alternatives is determined through various investment appraisals and the best option can be identified by comparing the outcomes of the alternatives. Furthermore, each individual is able to determine the viability of the alternatives by using the Excel model attached to this study and by inputting his/her own variables, where applicable.

**Research limitation:** Limited literature was available on the different alternative water heating systems. No indication could be found of the maintenance cost of the different water heating systems. Assumptions had to be made with regard to households, although no two households are the same.

**Areas for further research:** The same study could be performed, but with the focus on small businesses and large organisations. Furthermore, a study could be performed to determine the appropriate discount rate for individuals as well as the maintenance cost for water heating systems.

## **AFRIKAANSE OPSOMMING**

**Sleutelwoorde:** Alternatiewe waterverhittingstoestelle, beleggingswaardasie-metodes, gewone geiser, toename in elektrisiteitstariewe

**Agtergrond:** Elektrisiteitstariewe gehef deur Eskom het oor die afgelope drie jaar drasties toegeneem met 'n 25% jaarlikse tariefverhoging tot en met April 2012. Hierdie verhoging is goedgekeur deur Nersa. Daar is op hierdie stadium geen aanduiding oor wat in die toekoms verwag kan word ten opsigte van tariefverhogings nie. Heelwat van die huiseienaars in Suid-Afrika kyk tans na maniere om hul maandelikse elektrisiteitsverbruik te verminder, met die fokus op veral alternatiewe water verhittingstoestelle. Son-geisers is veral populêr, maar dit mag dalk nie die beste opsie beskikbaar op die mark wees nie.

**Doel van die studie:** Die doel van hierdie studie is om te bepaal watter alternatiewe water verhittingstoestel vir huishoudings finansieel die beste sal wees om te installeer om sodoende kostes te bespaar. Hierdie word bepaal deur die kapitale uitleg en die operasionele kostes wat benodig word te vergelyk met die besparings wat gegenereer word deur die belegging, met inagneming van die grootte van die huishouding.

**Ontwerp en metode:** 'n Literatuurstudie is gedoen oor die alternatiewe waterverhittingstoestelle om te verstaan hoe elk van hulle werk, asook watter besparing gegenereer kan word deur elk van die alternatiewe. Verskeie kapitaalinvesteringsmetodes wat relevant sal wees vir die doel van hierdie studie is deur 'n literatuurstudie geïdentifiseer. Daar is gevind dat die netto huidige waarde, ekwivalente jaarlikse annuïteit, interne opbrengskoers, aangepaste interne opbrengskoers, rekeningkundige opbrengskoers, verdiskonteerde-terugbetalingstydperk en die ekonomiese waarde toegevoeg die beste tegnieke sal wees om te gebruik vir die doel van hierdie studie.

**Gevolgtrekking en bevindings:** Daar is gevind dat al vyf alternatiewe waterverhittingstoestelle tot 'n seker mate finansieel lewensvatbaar sal wees binne 'n huishouding met hoë sowel as lae volume warmwaterverbruik. Hierdie gevolgtrekking is gegrond op die feit dat al die beleggingswaardasie-metodes 'n positiewe uitkoms gelewer het. Die gevolgtrekking kan dus gemaak word dat ongeag watter alternatiewe waterverhittingstoestel geïnstalleer word om 'n gewone geiser te vervang binne 'n huishouding, 'n besparing gegenereer sal word.

**Aanbevelings:** Daar word aanbeveel dat 'n huishouding met lae volume warmwaterverbruik 'n tydsakelaar installeer, aangesien hierdie beleggingsopsie die hoogste interne opbrengskoers, veranderde opbrengskoers, rekeningkundige opbrengskoers en verdiskonteerde terugbetalingstydperk verskaf. Die tweede beste beleggingsopsie vir 'n

huishouding met lae volume warmwaterverbruik is 'n hittepomp en die derde beste beleggingsopsie is 'n gas-geiser. Vir 'n huishouding met hoë volume warmwaterverbruik is die beste beleggingsopsie weereens 'n tyd skakelaar, aangesien hierdie opsie die hoogste interne opbrengskoers, aangepaste opbrengskoers, rekeningkundige opbrengskoers en verdiskonteerde-terugbetalingstydperk het. Die tweede beste beleggingsopsie is 'n hittepomp en 'n gas-geiser is die derde beste beleggingsopsie.

**Waarde van hierdie studie:** Hierdie studie fokus op vyf alternatiewe waterverhittingstoestelle vir 'n huishouding in Suid-Afrika in tye waar elektrisiteitstaries skerp toeneem. Die finansiële lewensvatbaarheid van al vyf alternatiewe word bepaal deur verskeie kapitaalinvesteringsmetodes en die beste beleggingsopsies tussen die alternatiewe word geïdentifiseer deur die uitkoms van die verskillende beleggingsopsies te vergelyk. Verder sal elke individu die lewensvatbaarheid van die alternatiewe kan bereken deur sy/haar eie inligting (waar van toepassing) in 'n Excel-model, wat aangeheg is by hierdie studie, in te voer.

**Navorsingsbeperkings:** Beperkte literatuur was beskikbaar oor die verskillende alternatiewe waterverhittingstoestelle. Geen aanduiding kon gevind word oor die onderhoudskoste van waterverhittingstoestelle nie. Verder moes aannames gemaak word oor huishoudings, maar geen huishoudings is dieselfde nie.

**Areas vir verdere studie:** Dieselfde studie kan uitgevoer word met die fokus op klein ondernemings sowel as groot organisasies. Daar kan ook verdere studies uitgevoer word oor die verdiskonteringskoers vir individue, sowel as 'n studie oor die onderhoudskoste van waterverhittingstoestelle.

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## LIST OF ABBREVIATIONS USED

ARR	Accounting rate of return
CAPM	Capital asset pricing model
CBA	Cost benefit analysis
CD	Compact disc
<i>CE</i>	<i>Capital employed</i>
EVA	Economic value added
FV	Future value
GWh	Giga Watt hour
<i>i</i>	Discount rate
i.e.	That is (in other words) ( <i>id est</i> )
$I_0$	Internal rate of return
IRR	Internal rate of return
<i>K</i>	Discount rate
$K_d$	Cost of debt
$K_e$	Cost of equity
$K_g$	Kilogram
kWh	Kilo Watt hour
MIRR	Modified internal rate of return
Mr.	Mister
<i>n</i>	Number of years
NERSA	National energy regulator of South Africa

NOPAT	Net operating profit after tax
NPV	Net present value
NPV*	Equivalent annual annuity
par	Paragraph
PI	Profitability index
R	Rand
RH	Rural areas with high population
RL	Rural areas with low population
TW	Terra Watt
UH	Urban areas with high population
UL	Urban areas with low population
VAT	Value added tax
WACC	Weighted average cost of capital
WWF	Worldwide fund of nature
#	Number
%	Percentage
°C	Degrees Celsius
&	And

# 1. CHAPTER ONE: INTRODUCTION

## 1.1 BACKGROUND

Environmental concerns are becoming a worldwide focus, with global warming part of our daily vocabulary. Carbon dioxide is one of several “greenhouse gases” that naturally helps with global climate control by capturing heat in the earth’s atmosphere. However, due to human activities such as the burning of natural gas, coal and oil, deforestation and population growth, the emission of greenhouse gases accelerated unnaturally, leading to global warming (West, 2011). There seems to be some debate around the true impact of high levels of elevated greenhouse gases on the world and its inhabitants. According to Robinson, Robinson and Soon (2007:12), the increase in carbon dioxide is anything but harmful to the environment. They stated that the increase of carbon dioxide will better the health, longevity, prosperity and productivity of humans, accelerate the growth rate of plants, especially in drier areas, and this will lead to a flourish of animal life. However, Zurich (2009) believes that the emission of carbon dioxides must be limited to 1 000 billion tonnes in the 50 years from 2000-2050 to ensure that global warming increases by less than 2°C. According to him, 234 billion tons of emissions have already been released into the atmosphere between 2000 and 2006, meaning that the target will already be reached in 2030. Therefore, the annual emissions of carbon dioxide will need to be halved, to ensure that global warming does not become a more serious problem.

The Union of Concerned Scientists (UCSUSA) (2010) stated that in 2008 the Energy Information Agency (Department of Energy), who estimates carbon dioxide emissions from all sources of fossil fuel burning and consumption, ranked South Africa as the country with the thirteenth highest carbon dioxide emissions in the world, with total emissions of 451 million metric tons per year, i.e. 9.25 ton/capita. This is clear when considering that ten out of the eleven base-load power stations within South Africa are coal-fired stations, with another one being built, which will increase the emission of carbon dioxide (Eskom, 2008).

The necessity for sustainable and renewable energy resources that reduce the impact of fossil fuel depletion and carbon dioxide emissions on the environment has become evident (Fthenakis, Mason & Zweibel, 2009:387). The demand for energy resources increases daily because the world’s population is growing and more and more people move into the middle-class category, with only 3 billion of the world’s 7 billion population living in energy poverty, in other words they do not have access to sustainable and affordable modern energy (Kullman, 2010). South Africa faces a similar challenge as the rest of the world as a result of the increasing energy demands of its growing economy.

In support of its “Go Green” initiative, Eskom provides a rebate to households when installing a solar geyser. This rebate consists of a percentage of the total cost of the heating system (investment cost plus installation cost). The percentage is calculated on the performance and reliability of the individual system. The more reliable and energy efficient the system, the better the rebate one could claim, with the maximum rebate from 29 April 2011 being the current average rebate on the programme (Eskom, 2011b). This approach is also followed in countries like Australia to motivate citizens in the form of a subsidy to install a solar geyser (Hessami, 2006:118).

## **1.2 WATER HEATING SYSTEM ALTERNATIVES**

Water heating costs within households are the second largest energy cost on the electricity bill, with space heating taking up the biggest part (Hackett & Gray, 2009:36). With constant annual rate increases imposed on South African citizens by the South African electricity supplier (Eskom), households are being forced to search for alternatives that can reduce the cost of their monthly electricity bill.

With this said, house owners are searching for alternative ways to cut on operational costs by using natural or renewable energy resources, such as solar geysers, natural gas, or different technologies, such as time switches, heat pumps or instant heaters. These are just a few alternative water heating systems identified through internet research and conversations with several individuals. However, solar geysers may often require a large capital investment, of which the payback period (the period for the annual net cashflows to equal the initial investment cost) is extremely slow (Zaki, 2008:51).

### **1.2.1 Solar energy alternatives**

Solar electric generators are a good example of a sustainable and clean renewable energy resource that reduces and in some cases even eliminates the emission of carbon dioxide into the environment (Dayal, s.a.). Therefore, it has become important to investigate this type of energy resource. Solar power results from the conversion of solar energy in the form of light into useable energy such as electricity or heat. When sunlight hits certain materials, like silicon, the energy will turn into an electrical current, which can be utilised as electric power (Locke, 2008). The lifetime of solar cells is short, making the use of solar power expensive (Grätzel, 2007:994).

According to Barber (2007:1008), the sun provides an annual average rate of 100 000 Terawatts (TW) of solar energy to the earth, exceeding the approximately 14 TW of demand a year by approximately 7 000 times. This makes solar energy a sustainable energy resource, especially in areas with high solar potential (Kaldellis, Zafirakis & Kondili, 2010:1454).

Fluri (2009:5079) did a study on the potential for implementation of solar energy plants in South Africa and found that four out of the nine provinces (Northern Cape, Free State, Western Cape and a small part of the Eastern Cape) will be suitable for solar energy plants; the only significant constraint is the availability of water supplies, which is important for the operation of such a plant, especially within the Northern Cape area. Therefore, we can say that South Africa is suitable for the use of solar geysers.

### **1.2.2 Time switch on a conventional geyser**

The basic principal of a time switch is not only to manage the total power consumption, but also to manage the consumption during various times of the day (Otto, 2011). The motivation to manage this is because Eskom charges different rates during different times of the day. In peak periods, rates are higher than the rates charged during off-peak periods (Eskom, 2011b:34).

The typical time switch uses a static configuration with regard to time management; however, more intelligent systems combine the use of a time switch and alternative energy sources based on a monitoring algorithm. An example would be the management system of a solar geyser that uses an electric heating element on cloudy or rainy days (Otto, 2011).

### **1.2.3 Heat pumps**

A heat pump works on the same principle as an air conditioning unit, but instead of using it as an air cooling system, with heat as a by product, the focus is on utilising the heat to generate hot water (Van Eldik, 2008). According to M-Tech Industrial (Pty) Ltd. (2002), a heat pump's performance depends on the outside air temperature. The higher the air temperature, the more efficient the heat pump will work.

The energy saving is due to the fact that the heat pump not only uses a heating element, but also uses the outdoor air temperature to produce hot water, therefore less electricity is needed to bring the water to the preferred temperature (M-Tech Industrial (Pty) Ltd., 2002).

The energy efficiency of a heat pump therefore directly correlates with climate conditions (Lienau, Boyd & Rogers, 1995:8).

#### **1.2.4 Gas geysers**

A gas geyser is similar to a conventional geyser; the only difference is that the water is not heated by an electric element, but through a gas burner at the bottom of the tank, eliminating the use of electricity (Formisano, 2006?).

According to the American Council for an Energy-Efficient Economy (ACEEE) (2007), the gas burner turns on when the water temperature drops below a certain point, and automatically switches off once the water reaches the high temperature limit.

#### **1.2.5 Instant heaters**

Instant heaters, otherwise known as tankless water heaters, heat water as you need it, without storing hot water supply and constantly heating and re-heating water to keep it at a preferred temperature (Lingro Gas Appliances, s.a.). The instant heater eliminates the conventional geyser and replaces it with a full-flow bypass valve (Cable, 2005:71).

Tank type water heaters constantly need to switch on to maintain the required water temperature, even if no hot water is used, increasing the unnecessary use of electricity or gas, where an instant heater only supplies the hot water demand without storing any hot water (Orloff, s.a.).

### **1.3 PROBLEM STATEMENT**

Eskom recently increased its rates for electricity usage in 2011 by 25% for local entities, 14.3% for residential usage and 25.78% for rural areas (Eskom, 2011a). This made it necessary for the public to take action and save on electricity usage. As a result, this increase in tariffs could make alternative sources of electricity, such as solar power, more economically viable. Many South Africans started implementing alternative heating systems within their households with the aim of reducing the electricity usage of their geysers, thereby reducing their total electricity bill.

Considering all the above, the question can be raised which of the mentioned alternatives in water heating systems makes most economic sense. The research question of this study can therefore be formulated as follows: What are the household economic implications of key alternative water heating systems within the South African context?

## **1.4 RESEARCH OBJECTIVES**

This section constitutes the discussion on general and specific objectives as defined in this study.

### **1.4.1 General objective**

The general objective of this research is to determine what the most financially viable investment will be to reduce electricity cost when it comes to water heating systems for use in households. This is done by comparing the capital expenditure and operational cost needed with the financial benefits generated by the investment, taking into consideration the size of the household.

### **1.4.2 Specific objectives**

The specific objectives of this study are the following:

- To conceptualise from the literature the financial impact of the conventional geyser with regard to the average electricity bill, as well as the different options as alternatives to reduce the electricity usage in order to generate hot water.
- To conceptualise from the literature the relevance of different investment appraisal techniques in deciding on the most financially viable option as alternative to the conventional geyser to reduce electricity usage in order to generate hot water.
- To consider, within the context of both high and low volume consumption households, the investment cost, net present value, internal rate of return, modified internal rate of return, accounting rate of return, payback period and economic value added for: a solar water heating system, a time switch on a conventional geyser, a heat pump, a gas geyser and an instant heater.
- To provide recommendations regarding the most financially viable water heating system for a household, depending on the volume of hot water consumption.

## **1.5 RESEARCH METHOD**

This research consisted of two phases, namely a literature review and an empirical study.

### **1.5.1 Phase 1: Literature review**

The literature review incorporates the relevant and available literature. This includes a study on the relevance of solar energy as well as a study on the concept of a solar water heating system, a time switch on a conventional geyser, a heat pump, a gas geyser and an instant heater.

Different management accounting methods are investigated, such as:

- A cost-benefit analysis, which consists of three basic steps, namely the identification of all the factors; valuations of the cost and benefits; and the decision of which project to implement (Brzozowska, 2007:79).
- Discounting the net cashflows to determine the net present value (NPV). The net cashflows are a result of subtracting the costs from revenue/cost avoidance (Meek, Whittier & Dalsted, 49).
- Weighted average cost of capital: Miller and Bradford (2001:230) state that the cost of capital is a combination between debt and equity that will be used in the long term for several investments, and not the combination of debt and equity used for the specific investment analysed.
- Payback period of an investment: This determines how long it will take before the initial investment is paid back out of future cashflows (Ogilvie, 2009:304).

These accounting methods are applied in order to determine which investment is more economically viable.

### **1.5.2 Phase 2: Empirical study**

The empirical study focuses on project appraisals of the five investment options identified:

- i) A solar water heating system
- ii) A time switch on a conventional geyser
- iii) A heat pump
- iv) A gas geyser
- v) An instant heater

This includes an investment appraisal for a household with low volume hot water consumption, and a household with high volume hot water consumption within an urban environment. Other possible methods of saving electricity with respect to water heating are only covered as part of the literature study.

In performing these investment appraisals, the net present value, equivalent annual annuity, internal rate of return, modified internal rate of return, accounting rate of return, discounted payback period and economic value added of the investment are determined.

An important part of the analysis is to calculate the cost per kWh of energy saved by implementing the five different investment options, as this forms an integral part of the cost benefit analysis (Olivier, Harms & Esterhuysen, 2008:1079).

The cost saving calculation was performed making use of a heat switching module created by an engineer at Eskom, Mr J. Dreyer, whereby the per capita usage of a household was determined. From there, the energy saving per scenario was calculated and the correct rand value per kWh used to determine accurate benefit estimations.

The average cost per investment, installation cost and rebate were determined by the average value of three different quotations. The repo rate represented the WACC.

## **1.6 OVERVIEW**

The study is divided into six chapters:

### *Chapter 1: Background*

This chapter provides the background on the relevance of sustainable energy resources and how a household can utilise such resources. This is followed by a problem statement and objectives of this study.

### *Chapter 2: Water heating in a South Africa household*

This chapter focuses on the financial impact of water heating with regard to the average electricity bill in households. The concept of the different investment options to reduce electricity usage with regard to water heating is also covered in this chapter.

### *Chapter 3: Investment appraisal methods*

This chapter focuses on the different methods that are used to perform an investment appraisal, and which method is relevant for this study.

### *Chapter 4: Research methodology*

This chapter focuses on the research method that is followed in this study. The determination of the different inputs to the investment appraisal is addressed and the method of calculating the energy saving per scenario is discussed.

### *Chapter 5: Results*

This chapter consists of the project appraisal calculation for each of the five options. There are ten investment appraisal calculations that will be performed, namely two investment appraisals for the solar water heating system; two for the time switch; two for the heat pump; two for the gas geyser; and two for the instant heater. Investment appraisals are performed for a household with low volume hot water consumption and for a household with high volume hot water consumption in an urban environment.

### *Chapter 6: Conclusions and recommendations*

This chapter provides a summary of the study and consists of a conclusion, recommendations and areas that can possibly be studied further.

## **2. CHAPTER 2: WATER HEATING IN A SOUTH AFRICAN HOUSEHOLD**

### **2.1 INTRODUCTION**

The Energy Information Agency (Department of Energy) ranked South Africa as the country with the thirteenth highest carbon dioxide emissions in the world (UCSUSA, 2010). According to Peet Du Plooy, a trade and investment advisor for Worldwide Fund for Nature (WWF), South Africa emits more carbon dioxide than the rest of Africa combined, mostly due to high energy demands (Copans, 2008).

This is evident from *Figure 2.1*, showing the spread of all the Eskom power stations across South Africa, where ten out of the eleven base-load power stations are coal fired, with another one being built (Eskom, 2008).

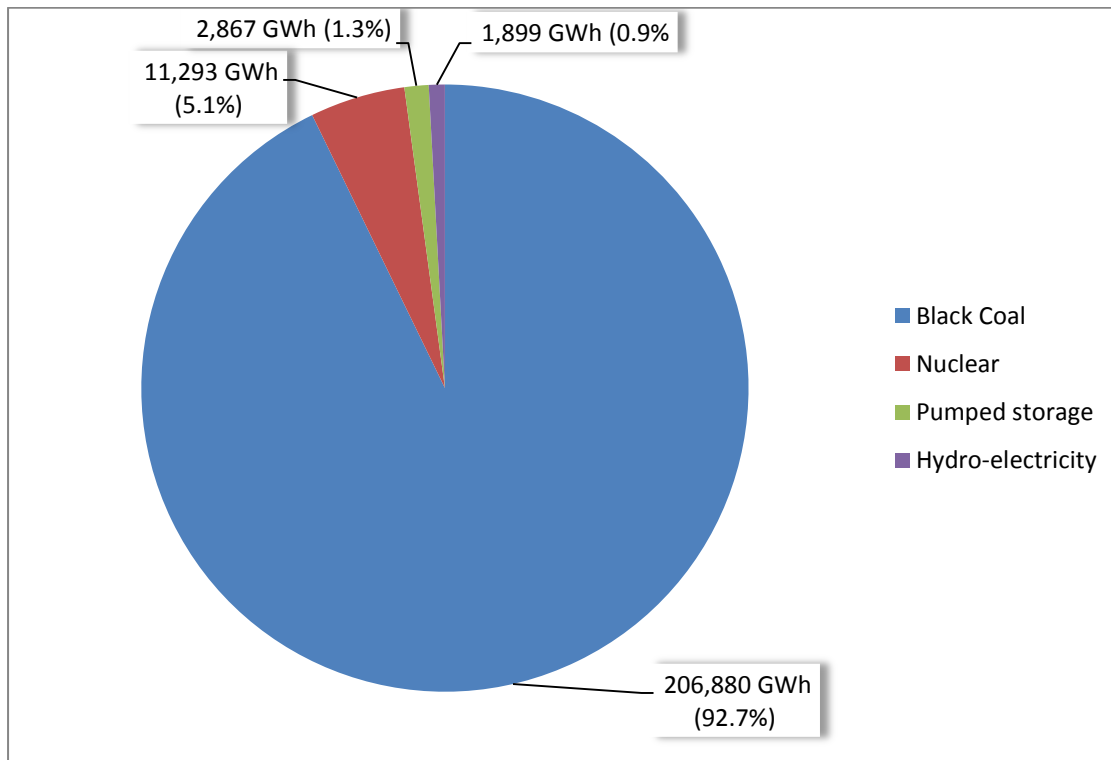
Figure 2.1: Eskom power stations



Source: Eskom, 2008

In 2006, 92.8% of South Africa's energy was generated by the use of black coal (*Figure 2.2*) (Statistics South Africa, 2006:10), generating 206 880 Gigawatt hours (GWh) of the total 222 939 GWh generated within South Africa. The remainder of the energy is generated as follows: 11 293 GWh generated through nuclear power, 2 867 GWh through pumped storage and 1 899 GWh through hydro-electricity, fuel oil and natural gas. 10 310 GWh were purchased from neighbouring countries.

**Figure 2.2: Fuel and other energy sources used in the generation of electricity, 2006**



Source: Statistics South Africa, 2006:10

Kirkland and Hunter (2006:348) recommend that government must foster economic opportunities within rural areas by moving factories to these areas, in order to reduce economic inequality. According to them, this will generate income within the households in these rural areas, making electricity affordable for those currently without modern energy resources. However, this will increase electricity demand, forcing Eskom to provide more electricity, increasing the already high stress on the environment.

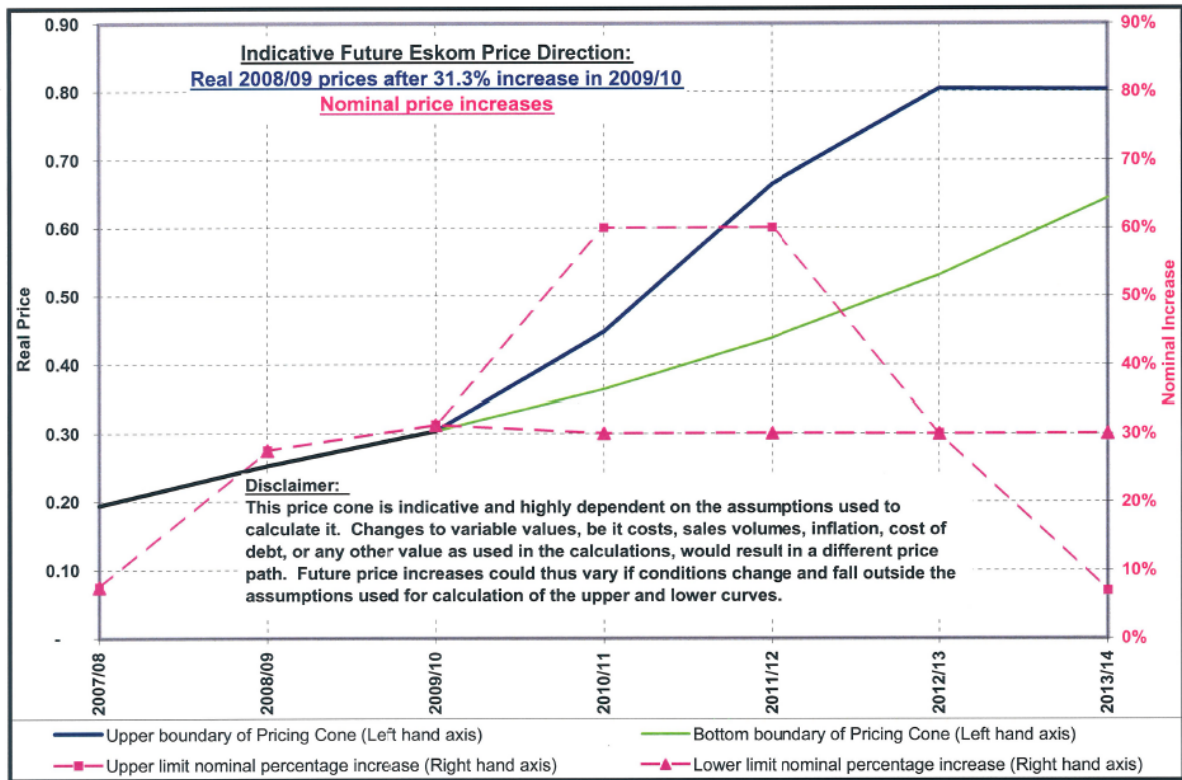
The question could be asked why Eskom does not concentrate on using renewable energy resources to meet the energy demand within South Africa. The main reason is that renewable energy resources, such as solar energy, are extremely costly sources of energy. Expensive solar energy storage systems are needed to ensure a constant energy supply in all kinds of weather conditions. Minea (2010:77) states that solar power must concentrate

energy on a substantially large area to generate enough capacity. Therefore, the production cost of solar energy is too high to make it competitive with nuclear or fossil energy (Grätzel, 2007:993). Furthermore, renewable energy resources, such as micro-hydropower, biomass, biogas, wind and solar are not able to meet energy demands for long periods of time due to the high cost of systems and storage sub-systems, and can therefore only be used in combination with conventional energy resources (Kanase-Patil, Saini & Sharma, 2011:2809). Therefore, the assumption could be made that it might not be economically viable for Eskom to consider renewable energy resources, as this may increase the already high electricity cost even more.

According to Wallenborn, Orsini and Vanhaverbeke (2011:147), studies showed that people make choices set within certain criteria and constraints, of which energy saving is not necessarily high on the priority list. Aitken (2007:26) states that a household's income will dictate their energy consumption, as well as the type of energy used within a household. However, income is not the only factor that dictates household energy consumption. Miah, Foyisal, Koike and Kobayashi (2011:3757) state that households have a significant impact on the total energy consumption of a country, with factors such as socio-economic, demographic, geographic and dwelling characteristics determining the energy need of a household.

South Africans faced a substantial increase in electricity cost due to Eskom raising tariffs with 25% for local entities, 14.3% for residential usage and 25.78% for rural areas in 2010 (Eskom, 2011a). According to a media statement released by NERSA on 24 February 2010 (Nersa, 2010), they approved an average price increase of 24.8% on 1 April 2010, another average price increase of 25.8% on 1 April 2011, followed by an average price increase on tariffs of 25.8% applicable from 1 April 2012. According to a graph (Figure 2.3) created by Nersa (2009) showing the expected direction of prices charged by Eskom, there will be a sharp increase in prices annually, with the last increase on 1 April 2012, where after prices will stabilise (see Figure 2.3). To be realistic, it may be accurate to assume that electricity prices will increase with the inflation rate thereafter as there is no information available on what to expect after 2012. However, a report created by Solidarity Research Institute economist, Mike Schussler (2008:20), indicates that South African households faced an average annual price increase of 7.2% between 1996 and 2007, which is more than the average annual inflation rate of 5.7% for the same period. Schussler (2008:20) states that households were the only category of Eskom customers that faced an increase above the inflation rate; all other categories faced price increases below the inflation rate.

**Figure 2.3: Indicative future Eskom price direction**



Source: Nersa, 2009

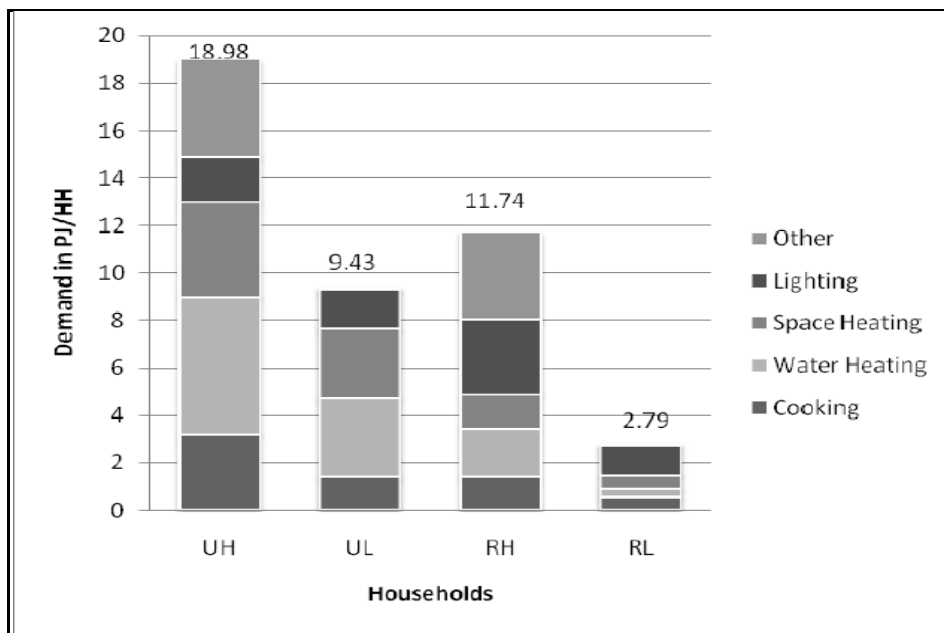
Therefore, households are seeking alternative energy resources to cut on their monthly electricity bill, with the latest trend in South Africa being the implementation of solar geysers as cost reduction method (Gosling, 2010). This is evident when considering that an average of 762 Eskom subsidy applications has been submitted per month as from the beginning of 2010 (Gosling, 2010).

## 2.2 THE FINANCIAL IMPACT OF WATER HEATING

According to Powersaving (2008) and Go greener tips (2010), a conventional geyser can contribute up to 50% of the total electricity bill within a South African household. This is fairly high in comparison with a country like Japan, where the share of energy consumption due to water heating is approximately 30% of the total electricity bill (Goto, Goto & Sueyoshi, 2011:208). The cost of water heating depends on the hot water demand, cost per unit electricity used to heat up the water (different rates are charged in South Africa depending on the total kWh used, better known as inclining block tariffs (Eskom, 2010b)), the cost of the water heating system, as well as the efficiency of that specific system (Kroetz & Friedland,

2008:1359). Colton (2002:75) goes further and says that there is a clear relationship between the electricity usage within a household, and the income of that household, whether the electricity is used for space heating, hot water, air conditioning, refrigeration or lights. Therefore, the less the income of a household, the less electricity that household is likely to use. This is evident from Figure 2.4.

**Figure 2.4: End-use demand per household**



Source: Nyatsanza, Davis, Merven and Cohen, 2008

Figure 2.4 indicates the different income groups and their electricity consumption in 2001. It is clear that water heating represents a fairly large portion of the electricity consumption within South African households. UH represents the high income group within urban areas, UL represents the low income group within urban areas, RH represents the high income group within rural areas and RL represents the low income group within rural areas. Considering that this study compares alternative ways of how households in urban areas can save on their monthly electricity bill, more specifically with regard to water heating, it is clear that households within the urban areas consume a large volume of hot water.

Within South Africa, the average hot water usage per person per day amounts to around 60 litres of hot water (Meyer, 2000:59). This average is calculated by considering the annual average hot water consumption per person per day for a low-, medium- and high-density household, which are 91.4, 59.3 and 25.4 litres, respectively. The average temperature of a conventional geyser for the purpose of this study is 75°C with a 65°C element activation

temperature, which is the water temperature at which the geyser element will switch on again (Dreyer, 2011). There are different aspects that play a role with regard to energy consumption within households. These can be divided into four sub-categories (Yu, Zhang & Fujiwara, 2011:4172):

- 1) Individual attributes that refer to age, gender, education and environmental consciousness;
- 2) Household attributes such as household size and income;
- 3) Ownership and usage of in-house appliances, which refer to the duration of usage during the week; and
- 4) The energy consumption per month in monetary value.

These aspects can also have an influence on the volume of hot water consumption within a household, affecting the energy usage of a conventional geyser.

The increase in energy prices leads to energy consciousness by households, making energy-efficient water heating systems more financially viable, as they can reduce energy consumption costs, creating a “trade-off” between operating costs and capital costs (Goto *et al.*, 2010:204).

### **2.3 METHODS OF REDUCING WATER HEATING COSTS**

Since 1991, the South African government’s main objective was to provide electricity to the previously disadvantaged communities, increasing the national energy demand significantly (Bredekamp, Uken & Borrill, 2006:2). Eskom is unable to increase capacity because it takes between ten to twelve years to build a new power station (Bredekamp *et al.*, 2006:2). To manage this increase, “demand-side management” (DSM) was introduced by Eskom, whereby energy consumers are informed about different ways on how to reduce electricity demands. One of which is the Solar Water Heating Programme, whereby incentives are offered to consumers to switch to solar geysers (Eskom, 2010c). Auffhammer, Blumstein and Fowlie (2007:9) state that DSM programmes tend to be helpful to mitigate the environmental impacts due to the increase in energy demands and that these programmes are very cost efficient, generating savings for electricity consumers.

The reduction of energy consumption by households will not only contribute to a cost saving for the household, it will also have a positive impact on greenhouse gas emissions (Koroneos & Kottas, 2007:122).

There are several actions that a household can take to reduce the electricity usage of their geyser, reducing their electricity bill by up to 25% per month. These include (South Africa Online, 2010):

- 1) Switch off geysers not located in the main living area of the house, for instance the geyser in the guest quarters that is not used frequently;
- 2) Make sure the geyser temperature is not set higher than 55°C;
- 3) Use a geyser blanket;
- 4) Insulate the water pipes leading from the geyser to the taps;
- 5) Install a time switch that turns the geyser off when it is not needed; and
- 6) Install a solar geyser.

These represent some different alternatives that can be implemented by households, but do not give all the alternative investment options. Below follows a discussion of six available investment options that will help reduce the electricity consumption of a conventional geyser, either by replacing the conventional geyser, or attaching systems to a conventional geyser that can reduce the overall electricity usage.

### **2.3.1 Solar geyser**

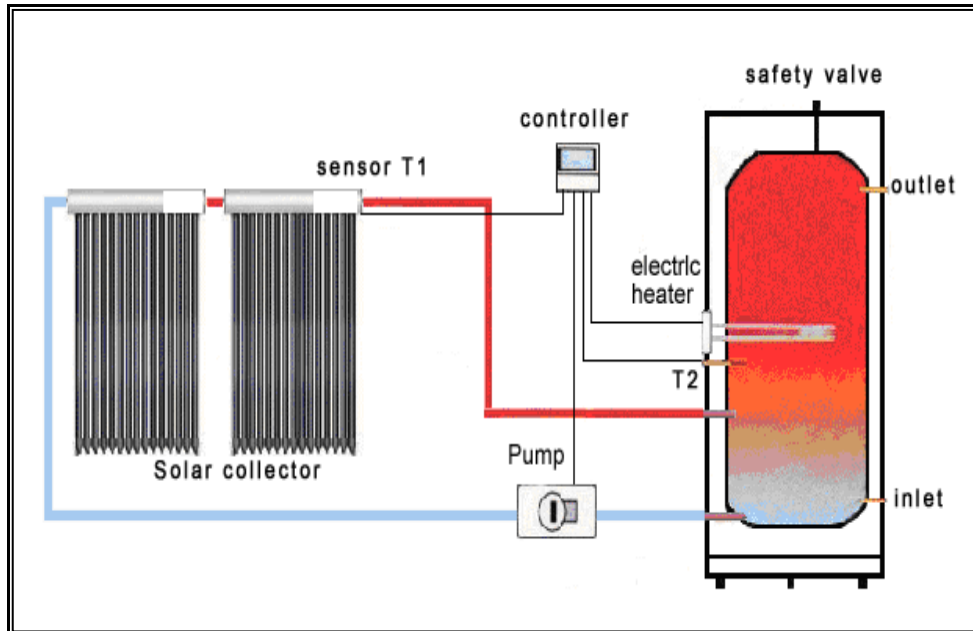
The South African Department of Energy introduced a National Solar Water Heating Programme in 2008 whereby they offered subsidies to households installing a solar water heating system in order for them to achieve their one million solar geyser goal by 2014 (Du Toit & Gilder, 2010:389). Kablan (2003:2028) states that solar water heating is an important area to take advantage of solar energy, but due to high initial investment costs many households consider solar water heating systems as being too expensive. According to Mohsen and Akash (2002:136), a solar water heating system is the most beneficial water heating system compared to other options within the market.

#### ***Technical aspects of a solar geyser***

A solar water heating system consists of two major components, as can be seen in Figure 2.5. These components are a collector usually located on the roof of a building and a storage tank located inside the building. A pump is utilised to circulate the water between the tank and collector when the water within the solar collector exceeds the temperature of the water in the storage tank by a specific margin (Purohit & Michaelowa, 2008:801). Water

running through the tubes of the solar collector can heat up to a maximum temperature of 90-95°C due to solar radiation absorbed by the collector (Pillai & Banerjee, 2006:163).

**Figure 2.5: Solar heater**



Source: Dako Power, s.a.

### ***Financial aspects of a solar geyser***

With the high investment capital needed (between R14 000 and R20 000) to install a solar water heating system, many households face the problem of where to find financing. According to Wasserman (2010), there are several options available that can assist households in getting funding for this installation. These include the increase of a mortgage loan, applying for a home improvement loan at the bank, or making use of the financing schemes available from solar geyser suppliers. ITS (s.a.) states that a solar geyser, for a normal household, will repay itself within three to four years after purchase, but this depends on the location of the household, as well as the hot water consumption within that household. ITS (s.a.) also states that, under normal circumstances, a solar geyser does not have any maintenance requirements, therefore no maintenance costs.

It is important to note that the implementation of a solar geyser does not eliminate the usage of electricity with regard to a geyser, but reduces it significantly as the normal geyser will only switch on when the water does not reach the required temperature (Li & Yang,

2010:131). Solar water heating systems can reduce the monthly electricity cost of a conventional geyser with up to 40% (Nyatsanza *et al.*, 2008).

### 2.3.2 Time switch on a conventional geyser

Bourke and Bansal (2010:1771) state that hot water usage differs from household to household. There is in most cases a definite peak in energy usage in the morning, late afternoon and evening, as can be seen from Table 2.1. Within the daily load profile it is evident that 45% of the daily electricity is used during the late afternoon and evening when, for example, the occupants are back from work. These peaks in energy usage cannot only be due to hot water consumption, but it plays an integral part.

**Table 2.1: Standard daily load profile**

<b>Daily load profile</b>	
<b>Time</b>	<b>Proportion</b>
06:00	5%
08:00	16%
10:00	15%
12:00	11%
14:00	8%
16:00	7%
18:00	11%
20:00	13%
22:00	11%
23:00	3%
<b>Total</b>	<b>100%</b>

Source: Bourke and Bansal, 2010:1771

#### ***Technical aspects of a time switch***

A time switch is a device that works on an analogue clock alarm that switches a conventional geyser on and off (Talukder, Gholap & Kanyemba, 2004:1). When using a time switch on a conventional geyser, one manages the time when the geyser switches on to reheat the water, causing a reduction in the number of times that the geyser element switches on, and therefore reducing the energy consumption of a geyser (Powersaving, 2008).

A small unit (relay) is installed in the house that will control the electricity supply to the geyser, only switching the geyser element on during predetermined periods (Tshabalala,

2011). According to Control Wave (2001), “unmanaged switches are extremely easy to install and operate because little or no user configuration is required. Once the Ethernet connections are made and the unit is powered up it will immediately begin to operate.”

### **Financial aspects of a time switch**

Mayothi (2010) mentions that there is confusion pertaining to whether the switching off of a geyser will really contribute a saving on electricity usage; therefore, they did a study on what the energy saving will be if the geyser only heats up during certain times of the day. The study was conducted on a conventional geyser with no geyser blanket, serving a household of two people, who normally shower/bath in the morning before work. They found that if the geyser was used on the same principle as a kettle, only supplying hot water when you need it, instead of using it like an urn that provides constant boiling water, one can save up to 25% of the energy consumption of a conventional geyser. Mr J Dreyer (2011), a nuclear engineer at Eskom, who built a heat switching model especially for this study, found that the cost saving due to the installation of a time switch can even increase up to 72%, all dependant on the number of people in the household (Table 2.2).

**Table 2.2: Saving due to the installation of a time switch**

<b>Water consumptions</b>	<b>Size of household</b>	<b>Average temperature</b>	<b>Electricity usage per day</b>	<b>Electricity usage per month</b>	<b>Cost per month</b>	<b>Percentage increase/decrease</b>
<b>[litre/day]</b>	<b># persons</b>	<b>[°C]</b>	<b>[kWh]</b>	<b>[kWh]</b>	<b>[R]</b>	<b>[%]</b>
60	1	62.902	8.243	247.30	181.66	- 37.01
120	2	60.783	9.510	285.30	210.32	- 45.77
180	3	59.031	10.693	320.80	237.10	- 47.30
240	4	58.145	13.200	396.00	314.34	- 53.11
300	5	57.160	13.200	396.00	314.34	- 60.84
360	6	55.812	13.641	409.22	328.82	- 63.13
420	7	54.523	13.998	419.95	340.57	- 65.67
480	8	53.415	14.302	429.05	350.53	- 68.17
540	9	52.407	14.567	437.02	359.26	- 69.82
600	10	51.504	14.807	444.22	367.35	- 72.11

Source: Dreyer, 2011

Therefore, installing a time switch on a conventional geyser in order to control the time it switches on and off, could save energy. Furthermore, a time switch will help maintain the circuit breakers of the conventional geyser, as the circuit breakers were not made to be physically switched off and on, and this can be costly to replace (Power Saving Services, 2010).

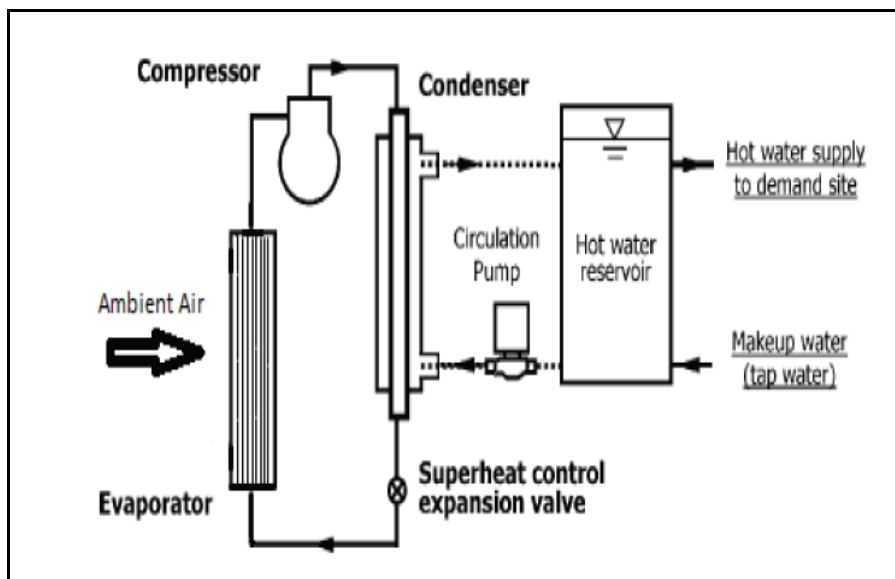
### 2.3.3 Heat pump

A heat pump uses heat already available in the atmosphere to generate enough energy to heat up water for domestic use. Heat pumps are especially used within countries like Germany, which is the leading country in developing heat pumps (Gemilli, Mancini & Longhi, 2011:2474-2475). The European Union supports the utilisation of heat pumps in order to reduce greenhouse gases, therefore promoting this as sustainable energy technologies, which caused an increase in the installation of heat pumps, especially in countries like France and Sweden (Goto *et al.*, 2010:197).

#### ***Technical aspects of a heat pump***

A typical heat pump consists of four major components, as can be seen in Figure 2.6, namely a compressor, evaporator, condenser and a superheat control expansion valve (Fardoun, Ibrahim & Zoughaib, 2011:327). The hot water is transferred to the hot water reservoir and stored there, ready for supply to the demand site.

**Figure 2.6: Air source heat pump water heater**



Source: Fardoun *et al.*, 2011:327

A conventional geyser is a convenient way of water heating with regard to installation and operation, but the energy efficiency of a conventional geyser is very low in comparison to a heat pump, as a heat pump can supply more heat using the same amount of electricity (Kim, Kim & Chung, 2004:415). However, the operation of a heat pump is dependent on the external thermal conditions (Kim *et al.*, 2004:416). The reason for this is because a heat

pump uses the outdoor air temperature to produce hot water (M-tech Industrial (Pty) Ltd., 2002).

### ***Financial aspects of a heat pump***

According to Fardoun *et al.* (2011:330), the use of an air source heat pump can reduce the electricity usage on a conventional geyser by 70%. This is in agreement with GEO plus's (2006) statement that a heat pump can save up to two thirds of the energy consumption of a conventional geyser. Solar energy technologies can also be combined with a heat pump, where solar and ambient air energies are absorbed and used to produce hot water, reducing electricity usage even more (Huang & Chyng, 2001:411).

GEO plus (2006:4) states that the installation cost of a heat pump is more than the installation cost on a conventional geyser, but significantly less than that of a solar geyser. Eskom offers a rebate on the installation of a heat pump (Eskom, 2010a). The rebate depends on the size of the heat pump installed: One can expect a rebate of R4 320 for a tank size between 300-500 litres, and a R3 668 rebate for a tank size between 100-300 litres (Eskom, 2010a). The payback period within the residential sector for a heat pump is between two to four years, depending on the level of hot water consumption (GEO plus, 2006?:4). According to a study done by Cane, Morrison and Ireland (1998), the service and maintenance costs associated with a heat pump are significantly lower than the service and maintenance cost on a conventional geyser.

### **2.3.4 Gas geyser**

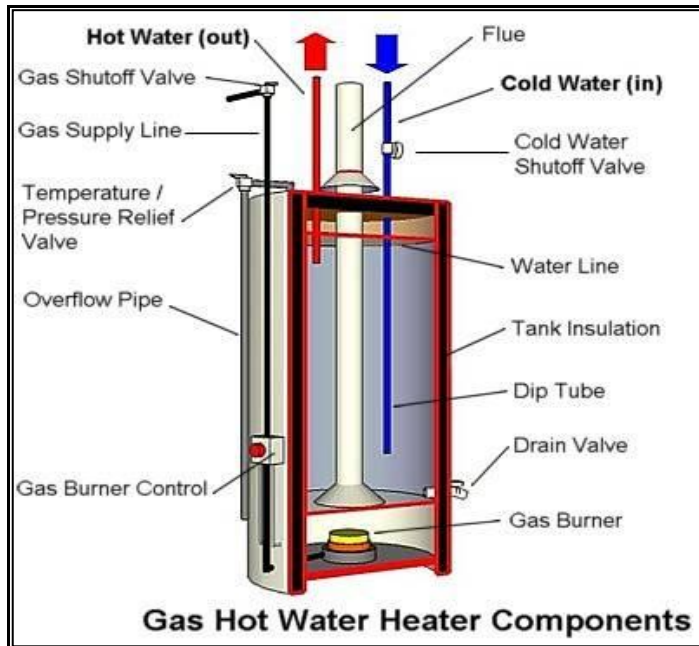
Gas water heaters are a storage type water heater that constantly maintains the water temperature during the day (Aguilar, White & Ryan, 2005:16). Aguilar *et al.* (2005:17) state that a gas water heater heats the water faster, saves on energy consumption, therefore cutting on energy cost. A gas geyser's useful life is expected to be around twelve years if maintained properly, but frequent maintenance does not eliminate the hazards associated with a gas geyser, such as explosions (Kablan, 2004:1071).

Although gas geysers are a cost-efficient method of heating water for household usage, it can generate carbon monoxide, hydrocarbons and nitrogen oxides that can cause health problems if not properly installed (Sharma, Gupta, Paul, Puri & Garg, 2009:170).

### ***Technical aspects of a gas geyser***

Figure 2.7 provides a clear indication of what the different components within a gas geyser are. The water in the tank is heated by the combustion of gas, creating energy, which is transferred from a flame, at the gas burner, to the water (Mahanagar Gas, s.a.)

**Figure 2.7: Gas water heater components**



Source: Formisano, 2006

### ***Financial aspects of a gas geyser***

The installation costs associated with a gas geyser are dependant on the scale of work needed, the piping required and all the fittings, connections, regulator, etc. needed for proper functioning of the gas geyser (The Gas Experts, 2009).

The monthly gas consumption amounts to an average cost of around R320, dependent on the volume of hot water consumption, and eliminates the electricity cost (Geysers, 2011). Oorja Solutions (s.a.) calculated the monthly gas expenses of a gas geyser in India, and found that the cost of gas associated with a gas geyser is around 25% of the total cost of the electricity cost associated with a conventional geyser. They also state that the only maintenance cost on a gas geyser will be when the gas supply hose is damaged and needs to be replaced, which is a minimal cost.

### **2.3.5 Instant heater**

An instant heater is a small unit not much bigger than a normal laptop that is mounted to a wall; therefore, this alternative is a space-saving option when considering water heating systems (Jamee, 2011). Therefore, energy saving is not the only advantage of an instant water heater. Conventional geysers tend to leak after a while due to water storage and can cause damage to the property, where an instant heater does not cause such damages as it does not store any water. Stroozas (2007) mentions that an instant heater reduces the energy losses due to standby hot water in the storage tank waiting to be used. He also states that instant heaters reduce the water wastage due to running taps waiting for the hot water coming from storage tanks, and that this type of water heaters work extremely well within the food service industry where the demand for hot water is high.

#### ***Technical aspects of an instant heater***

An instant heater does not store hot water in a storage tank like a conventional water heater. The water is heated on demand when it passes through the heating elements in the water heater once the faucet or valve is opened, and stops when the faucet or valve is closed again (Tidwell & Clamp, s.a.).

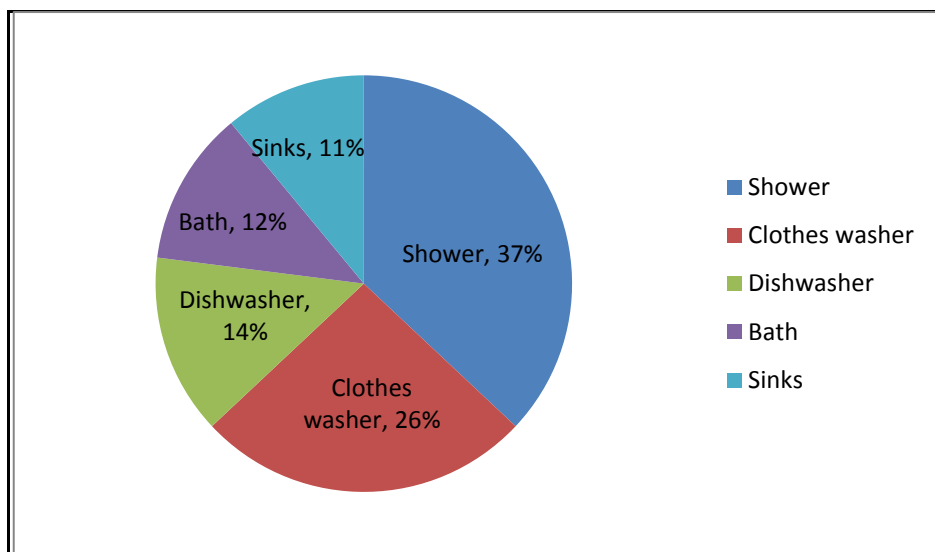
Instant water heaters need to be serviced once a year in order to extend its useful life, as calcium builds up in the tank, restricting water flow and damaging the water heater (Consumer Reports, 2008). This is done by flushing the instant heater with vinegar water. According to HCF (s.a.), the operating cost of an instant water heater is less than that of a conventional water heating system, contributing to a cost saving. HCF (s.a) further states that almost every part of an instant heater can easily be replaced, without replacing the whole unit. They state that the instant heater is basically maintenance free.

#### ***Financial aspects of an instant heater***

Instant heaters can generate an energy saving of between 27 and 50% of the total cost associated with a conventional geyser if installed on each hot water outlet within a household in the United States (United States Department of Energy, 2011). Currently, this is the best indication of what the electricity saving will be, as instant water heaters are not that well known in South Africa as yet. This is evident through the number of suppliers of instant water heaters in South Africa.

The useful life of an instant heater is expected to be around 20 years, but the useful life can be extended if maintained properly (United States Department of Energy, 2011). To install an instant heater on every hot water outlet within a household can become expensive. The United States Environmental Protection Agency (EPA) (Energy star, 2011) did a study to see how the hot water usage can be allocated to different areas within a household, which can provide a good indication as to where it may be financially viable to install an instant heater (see Figure 2.8).

**Figure 2.8: Hot water usage**



Source: Energy star, 2011

### 2.3.6 Geysers blanket

A geysers blanket is wrapped around a conventional geyser to keep the water hot for longer, saving electricity and reducing carbon emissions (Green SA, 2007).

#### ***Technical aspects of a geysers blanket***

A geysers blanket is an insulation blanket wrapped around a conventional geyser as well as a few metres of the outlet piping to reduce standing losses. This reduces the number of times the element of a conventional geyser needs to switch on, as the water stays warmer for longer, and through this reduces electricity consumption.

A geysers blanket has the potential to save up to 12% of the electricity used on a conventional geyser (Nyatsanza *et al.*, 2008). According to Harris, Kilfoil and Uken (2006), a

geyser blanket can reduce standing losses by up to 27% if the geyser is properly wrapped as well as two meters of the outlet piping and one meter of the inlet piping. If only the geyser is wrapped, the standing losses will only be reduced by 21.7%.

**Financial aspects of a geyser blanket**

A study done by Bosman, Grobler and Dalgleish (2006:64) showed that the installation of a geyser blanket will contribute an average saving of 18% of the electricity cost of a conventional geyser. They noted that the reduction of the set point temperature of a conventional geyser from 75 to 55°C will realise double the saving of a geyser blanket.

Mr J Dreyer (2011) also did a calculation to determine what the exact saving will be if a geyser blanket was installed, and found that a geyser blanket is only worthwhile to install if the household is small (Table 2.3). This is because more people in a household consume more hot water on a regular basis, therefore the water in the geyser does not stay warm for long periods of time and the heat loss is not that significant. From his calculations it is clear that if the household is between one and four people, the cost saving can on average be up to 22%, but it comes down to as little as a 3.64% cost saving if the household reaches a total of ten people.

**Table 2.3: Saving due to the installation of a geyser blanket**

Scenario 4						
Water consumption	Size of household	Average temperature	Electricity usage per day	Electricity usage per month	Cost per month	Percentage increase/decrease
[litre/day]	# persons	[°C]	[kWh]	[kWh]	[R]	[%]
60	1	69.829	10.098	302.95	223.63	-22.45
120	2	69.832	12.866	385.97	303.36	-21.79
180	3	69.816	16.155	484.65	411.41	-8.56
240	4	69.679	19.377	581.32	517.27	-22.84
300	5	69.824	21.905	656.92	725.37	-9.64
360	6	69.729	23.905	717.15	797.70	-10.55
420	7	69.793	28.290	848.70	955.69	-3.65
480	8	69.857	29.762	892.87	1008.74	-8.40
540	9	70.033	33.598	1007.95	1146.95	-3.65
600	10	70.146	36.977	1109.32	1268.70	-3.64

Source: Dreyer, 2011

When considering Table 2.3, it appears that a geyser blanket contributes an average saving of approximately 11.5% (the average between 22.8% the highest saving, and 3.6% the lowest saving) on the electricity costs of a conventional geyser. This is not nearly as much as the other possible options to reduce energy usage of water heating, but this is a cheap method when one does not have the capital means to invest in the more expensive options, but still would like to reduce monthly electricity costs. The average cost of a geyser blanket is around R200 for a large geyser blanket (I am changing the world, 2011).

It is worth mentioning that a geyser blanket is a quick way of reducing the energy consumption of a conventional geyser by up to 23%, but it is only effective if the household is small. This investment option will not be evaluated further as it is only effective for small households.

#### **2.4. SUMMARY**

It is evident that the energy consumption within South Africa is rapidly increasing year after year. This has forced the South African Energy supplier, Eskom, to take action and increase the energy supply. However, new power stations had to be built in order to fund these projects. Eskom increased the electricity charge-out rate by an average of 25% for a period of three years.

This put a lot of strain on South African households; therefore, they started to consider alternative ways of saving electricity. The popularity of solar geysers increased rapidly over the past few years, mainly because Eskom offers a rebate on the installation of a solar geyser.

However, a solar geyser is not the only way, with regard to water heating systems, that a household can reduce its electricity consumption. In this chapter, six alternative ways were identified and discussed, each with its own characteristics. These alternatives include a solar geyser, a time switch, a heat pump, gas geyser, an instant heater as well as a geyser blanket.

In this chapter, the different alternatives to the conventional geyser for generating hot water were discussed. With this, the first specific objective has been achieved, namely to conceptualise from the literature the financial impact of the conventional geyser with regard to the average electricity bill, as well as the different options as alternatives to reduce the electricity usage in order to generate hot water.

In Chapter 3, the different investment appraisal techniques that could be used to evaluate the different investment alternatives identified in this chapter will be discussed.

### **3. CHAPTER 3: INVESTMENT APPRAISAL METHODS**

#### **3.1 INTRODUCTION**

Cicea, Vasilescu and Banacu (2009:95) state that investors do not consider investing in any investment unless it is profitable. To determine the profitability of an investment, management accounting and financial management offer different methods of calculating the financial impact of different investments on an organisation, by using different investment appraisal methods. The different investment appraisal methods, as well as those methods that will be relevant for determining the best investment with regard to alternative water heating systems, will be discussed in this chapter.

#### **3.2 INVESTMENT APPRAISAL METHODS**

Economic growth and welfare are dependent on capital resources used productively, the infrastructure of a country, the human capital employed, the knowledge available, productivity and the quality of institutions (European Commission: Directorate General Regional Policy, 2008:13). In order for a country to have all the above-mentioned resources available, it will need to make decisions at present, and invest capital and resources with the hope that it will deliver benefits in the future. The same applies to any investor, as he/she will need to invest in order to grow and increase his/her wealth.

All these investors have different investment options at any moment in time that can be considered worthwhile to invest in. In order for investors to choose the right investment, they need to know what investment will generate the greatest return or value for money (Garrison, Noreen & Brewer, 2008:626). Garrison *et al.* (2008:578) state that investors compare the costs and benefits of all the alternatives in order to make a decision.

Investment appraisals are one of several tools used by management accountants for decision-making, acting as decision-facilitating information, of which the main intention is to reduce pre-investment uncertainty and provide the decision-maker with relevant information to make the best decision, while keeping the investment objectives in mind (Wall & Greiling, 2011:93). The main objective of an investment appraisal is to calculate, from the forecasted cashflows, whether the investment will be suitable for the investor (Laurentiu, 2010:347). Laurentiu (2010:348) also states that if there is more than one investment option, investment appraisals are used to rank the investment options. All the inputs to investment appraisals are estimates of what can be expected and therefore the outcome of investment appraisals is not set in stone, but will provide a clear understanding to the investor of what to expect.

According to Savvides (1994:1), the first step in conducting an investment appraisal is to utilise information gathered of a certain type of investment in the past to predict what will happen if the same investment takes place in the future. This is a process of forecasting, whereby the best possible estimates are calculated that will be used as inputs into the appraisal analysis.

An investment decision is one of the biggest challenges faced by investors. It is critical to make the right decisions to decrease the probability of failure in the future, therefore making the investment assessment critical in any investment decision (Schuster, 2011:24; Correia, Flynn, Uliana & Wormald, 2010:8-3). Garrison *et al.* (2008:626) agree with this by stating that an investment can directly affect one's profitability in the long run.

When doing investment appraisals, one takes into consideration the incremental cashflows associated with the investment. Incremental cashflows are those cashflows that occur due to the investment and will cause changes to the current cashflow of the business/individual (Correia *et al.*, 2010:8-17). Those cashflows that would have taken place regardless if the investment would have taken place or not, are not relevant for investment appraisals (Firer & Gilbert, 2004:41; Garrison *et al.*, 2008:578; Correia *et al.*, 2008:8-17). The same applies to sunk costs that were paid before the actual project started, for instance investigation cost (Correia *et al.*, 2010:8-17-18).

For private investments, the financial cashflows can be defined as the investment inputs and outputs calculated on the market price (Foltyn-Zarychta, 2010:290). The market price represents the price of an investment on the open market at any given time (Garrison *et al.*, 2008:547). The higher the capital requirement of a project, the higher the profitability of the project needs to be to make it worthwhile for the investor to invest in the investment option (Stalder, Lacy, Cross, Conatser & Darroch, 2000:33).

The traditional methods of investment appraisal include some of the following: net present value (NPV), internal rate of return (IRR), discounted payback period and the profitability index (PI) (Bućko, 2010:61).

### **3.2.1 Cost benefit analysis**

A cost benefit analysis (CBA) is an investment appraisal method that takes into account internal costs and benefits, which refer to costs and benefits carried by an investment party, as well as external costs and benefits, which refer to costs and benefits relevant to the economy as well as the environment (Diakoulaki, Zervos, Sarafidis & Mirasgedis,

2001:1728). Diakoulaki *et al.* (2001:1729) state that there are five stages within a cost benefit analysis:

- All inputs and outputs of the technology used must be recorded in detail; these relate to the capacity, efficiency, etc. of the technology.
- Determine the costs and benefits associated with the investment; these include private costs that are market related and also the external costs relating to the environment, which are determined using special methods that derive from the neoclassic economic theory.
- Calculate the present values of all costs and benefits identified in stage 2 by using a suitable discount rate.
- Calculate the net present value, internal rate of return and the benefit cost ratio of the project.
- Do a sensitivity analysis where an investigation takes place to determine what the impact will be on results, calculated in stage 4, if some of the critical parameters change.

When looking at each of the above-mentioned five stages, it is clear that a CBA does not only consider the financial aspects associated with an investment, but also non-financial aspects such as the capabilities of the technology implemented as well as the impact on the environment. A CBA is therefore an intensive investment appraisal method.

### ***Advantages of a CBA***

According to Kopp, Krupnick and Toman (1997:ES-1), the advantages of a CBA is that it is clear, accountable, it provides a framework for data collection whereby gaps can be identified, and a CBA uses monetary values to determine the impact of an investment by calculating the net benefit. They recommend that an investment decision must not solely be based on the outcome of a CBA, but that a CBA must also play an important part in any investment decision. A CBA is commonly used to evaluate public projects (Mohamadian, Noori, Mohamad & Hosseini, 2011:551), as it is an in-depth analysis of an investment.

### ***Limitations of a CBA***

A CBA is a complex investment appraisal method, where it can become difficult to determine a monetary value for some costs and benefits (Atkinson & Mourato, 2008:334). The fact that estimates are used in a CBA reduces the reliability of the outcome of a CBA and therefore a

CBA is just a quantitative analysis (Oka, 2003:26). Furthermore, a CBA needs to take into account environmental factors as well as indirect impacts (Diakoulaki *et al.*, 2001:1728). According to Florio and Vignetti (2003:4), rules must be set when conducting a CBA otherwise it will not provide a smooth and fair outcome.

### ***The relevance of a CBA for this study***

A CBA seems like a thorough investigation of an investment by not only considering the impact on the investor, but also determining the external costs and benefits for the economy and the environment. Although the reduction of electricity usage will benefit the environment, the electricity reduction by a single household in terms of the total energy consumption of a country like South Africa is beyond the scope of this study.

Therefore, a CBA investment appraisal method will not be used for this study.

### **3.2.2 Net Present Value**

Traditionally, investments were analysed by simply calculating the cost and benefit associated with the investment over a certain period of time, adding up all the costs and all the benefits, which gave the net cost and net benefit for the investment, and then deducting the one from the other, giving the net value of the investment (Michel, 2001:27). This created a problem as this method did not take into account the time value of money, and therefore gave incorrect values on investments. To solve this problem, the net present value (NPV) adjusts the cashflows each year to show their actual value at present before adding up the net cashflows to determine the value of the investment (Michel, 2001:27; Verbruggen, Marchohi & Janssens, 2011:906; Garrison *et al.*, 2008:627; Abadie, 2009:740; Correia *et al.*, 2010:8-5).

The NPV is one of the most used investment appraisal methods (Verbruggen *et al.*, 2011:906). It is interlinked with the internal rate of return (IRR) and payback period of a project. This is because the IRR is defined as the rate at which the NPV is equal to zero, and the NPV indicates whether the project will provide investors with the required rate of return. Therefore, if the NPV is greater than zero, it means that the proposed investment will provide the required rate of return over the minimum required period (the payback period) (Bučko, 2010:62; Drury, 2008:295; Garrison *et al.*, 2008:628; Correia *et al.*, 2010:8-6). Akcay and Uzunoç (2005:1665) state that if the objective of the investor is to maximise profit, or save cost, the NPV method will help to make an informed decision.

A commonly used method of calculating the NPV of an investment is a cost benefit analysis (CBA), as this tool compares the desirable and undesirable impacts for each year (Adhikari & Supakankunti, 2010:128). The costs represent the resources used to fund and maintain the investments, where the benefits are the desirable impacts resulting from the investments, such as cost savings (Adhikari & Supakankunti, 2010:128-129). Michel (2001:28) feels that the opportunity costs associated with an investment must also be included in the cost of an investment, as this will provide a more realistic view of the value of the investment.

In order to calculate the NPV, Michel (2001:27) recommends four basic steps:

*Step 1:* calculate the estimated costs and benefits for each year.

*Step 2:* calculate the discount rate relevant to the company or investment.

*Step 3:* calculate the NPV of the investment by discounting the cashflows for each year by the discount factor for that year, and sum all the years.

*Step 4:* compare the NPV of the investment with the NPV of the alternative options.

***The formula for NPV***

$$NPV = \frac{FV_1}{1+K} + \frac{FV_2}{(1+K)^2} + \frac{FV_3}{(1+K)^3} + \dots + \frac{FV_n}{(1+K)^n} - I_0$$

Where:

$I_0$  = the initial investment cost

FV to  $FV_n$  = the future values of the annual cashflows

K = the discount rate used to evaluate the investment

(Drury, 2008:296)

Drury (2008:296) also mentions that a table can be used whereby each year's cashflows are indicated and summed to get the total cashflow for that year. The totals are then multiplied by the appropriated discount factor for each year, giving the net cashflows. The net cashflows are then summed to determine the NPV.

### ***Advantages of NPV***

The NPV already provides for the return on investment, therefore if the NPV is greater than zero, the investment will cover the investment cost, plus additional risk carried by the investor for tying up funds in the investment (Garrison *et al.*, 2008:630). Furthermore, the NPV considers all cashflows associated with the investment and reflects the time value of money by discounting the cashflows at the determined cost of capital (Michel, 2001:27).

### ***Limitations of NPV***

According to Abadie (2009:740-742), there are a few limitations when computing the NPV of an investment. Firstly, the discount rate is kept constant most of the time for all investments, although the different investments carry different risk. Therefore, the NPV is only as realistic as the discount rate (Financial Modeling Guide, s.a.). Secondly, the different options with regard to an investment might be of different types, making it difficult to accurately compare the options. There are difficulties associated with the forecasting of future costs and benefits (Michel, 2001:30). All these limitations can make it easy to manipulate the outcome of the NPV analysis (Michel, 2001:30).

These limitations can be overcome by using a sensitivity analysis, which will be discussed later.

### ***The relevance of NPV for this study***

The NPV method takes into account all internal costs and benefits associated with an investment option, discounted at an appropriate discount rate, and gives an indication to the investor as to whether to invest in an investment or not. These costs and benefits are fairly easy to determine, as none of the external costs referred to in the cost benefit analysis are taken into account, therefore market values can be used.

The NPV investment appraisal method will be relevant for this study, as it will show the investor whether the hot water heating system will be financially viable to install at different volumes of hot water consumption. The table method mentioned by Drury (2008:298) will be used as this will give a more detailed view of what the annual cashflows are made up of.

### 3.2.3 Internal rate of return (IRR)

The IRR is the discount rate at which the present value of cashflows over the measurement period is equal to the investment at the beginning of the period (Cicea & Buşu, 2011:440; Bućko, 2010:62; Drury, 2008:298; Garrison *et al.*, 2008:633; Correia *et al.*, 2010:8-7). Therefore, it is the discount rate at which the NPV of a project will be equal to zero. It determines the profitability of an investment and gives an indication of the worth of an investment (Akçay & Uzunoç, 2005:1666).

According to Chen (2008:31-32), the NPV method is more likely to be recommended by academia, but in some industries the IRR is more preferred as an investment appraisal method as it is easy to understand by non-financial people. The IRR is compared with the discount rate used to evaluate an investment; therefore, if the IRR of an investment is higher than the discount rate used, then the investment can be accepted (Block, 2011:54; Correia *et al.*, 2010:8-7). The IRR will only be higher than the discount rate used to evaluate the investment if the NPV of the investment is positive (Drury, 2008:299). The investment with the highest IRR will be the most promising to undertake, therefore it can be assumed that the investment with the highest IRR will be ranked highest (Correia *et al.*, 2008: 8-8). However, Chen (2008:31-32) states that a single IRR is only appropriate for investments with a conventional cashflow, but will not be sufficient for investments with non-conventional cashflows. He states that multiple IRRs should be calculated for non-conventional cashflows; if the discount rate of the investment falls between the two IRRs, the NPV will be positive and the investment can be accepted (Chen, 2008:37).

The IRR as well as the NPV are the most frequently used investment appraisal methods (Shinoda, 2010:41; Leon, Isa & Kester, 2008:177), and they are key in justifying whether an investment should be implemented (Maric, Invanisevic, Mitrovic, Aleksic & Ravcanin, 2011:3269).

#### **Formula for IRR**

The IRR is calculated by determining the value of K in the following formula (Drury, 2008:298):

$$I_0 = \frac{FV_1}{1+K} + \frac{FV_2}{(1+K)^2} + \frac{FV_3}{(1+K)^3} + \dots + \frac{FV_n}{(1+K)^n}$$

It is easier to use the discount table. By using the initial investment cost, the net cashflows of each year, the useful life of the investment and the net present value discount table, the IRR can be calculated by firstly determining the factor of the IRR (Garrison *et al.*, 2008:633) as follows:

$$\text{Factor of the IRR} = \frac{\text{Investment required}}{\text{Net annual cash inflow}}$$

The discount factor can be calculated by using the above formula. If the net present value discount table is used, use the line indicating the useful life of the investment, and find the discount factor closest to the one calculated above. The IRR will be the percentage indicated at the top of the table (Garrison *et al.*, 2008:633). However, this method only works when the annual cash inflows are identical. Garrison *et al.* (2008:632) and Correia *et al.* (2010:8-9) suggest using computer software such as Excel that calculates the IRR and NPV by using spreadsheets and formulas.

### ***Advantages of IRR***

When computing the IRR, the cost of capital is not required, making this investment appraisal method easier than others (Correia, 2010:8-8). Furthermore, the IRR indicates whether an investment will increase the value of the firm, taking into account the time value of money (Drury, 2008:298.). Correia *et al.* (2010:8-8) and Chen (2008:32) state that the IRR is easily understandable and is more popular to use in practice than the NPV is. Kierulff (2008:322) agrees with Correia *et al.* by stating that management seems to be more comfortable using percentages and therefore they prefer to use the IRR.

### ***Limitations of IRR***

Baker (2006) states that the assumption that a project with the highest IRR is better to invest in, is only true if all the investments that are compared have their initial investment cost first and the benefits later in the investment life cycle. He further states that one should take into consideration that the higher the IRR, the higher the risk associated with the investment will be, and therefore there is a probability that the benefits will not realise. Due to the impact on the IRR if cashflows happen later in the lifecycle of an investment, for instance an environmental clean-up, Baker (2006) believes that this appraisal method is not sufficient to evaluate different investment options. He states that investments with cashflows later in the

investment lifecycle will have a much lower IRR, but might be the best between the alternatives compared.

According to Drury (2008:302), the IRR will not give a correct ranking of mutually exclusive projects due to the reinvestment assumptions it makes, and the NPV should rather be used. The IRR has several drawbacks as it is very complex to calculate, it is not always comparable with the cost of capital, it may not be compatible with the NPV and therefore will give different outcomes and rankings, and the IRR cannot be used if there is a variable cost of capital (Magni, 2010:151; Bester, 2006:32). These assumptions include the fact that the IRR assumes that the cash inflows generated during the lifetime of the investment will be reinvested at the IRR, and if it is high, this might not be the case (Steven, 2010:40; Kierulff, 2008:323). Another drawback stated by Cicea and Buşu (2011:441) is the fact that the IRR only takes into account monetary income, which eliminates benefits that cannot be quantified, but that might be relevant.

To overcome these drawbacks, a recommendation is that one should use the modified internal rate of return (MIRR) (Kierulff, 2008:322).

### ***Modified internal rate of return (MIRR)***

The MIRR, which works on the same principle as the IRR method, takes into account the same initial investment cost, but with a single terminal payment (ACCA, 2008; Financial Modeling Guide, s.a.). According to Kierulff (2008:322), the MIRR provides a more accurate value to determine the financial attractiveness of an investment, as it is a more realistic return rate. The Financial Modelling Guide (s.a.) states that the reason why the MIRR is more realistic is mainly because the IRR assumes that cash inflows from an investment will be reinvested at the IRR, whereas the MIRR assumes that cash inflows will be reinvested at the cost of capital of the investor. Therefore, the MIRR calculates the discount rate that makes the value of the investment equal to the future value of the cash inflows generated by the investment (Kierulff, 2008:326). When calculating the MIRR, the initial investment cost appears at the beginning of the investment cycle, with all the other cashflows only happening in the last year of the investment cycle; the years in between are equal to zero (Kierulff, 2008:326). Correia *et al.* (2010:8-13) mention that Microsoft Excel can be used to calculate the MIRR.

### ***Relevance of IRR for this study***

The IRR determines at what rate the NPV will be zero, therefore indicating if the investment's cash inflows are more than what the investment will initially cost the investor. The IRR is a good investment appraisal method to compare different investment options with different cashflows and different life spans; therefore, the IRR method will be a relevant investment appraisal method for this study.

Furthermore, the MIRR will also be calculated as this will mitigate the identified risks associated with the IRR.

### **3.2.4 Accounting rate of return (ARR)**

The ARR reflects the performance of a project as a percentage of the net income divided by the book value of the initial investment; therefore, the ARR also takes into account non-cashflow items, such as depreciation (Feenstra & Wang, 2000:3; Drury, 2008:307; Correia *et al.*, 2010:8-11). Feenstra and Wang (2000:7) also define the ARR as the ration between the accounting profit and the book value of the investment at the beginning of the period. The ARR method calculates the average return expected over the average investment cost, which can be compared to the company's after tax return on an investment rate, or the return on assets rate (Taylor, 1994:27).

The ARR differs from other investment appraisal methods as it refers to profit instead of cashflows and therefore can be seen as an income statement analysis (Drury, 2005:513; Correia *et al.*, 2010:8-11). Drury (2008:308) also states that the ARR method is better to use than the payback period as it compares differences in the useful life of the investment. For instance, if the payback periods of investments are the same, the ARR will help to identify which investment is better to invest in as it will show what investment has the highest return rate.

### ***Formula for ARR***

The ARR is calculated as follows (Drury, 2008:307; Correia *et al.*, 2010:8-11):

$$\text{Accounting rate of return} = \frac{\text{Average annual profits}}{\text{Average investment}} \times 100$$

Where:

Average annual profit is the total net income divided by the useful life of the investment.

Average investment is the initial investment cost divided by two.

### ***Advantages of ARR***

The ARR as investment appraisal method takes into account the difference in useful life of the investments compared (Drury, 2008:308). This is a fairly easy calculation and understandable as it uses the financial statement information and not the cashflows of the investment (Needles, Powers & Crosson, 2011:1167).

### ***Limitations of ARR***

The ARR fails to take into account the time value of money, and therefore the ARR puts the same weight on R100 in the future as a R100 today (Drury, 2008:308; Taylor, 1994:27; Correia *et al.*, 2010:8-12). Drury (2008:308) further mentions that the ARR ignores the time when the cashflows take place; therefore, it will give the same ARR for an investment where the cashflows are towards the end of the expected life, as for an investment where the cashflows are sooner, taking into account that the average cashflows are the same. Taylor (1994:27) mentions that the ARR is also subject to different accounting policies and interpretations, which makes it easy to manipulate the results. Florio and Vignetti (2003:8) state that depreciation causes a double counting of the initial investment cost. Therefore, only the tax on the depreciation should be deducted.

Taylor (1994:27) suggests that the ARR should not be used to make investment decisions, but should rather be used to ensure that all projects invested in give an ARR that is greater than the after tax return on assets of the company, as this will ensure that shareholders' wealth increases.

### ***Relevance of ARR for this study***

Although non-cashflow items may not play a significant part within households, such as depreciation, the ARR will be calculated in this study. This is a good indication of what the return on investment will be for each of the alternatives.

### **3.2.5 Pay-back period**

The payback period is the number of years it will take the investment to generate enough revenue to exceed the initial investment cost (Abadie, 2009:739; Correia *et al.*, 2010:8-10). According to Keya (2011:42), the payback period reflects the time of return, which is important to calculate for long-term investments. Therefore, it is an indication of the liquidity of an investment (Bhandari, 2009:1). This investment appraisal method is the simplest way of evaluating the potential of an investment and is easily understood by people who are not familiar with investment appraisals, but should be used in conjunction with other appraisal methods (Correia *et al.*, 2010:8-10). It can be used as part of the initial screening of the investment or as additional information for further investment analyses.

According to Knapp and Jester (2000:2), the payback period method is commonly used when evaluating energy-efficiency projects. It is important to note that the payback period method is only as accurate as the cashflows indicated for each year. One should deduct any rebates received on the investment, for instance on a solar geyser and a heat pump, from the initial investment cost to ensure that the payback period is not overstated. This investment appraisal methods rules that the investment with the shortest payback period should be accepted (Bester, 2006:40).

#### ***Formula for payback period***

When the annual cash inflows are the same during the lifetime of the project, the payback period can be calculated as follows (Garrison *et al.*, 2008:642; Correia *et al.*, 2010:8-10):

$$\text{Payback period} = \frac{\text{Investment required}}{\text{Net annual cash inflows}}$$

However, if the annual cash inflows are not the same, the payback period is calculated by adding up the annual cash inflows, in annual order, until it is equal to the initial investment cost (Drury, 2008:304; Correia *et al.*, 2010:8-10).

#### ***Advantages of payback period***

According to Garrison *et al.* (2008:643-644), one of the main advantages of the payback period is that it gives an indication of what investments must be analysed further if a specified payback period was set before hand; for instance, any investment with a payback

period below two years. They further state that the payback period is especially important for investors with low cash supplies. In addition, this investment appraisal method is simple to calculate and gives some indication of the risk associated with the investment (Bester, 2006:39; Groppelli & Nikbakht, 2006:158; Kapil, 2011:384).

### ***Limitations of payback period***

Drury (2008:304), Garrison *et al.* (2008:642), Correia *et al.* (2010:8-10) and Bester (2006:40) state that there are a few limitations attached to using the payback period as the only investment appraisal method. These include the fact that the straight payback period method ignores the time value of money, and the benefits after the payback period are not taken into account; therefore, an investment with a smaller payback period will be ranked higher although the benefits later on may be less than an investment of which the payback period is a bit longer (Kapil, 2011:386). Bester (2006:40) further states that the payback period method does not really indicate if the value of the firm will be increased due to the investment, and may cause rejection of investments with a positive NPV. Therefore, the use of a simple payback period as the only investment appraisal method will not be sufficient, as it will not measure the true profitability of the investment (Garrison *et al.*, 2008:643), but it will help in making the right decision.

In order to mitigate the risk associated with the simple payback period not taking into account the time value of money, the discounted payback period could be used.

### ***Discounted payback period***

The discounted payback period is calculated by using the discounted cashflows; therefore, it will determine how long it will take to recover the initial investment cost, taking into account the required rate of return (Bućko, 2010:67; Drury, 2008:305; Correia *et al.*, 2010:8-12). According to Bhandari (2009:3), an investment is acceptable if the discounted payback period is less than the expected useful life of an investment or the time over which the investment is evaluated. Bhandari (2009:3) and Drury (2008:305) further state that by using the discounted payback period, all the useful properties of the simple payback period remain, but it additionally relates to the NPV and IRR. The discounted payback period will always be greater than the simple payback period. It might be that an investment measured by the simple payback period is in fact not profitable (Drury, 2008:305).

### ***Relevance of payback period for this study***

The payback period method gives an indication of how long it will take for the cashflows to cover the initial investment cost. This method is an easy way of determining if the investment will be worthwhile for the investor, and how long it will take the investor to recover the investment cost. Although this investment appraisal method must not be used as the only method for investment analysis, it can be useful when used in conjunction with other analyses. In order to relate to the NPV and the IRR and to overcome some of the limitations of the simple payback period, the discounted payback period will be relevant for this study.

### **3.2.6 Economic value added (EVA)**

EVA is the net operating profit after tax reduced by the cost of capital (Correia *et al.*, 2010:8-14); therefore, it is an indication of what portion of the net operating profit can be allocated to the equity holders after taking into account the economic cost associated with the investment. Therefore, EVA indicates the profitability of the investment (Zdeněk, 2011:71; Worthington & West, 2001:70; Sharma, 2010:201). The EVA is the calculation of the economic profit rather than the accounting profit as it takes into account the cost of capital employed, where accounting profit only considers the interest paid on loans (Lin & Zhilin, 2008:67).

Sharma (2010:201) states that the EVA takes into account the opportunity cost of all lost opportunities with regard to capital employed and therefore is an indication of whether the investment will meet the need of investors and determines whether they will earn the rate of return that they would have received if they had invested the money elsewhere. To increase the EVA of an investment, one must increase the earnings of the investment, reduce the amount of capital used or otherwise reduce the cost of capital (Correia *et al.*, 2010:8-15). The cost of capital is therefore one of the most important parts of the EVA equation (Sharma, 2010:201).

#### ***Formula for EVA***

$$EVA = NOPAT - (CE \times WACC)$$

Where:

NOPAT = Net operating profit

CE = Capital employed

WACC = Weighted average cost of capital

(Correia *et al.*, 2010:8-14; Lin & Zhilin, 2008:67; Ilic, 2010:94)

NOPAT does not take into account any non-operating expenditure, such as dividends paid (Sharma, 2010:201). The capital employed is the sum of shareholders' funds and loan funds and the WACC is a combination of the after tax interest rate paid on loans and the rate expected by shareholders on their investment.

### ***Advantages of EVA***

According to Zdeněk (2011;72), the advantages of using EVA is that it considers the risk associated with an investment, it can be used as a performance indicator, and it is fairly easy to calculate as it makes use of information from the financial statements. EVA is a good indication of the value of a company, and therefore it will affect the market price of the company's shares (Lin & Zhilin, 2008:67; Worthington & West, 2001:70).

### ***Limitations of EVA***

According to Hock (1999), there are basically four limitations associated with EVA. These include the following:

- EVA does not make provision for size differences between investment options as the EVA of a big investment will be higher than the EVA of a smaller investment.
- The financial numbers used within the EVA calculation can be manipulated in order for the investment to appear more financially viable (Abdeen & Haight, 2002:31).
- EVA focuses on short-term gains; therefore, the EVA for investments that do not generate profit immediately will be lower, unfairly indicating that it might not be a good investment (Shil, 2009:174).
- Lastly, EVA is very results orientated, but does not offer solutions on how to increase profitability, as it does not indicate where the main problem with an investment lies.

Sharma (2010:201) mentions that another problem with EVA is that the net operating profit after tax does not take into account the dividends paid out to investors, and therefore does not consider any non-operating expenditure.

### **Relevance of EVA for this study**

The EVA calculates the profitability of an investment with regard to the cost of the capital employed. This provides a clear understanding of what profit the investor will earn after taking into consideration the cost of capital, and whether it will be worthwhile to invest in the different water heating systems. With this in consideration, the EVA will be calculated in this study.

### **3.2.7 Profitability index (PI)**

The profitability index (PI) is very similar to the NPV method, but where the NPV indicates the difference between the present value of the future cash inflows and the initial investment cost, the PI calculates the ratio (Correia *et al.*, 2010:8-13). According to Karanovic, Baresa and Bogdan (2010:56), the profitability index is another way of stating the NPV of an investment as it is a ratio of the NPV of the investment over the initial investment, indicating whether the investor will reach its goal to make profit out of the investment. Correia (2010:9-14) states that the PI method will give the correct ranking when limited investment capital is available and an investor needs to choose the best value for money.

When calculating the PI and the outcome is exactly equal to 1, it means that the investment achieved the required rate of return; however, if the PI is greater than 1, the investment exceeded the goals of the investment (Karanovic *et al.*, 2010:56; Correia *et al.*, 2010:8-13).

### **Formula for PI**

The formula for PI is as follows (Attenhauser, 2008:3; Salehi, Ghorbani & Javid, 2011:2115; Correia *et al.*, 2010:9-13):

$$\text{Profitability index} = \frac{\text{Present value of future cashflows}}{\text{Initial cash investment}}$$

### **Advantages of PI**

The PI allows one to compare investments with different initial investment amounts, as it is not sensitive to the investment amount (Greer & Kolbe, 2003:298). Furthermore, it provides an indication of the proportion of money earned through the investment in relation to the

initial investment made; in other words, the increase in the firm's value (Peterson & Fabozzi, 2002:106).

### ***Limitations of PI***

The PI requires a cost of capital, which is difficult to calculate, and may cause the wrong decision to be made when mutually exclusive projects are compared (Peterson & Fabozzi, 2002:106). Furthermore, the PI does not provide any additional information other than what could have been gained by calculating the NPV, as the PI will never contradict the NPV (Attenhauser, 2008:4). Therefore, an investment with a positive NPV will always have a PI greater than 1. According to Karanovic *et al.* (2010:56), the PI is inferior to the NPV and must not be used as the only investment appraisal method. Godinho and Afonso (2004:12) state that most of the rate of return methods and ratios will give the ranking of projects, therefore making it unnecessary to perform both. In other words, the PI will provide more or less the same outcome as the IRR. The PI is inadequate to use whenever there is more than one constraint with regard to the choice of projects to invest in, and cannot be used when projects are mutually exclusive or when the investment in one project is dependent on the investment of another project (Brealey & Myers, 2003:97).

### ***Relevance of PI for this study***

The PI is a good method if one would consider investing in a combination of investments. This study does not focus on the combination of investments, but rather on what water heating system will be more financially viable to invest in. Therefore, the PI will not be considered in this study.

## **3.3 OTHER FACTORS TO CONSIDER**

Underlying to the above methods are a few factors to consider that are critical to the success of investment appraisals. These include the following:

### **3.3.1 Time value of money**

The time value of money refers to the value of money over a certain period of time. The value of R100 today is more than the value of R100 one year from now, due to interest that

can be earned over that period if the R100 were invested in an interest-earning environment (Garrison *et al.*, 2008:626). Fowles (s.a.) explains that by taking the time value of money into account, if you were promised R1 000 ten years into the future, you will be willing to take a lesser amount today, lets say R558 if the interest rate, on for instance a savings account, is 6%, as you will be fairly certain that the R558 will grow to R1 000 over a period of 10 years.

To take time value of money into account, it is important to understand what the impact of time value of money will be. In a study done by Mokhlesian, Ghomi and Jolai (2010:126), they determined the impact of time value of money on inventory control. In this study, it was evident that there are three important aspects to consider in order to understand the time value of money. The **future value** of all cashflows over a certain period of time, the **present value** of those cashflows, and the **discount rate** used to determine the percent value of the future cashflows.

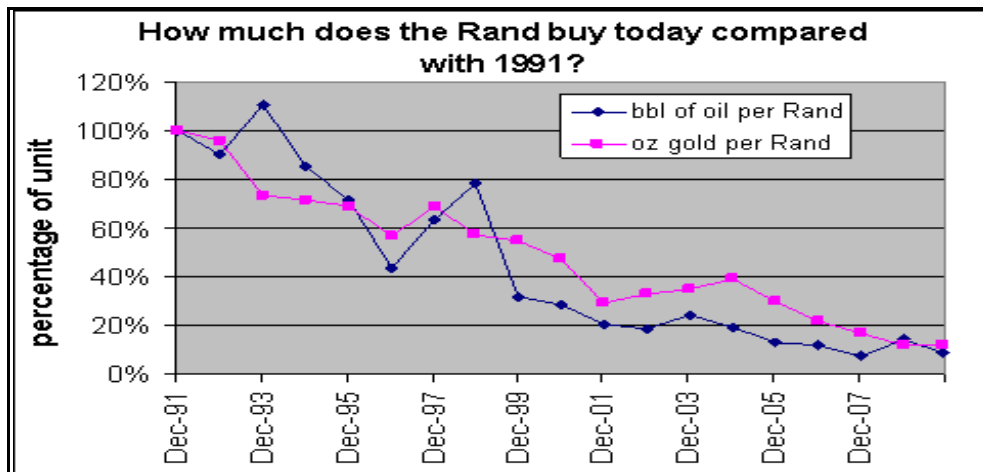
According to Sherrick, Ellinger and Lins (2000:1), there is a period of time between the inflow and outflow of cash within certain investments that results in different current values as the cashflows happen at different times in the future. Therefore, it will not be accurate to simply add up the different cashflows of each year and determine whether the NPV without discounting the cashflows with the discount factor for each year (Sherrick *et al.*, 2000:1).

When considering the above mentioned, it will be necessary for this study to take into account the time value of money in order to get the most accurate value of what can be expected by the different investment options in the future.

### **3.3.2 Inflation**

Although the time value of money addresses the interest/return that can be gained on a certain amount if it was invested today, another aspect of the value of money that needs to be considered is the purchasing power of money, and how it decreases over the years. As the rest of the world, the buying power of the South African Rand decreases every year, making the value of R1 today more than the value of R1 in the future. This is clearly indicated by Graph 3.1, where Galt (2009) shows the deterioration of the Rand's buying power since 1991.

**Graph 3.1: How much does the Rand buy today compared with 1991?**



Source: Galt, 2009

Inflation is a result of the demand in the market being more than the supply; therefore, prices increase although income may not necessarily increase (Hellerstein, 1997). According to the Trading Economist (2011), the average inflation rate for South Africa between 1981 and 2010 was 10%, with the latest inflation rate reported in July 2011 being 5.3%. The Trading Economist (2011) gave a graphic indication of the trends with regard to the South African inflation rate, as can be seen in Graph 3.2. In this graph, it is evident that the inflation rate is currently increasing.

**Graph 3.2: South African inflation rate**



Source: Trading Economist, 2011

When doing investment appraisals, inflation definitely needs to be taken into account, although it might not have an influence on the outcome of the appraisal (Garrison *et al.*, 2006:685; Drury, 2008:325; Correia *et al.*, 2010:9-6). This is only the case if the discount rate used reflects the market rate as the market rate already reflects the impact of inflation. The higher the inflation rate, the higher the market rate of return will be, and therefore cashflows need to be adjusted with inflation in order to be consistent (Garrison *et al.*, 2008:685; Drury, 2008:326; Correia *et al.*, 2010:9-6).

### **3.3.3 Weighted average cost of capital**

The weighted average cost of capital (WACC) is a combination of the cost of equity ( $K_e$ ) and the after tax cost of debt ( $K_d$ ), each carrying a certain percentage of weight (Wang & Hwang, 2010:252; Drury, 2008:329-330). In effect, the WACC is calculated with the assumption that a firm's financing mix is set and will therefore not be affected by any cashflows in the company (Wang & Hwang, 2010:255). According to Professor Stanley Block (2011:54) and Correia *et al.* (2010:7-2), the WACC, adjusted for investment risk, represents the interest rate at which investments are evaluated. Therefore, the WACC represents the minimum rate at which investors will be satisfied (Firer & Gilbert, 2004:41-42).

The discount rate acknowledges that a certain amount of money today is worth more in the future; therefore, a discount rate assigns weight to the value of future costs and benefits in order to measure the value of gains and losses consistently (Jeuland, 2010:185,202). The discount rate indicates the cost of lost opportunities to ensure that the postponement of those opportunities is accounted for and justified (Foltyn-Zarychta, 2010:290).

According to Savvides (1994:18), there was a great deal of debate on whether the discount rate must provide for risk. Some feel that the discount rate must be equal to the risk-free interest rate of a country, as they feel that the inclusion of risk is pre-judging the market, where others feel that the discount rate must include a premium to provide for market risk. Savvides (1994:18), however, feels that using the risk-free interest rate is unrealistic as this will set a standard for the investment that is below normal, and by including risk in the discount rate the analysis will stay valid and comparable. The impact on the present value is clear when looking at Foltyn-Zarychta's (2010:289) statement that a minimal change in the discount rate will have a substantial effect on the present value of the investment. Therefore, it will have an impact on the investment decision, especially when the investment is long term. For example, a discount rate change from 1 to 2% will reduce the present value of 1 000 000 after 100 years by 63% (from 369 711 to 138 033).

The formula to calculate the overall cost of capital is as follows (Drury, 2008:330; Correia *et al.*, 2010:7-4):

$$\text{WACC} = (\text{Proportion of debt capital} \times K_d) + (\text{Proportion of equity capital} \times K_e)$$

To calculate  $K_d$ , one uses after tax cost of raising new debt (Drury, 2008:329; Correia *et al.*, 2010:7-8). Correia *et al.* (2010:7-8) state that the cost of new debt should be market related. According to Wang and Hwang (2010:248), the most dominant method of calculating  $K_e$  is the use of the capital asset pricing model (CAPM). With the CAPM model, the assumption is made that there is a linear relationship between the beta of the asset and the required rate of return (Mard, Jones & Jenkins, 2009:21). The formula is as follows:

$$\text{Expected return on investment} = \text{Risk-free rate} + (\text{Expected return on the market portfolio} - \text{Risk-free rate}) \times \text{Beta}$$

Wang and Hwang (2010:255) advocate that it is incorrect to determine a set value for  $K_e$  as markets constantly change and the cost of equity differs over time, making a set WACC misleading. An incorrect discount rate can cause the current value of cashflows to be over- or under-stated (Cowling, Frankland, Hails, Kemp, Loseby, Orr & Smith, 2011:6). Abadie (2009:741) states that for each investment, a unique discount rate must be calculated that reflects the risk associated with the investment. The riskier the investment, the higher the discount rate will be.

Florio and Vignetti (2003:9) state that there are two options of achieving consistency with regard to discount rates:

- use the interest rate received on Government Bonds, which reflects the risk-free rate;
- or
- Use the prime rate of one of the biggest lenders in the market.

### **3.3.4 Discount rate for individuals**

To calculate the discount rate for individuals is a more challenging task. According to Teh, Teh and Sumaila (2011:898), the discount rate directly influences a person's willingness to trade, therefore the higher the discount rate of an investment, the more unwilling an investor

will be to invest in that investment. They also mention that an individual's discount rate is impacted by factors such as:

- **Income:** The annual income of an individual will impact the discount rate inversely; for example, the higher the individual's income, the lower his discount rate will be. Secondly, the higher the income of the individual, the lower the risk associated with the individual will be, as his payback ability on a loan will be much higher, making the interest rate charged lower.
- **Age:** Age impacts the discount rate in three stages. In an individual's childhood, the discount rate will be high. The discount rate will then decrease during adulthood, and will increase again when an individual reaches a certain age.
- **Education:** It is assumed that people with higher education will earn more income, decreasing the discount rate.

Lahav, Benzion and Shavit (2011:130) went further to state that a person's discount rate is affected by his willingness to wait; therefore, a person who focuses more on the present will have a higher discount rate than the person who is willing to wait. According to them, the discount rate of an individual is additionally affected by the amount of money needed for the investment as well as the direction of the investment. The amount needed and the time of the investment have a negative impact on the discount rate.

Determining an appropriate discount rate for an individual can be a difficult task. According to Verbruggen *et al.* (2011:907), private investors can only determine their appropriate discount rate within narrow ranges as there is no agreement from social investments as to what the accurate discount rate that will apply is. They state that there have been proposals for a discount rate of zero (to escape temporal myopia) to a very high discount rate (to avoid investing in the productive private sector), but currently it is acceptable to use a low discount rate for a social project. Harrison, Lau and Williams (2002:1616) did a study to determine a discount rate for individuals in Denmark, and found that the best way of determining a discount rate for an individual is to use the real economic commitments of the individual. They further stated that discount rates will differ from individual to individual, but that the discount rate will stay constant over the lifetime of the investment (Harrison *et al.*, 2002:1617).

According to Foltyn-Zarychta (2010:290), the discount rate for a private investment should be the market discount rate as this will lead to the optimising of the wellbeing of the investor; however, if a failure in the markets occurs, this rate will not be sufficient. It may be that the market discount rate is directly linked to the market interest rate. This will have an effect on the investment decision as investments are directly influenced by the interest rate; if the

interest rate increases, the investment value will decrease (Cicea *et al.*, 2009:94). Jeuland (2010:187) states that when the interest rate increases, individuals tend to focus more on saving, thereby decreasing consumption and investments. The discount rate used to evaluate investments for individuals is dependent on their real economic commitments, as stated by Glenn, Lau and Williams (2002:1616); for example, a bank loan or a savings account. If the individual has a bank loan, the discount rate will be equal to the interest rate paid on the bank loan. If the individual does not have a bank loan, his money would have been earning interest in a savings account or another investment; therefore, the discount rate will then be equal to the lost return rate.

As the interest rate paid/earned by each individual on their bank loan or savings account is different, the market discount rate will be used as the discount rate for the purpose of this study.

### **3.3.5 Time horizon**

The time horizon of a project analyses the quantitative qualities of the investment by determining how long the investment will last, by either looking at the ongoing investment needed or how long the benefits from the investment will still flow in (Dunbar, 2000). The time horizon of a project reflects the maximum number of years over which the project will be evaluated (Florio & Vignetti, 2003:6). According to them, this is a critical part of the investment appraisal as it will have an impact on the IRR. In other words, if the wrong time horizon is chosen, the IRR will not be accurate and this will have an impact on the investment decision. The time horizon can be an indication of the total lifetime of a project, or the time horizon can be set on a realistic standard (Floria & Vignetti, 2003:6-7).

### **3.3.6 Unequal lives**

When investments have unequal lives, it becomes difficult to accurately evaluate and compare the different investments, and incorrect ranking of options can happen (Pilotte, 2000:101). According to Pilotte (2000:102), investments that can only be invested in once, can be ranked by using the NPVs of the investment, but if the investment can be repeated, the investments need to be evaluated over the same time intervals. Therefore, the investments must be repeated until all of them provide services over the same number of years, better known as a replacement chain (Pilotte, 2000:102; Correia *et al.*, 2010:9-4). However, the main issue with investment with different life spans is that there will be different

options at different dates in the future, which might have different values and might affect the choices made by the investor (Brown & Davis, 1998:571; Correia *et al.*, 2010:9-3).

Brown and Davis (1998:572) as well as Correia *et al.* (2010:9-4) suggest that a possible solution to this problem is to compare the infinite NPV, also known as equivalent annual annuities (EAA), of each investment. To calculate this, the NPV for each investment option must be calculated over the expected lifetime of that specific investment (Brown & Davis, 1998:572), after which the equivalent annual annuity is calculated by using the following formula:

$$EAA = NPV / \text{present value factor of annuity for the useful life of the investment}$$

Where:

EAA = the equivalent annual annuity

NPV = the NPV calculated over the expected life time

Brown and Davis (1998:375), however, mention that there is no optimal solution to the challenges faced by investors when comparing investment with unequal lives. As these investment options are mutually exclusive, the equivalent annual annuity will be calculated for each of the alternatives.

However, investments that are independent from each other do not need to be comparable and must be accepted or rejected based on their NPV – the fact that they are unequal in life spans are irrelevant (Correia *et al.*, 2010:9-2).

### **3.3.7 Risk and method of mitigating risk**

It is clear from the above-mentioned investment appraisal methods that most of the inputs used in an investment appraisal are estimates of future spending. Because estimates are used, risks are created. These risks are mostly associated with the actual outcomes of the investment appraisal. Although Correia *et al.* (2010:10-2-10-16) mention several different risk assessment methods (sensitivity analysis, decision trees, probability distributions, expected values, certainty equivalents and scenario analysis), the most commonly used assessment methods are the sensitivity analysis and scenario analysis (Correia *et al.*, 2008:9-33).

There are also the traditional methods of mitigating risk, such as a probability distribution where a probability factor is allocated to each year's cashflow to determine the impact on the

outcome of the project appraisal (Correia *et al.*, 2010:10-3), giving expected values, but due to the scope of this study, these methods will not be discussed.

Because sensitivity analysis and scenario analysis are the most commonly used risk assessments, this study will only discuss these two methods.

### ***Sensitivity analysis***

A sensitivity analysis is a test to determine the impact on the outcome of an investment appraisal if one of the inputs to the appraisal will change (Savvides, 1994:1; Saltelli, 2002:579). According to Savvides (1994:1), the main purpose of a sensitivity analysis is to determine what the most sensitive inputs to the appraisal are, as these will be the most important variables of the analysis. The sensitivity analysis will give an indication to the investor as to what the impact on returns will be if one of the key variables changes.

There are various uses for a sensitivity analysis. These can be categorised into four main sections, which are decision-making, communication, quantification of the systems, and lastly, model development (Pannell, 1997).

Pannell (1997) states that one can use a sensitivity analysis for various reasons, but that one does not necessarily need to utilise all its uses at the same time. You can choose to test only one aspect of an investment appraisal. He states that the most common use of a sensitivity analysis is determining the sensitivity of the numerical numbers of an investment appraisal.

A sensitivity analysis gives an indication of what the critical variables are with regard to the investment. It will determine the impact on the results of the investment appraisal when one or several of the critical variables change. With this in mind, it will be important to determine what the impact on the investment outcome will be if the discount rate and energy consumption will change, as this will differ from household to household. Therefore, a numerical sensitivity analysis will be included in this study.

### ***Scenario analysis***

In addition to the sensitivity analysis, one can use a scenario analysis. A scenario analysis is where a number of the key variables change at the same time to create different views, for instance an optimistic and pessimistic view (Savvides, 1994:1). With the use of a scenario analysis, a broad range of outcomes can be calculated, which will help in facilitating

decision-making, as risks will be identified and the impact on outcomes due to the risks will be calculated (Karl, 2009).

Although scenario analysis is a way of mitigating risk, this model has several weaknesses that can cause an investor to make incorrect decisions. According to Karl (2009), these weaknesses include the quality of the model used, the quality of the data used as inputs to the model, as well as the quality of the person or team performing the scenario analysis. One of the biggest limitations of a scenario analysis is that it does not provide a probability of the scenario occurring; therefore, decisions can be made on an scenario analysis, but the likelihood of the scenario happening may be very low (Markham & Palocsay, 2006:29)

### ***Relevant risk assessment for this study***

For the purpose of this study, only a sensitivity analysis will be performed, as a scenario analysis does not provide an indication of the probability of the scenario happening, and this can lead to incorrect decisions. The sensitivity analysis will focus on the numerical aspects of the investment appraisal.

## **3.4 SUMMARY**

In order for investors to make the correct choice between different investment options, they need to use different investment appraisal methods. There are several appraisal methods available to use in order to make the correct decision. These include a CBA, NPV, IRR, ARR, payback period and EVA. Each of these appraisal methods has their pros and cons associated with them, with each of them relevant within different scenarios. After careful consideration, the investment appraisal methods that will be used in this study include the NPV method (including the equivalent annual annuity (EAA)), the IRR method (including the MIRR), the payback period, a sensitivity analysis as well as the calculation of the EVA.

As most of the investment appraisal methods rely on different assumptions and estimations made by the analyst, there is risk associated with the results generated by the investment appraisals. To mitigate some of these risks, one can do a sensitivity analysis or a scenario analysis by which the impacts on results are determined. For the purposes of this study, only a sensitivity analysis will be performed to determine what inputs have a substantial impact on results.

With this chapter, the second specific objective has been achieved, namely to conceptualise from the literature the relevance of different investment appraisal techniques in deciding on the most financially viable option as alternative to the conventional geyser to reduce electricity usage in order to generate hot water.

Chapter 4 will discuss the methodology used in order to conduct this study.

## **4. CHAPTER 4: RESEARCH DESIGN AND METHOD**

### **4.1 INTRODUCTION**

This chapter will provide a detailed overview of how this study was conducted. The proposed research method (par 1.5), consisting of two phases, a literature review and an empirical study, will be discussed.

The first step of this study was to specify the research question as clear as possible (Humphrey & Lee, 2008:265; Ryan, Scapens & Theobald, 2002:153). This was done in conjunction with the first phase of this study, a proper literature review, in order to obtain a better understanding of the current research available (Humphrey & Lee, 2008:265; Ryan *et al.*, 2002:153). A literature review is a study of different trends and debates in order to provide an overview of a specific discipline (Mouton, 2008:179). The study of trends and debates is done by reading multiple sources and theories relevant to the study in order to obtain a better understanding of the discipline (Mouton, 2008:179-180), and to determine the way in which the research should be approached (Humphrey & Lee, 2008:265).

The literature review was used to discuss the different water heating alternatives, and to determine the investment appraisal methods to utilise in the second phase of this study, which was an empirical study to determine the results of the most financially viable investment options between five alternative water heating systems. The literature was used to understand the result, and a comparison between the results was drawn.

In this chapter, the objectives of this study are mentioned, and the reasoning behind the research design as well as the research methodology is discussed. The research methodology focuses on the inputs to the investment appraisals, followed by how the different investment appraisal methods will be performed.

### **4.2 OBJECTIVE OF THIS STUDY**

The general objective of this study is to determine the most financially viable investment in order to reduce electricity cost when it comes to water heating (par. 1.4.1). In order to reach the general objective, the specific objectives of this study are as follows (par 1.4.2):

- To consider the financial impact of a conventional geyser with regard to the average electricity bill, as well as alternative options that can reduce the electricity usage in order to generate hot water.
- To consider from the literature the relevance of different investment appraisal methods.

- To consider, within the context of both high and low volume consumption households, the investment cost, net present value, IRR, MIRR, ARR, payback period and EVA for a solar water heating system, a time switch on a conventional geyser, a heat pump, a gas geyser and an instant heater.
- To provide recommendations regarding the most financially viable water heating system for a household, depending on the volume of hot water consumption.

## **4.3 RESEARCH APPROACH**

### **4.3.1 Frame of reference**

A research project usually addresses “real life” problems, such as problems in the social and physical world (Mouton, 2008:137). In order to describe and clarify all aspects of the research, the “Three Worlds” framework is used (Mouton, 2008:137). Within this framework, Mouton (2008:137) mentions three “worlds” wherein a research problem can occur:

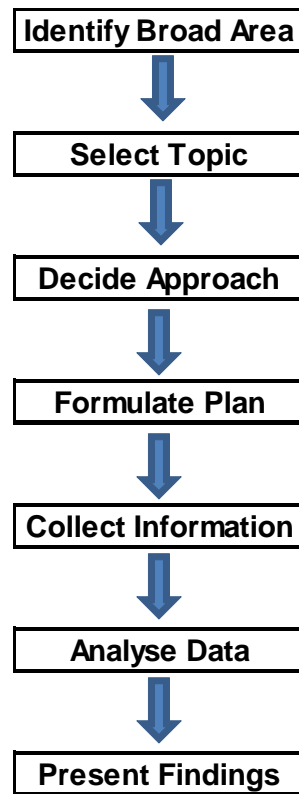
- World 1: The world of everyday life and lay knowledge. This world is the one where we live as ordinary humans everyday, with different contexts such as family, work, church and more.
- World 2: The world of science and scientific research. Within this world, phenomena from World 1 are formed into an objective of inquiry. This is a world of science, where the search for truthful knowledge is the main goal.
- World 3: The world of meta-science. This world goes beyond the main goal of World 2 and focuses on the reason and nature of what science is about.

This study takes an area from World 1, alternative water heating systems, and researches it to find truthful knowledge on the subject in order to determine the financial implication of alternative water heating systems. Therefore, this study is part of World 2.

### **4.3.2 Research design**

When conducting accounting research, there is a series of stages that needs to be followed in order to progress. Malcolm Smith (2011:14) calls this the research sequence (Figure 4.1):

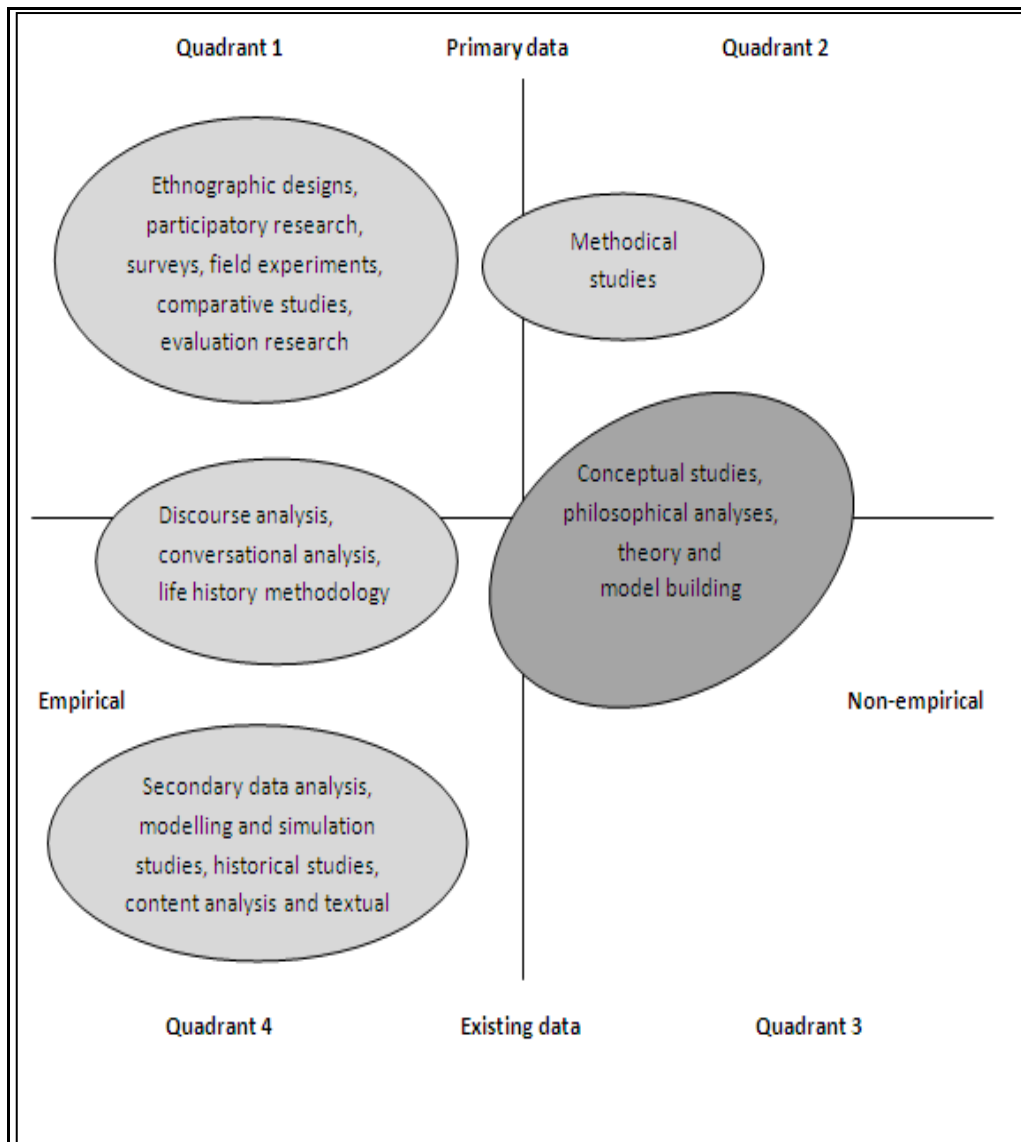
**Figure 4.1: The research sequence**



Source: Smith, 2011:15

This sequence is relevant to most forms of accounting research in order to progress from the original idea to publication (Smith, 2011:14). In order to reach a conclusion, a research design, which is most suitable for the study, needs to be selected. The researcher will choose a research design based on assumptions, the skill level of the researcher and research practices (Maree, 2010:70). Mouton (2008:143) mentions several different research designs. These designs are indicated in Figure 4.2 (Mouton, 2008:144). This study represents an ethnographic design, also called a case study, which focuses on a small number of cases within a social environment, namely a household; therefore, this study will fall within quadrant 1 of Figure 4.2 (Mouton, 2008:144) and represents an empirical study.

**Figure 4.2: Mapping designs (Level 1)**

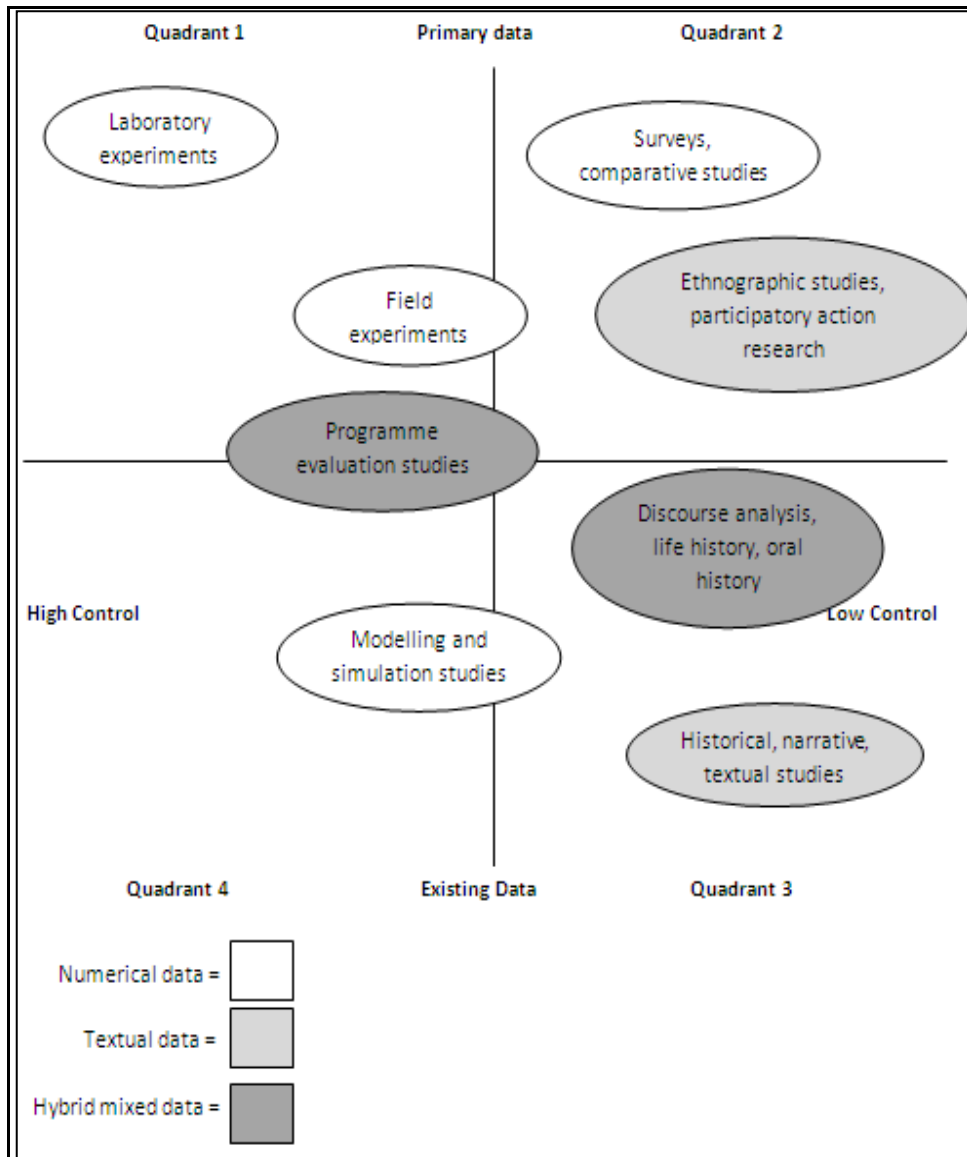


Source: Mouton, 2008:144

Mouton (2008:145) mentions that for an empirical study, depending on the research design, the use of primary and existing data will determine the level of control of the researcher. According to Mouton (2008:145), an ethnographic study or case study will use primary data and will therefore have low control. This is true to some extent in this study as the data used in the investment appraisal were gathered through several quotations, and therefore represent new data. However, some of the data used were gathered through existing sources. This will, however, still keep the control on this study low, meaning that if another individual were to do the same study, the outcome would not necessarily be the same as they would not get the same quotations from suppliers, and might make other assumptions

from the results of the investment appraisals. Looking at Figure 4.3 (Mouton, 2008:145), this study will fall within the top right quadrant.

**Figure 4.3: Mapping designs (Level 2)**



Source: Mouton, 2008:145

### 4.3.3 Research methodology and measuring instruments

A case study approach was used, as this study tried to form a universal truth by generalising a sample of the population, by making use of averages and variances (Smith, 2011:54). The sample will rarely be representative of the full picture, but the anomalies and outliers can be

identified and an analysis of the situation can be generated (Smith, 2011:54). This study did not focus on only one alternative water heating system or one investment appraisal technique, but made use of multiple sources and techniques to answer the research question (Maree, 2010:76).

The following investment appraisal techniques were used in order to measure the financial viability of each of the alternative water heating systems:

- Net present value;
- Equivalent annual annuity;
- Internal rate of return;
- Modified internal rate of return;
- Accounting rate of return;
- Discounted payback period; and
- Economic value added.

#### **4.4 STUDY POPULATION**

Five alternative water heating systems were evaluated in this research study. These alternatives include a:

- Solar geyser;
- Time switch;
- Heat pump;
- Gas geyser; and
- Instant heaters

Each of these alternatives was discussed in detail in Chapter 2, where a literature review was conducted on the technical as well as the financial aspects of each of these alternatives. Most of these alternatives are commonly used within South Africa, except for an instant heater, which is not that well established in the country, but is popular within countries like America. Limited academic papers were available on these systems, except for the solar geyser and heat pump, as not many studies were done on the effectiveness and the functioning of these systems.

Each of these alternatives generates a saving in electricity usage on a conventional geyser to some extent, and therefore will generate a cost saving for the investor. It was the objective of this study to calculate the financial viability of each of the alternatives in order to

determine the best investment option for a household with low volume hot water consumption, and a household with high volume hot water consumption.

The investment appraisals were performed to determine the best investment option for a household with low volume hot water consumption and a household with high volume hot water consumption. From the literature it was determined that an average of four people stay in a household with low volume hot water consumption and that an average of six people stay in a household with high volume hot water consumption.

Different investment appraisal methods were used within this study to determine the financial viability of the alternatives. The different investment appraisal methods were discussed in Chapter 3. From the literature review, the relevance of the investment appraisal methods, for the purpose of this study, were determined. Those appropriate were used for the empirical study in Chapter 5. The empirical study was performed by making use of the NPV, EAA, IRR, MIRR, ARR, discounted payback period and EVA investment appraisal methods.

#### **4.5 FACTORS AFFECTING APPRAISAL INPUTS**

The following factors do not necessarily represent an amount or percentage in the investment appraisal calculation, but have a fundamental impact on the outcome of this study, as these form the baseline from which further assumptions and calculations are made.

##### **4.5.1 Geyser temperature**

For the purpose of this study, Mr J Dreyer (Dreyer, 2011), an engineer at Eskom, used a maximum temperature for a conventional geyser of 75°C, as well as a 65°C element activation temperature, which is the water temperature at which the geyser element will switch on again (par. 2.2). According to him, 75°C is the normal temperature at which most household geysers are set. Mr J Dreyer created the heat switching model especially for this study to determine the energy cost associated with a conventional geyser (par. 1.5.2) (see Annexure A). In this heat switching model, he indicated what cost saving could be realised if the maximum temperature of a conventional geyser was lowered to 65°C, as well as an element activation temperature of 55°C.

To conclude: The maximum temperature of a conventional geyser, for the purpose of this study, is 75°C.

#### 4.5.2. Average hot water consumption per person

A study done by Meyer (2000:59) indicates that the average hot water usage per person in South Africa is 60 litres per day. Therefore, this is the usage that will be used for the purpose of this study.

#### 4.5.3 Average electricity usage per year

The average electricity usage per month was calculated by Mr J Dreyer (Dreyer, 2011) by using his heat switching model. To determine the electricity usage per month the assumption was made that the 60 litres of hot water consumption per person per day are spread over the day (par. 2.3.2). Bourke and Bansal's (2010:1771) table was used in the heat switching model to determine how much electricity is used to heat water for domestic use (see Table 4.1).

**Table 4.1: Standard daily load profile**

<b>Daily load profile</b>	
<b>Time</b>	<b>Proportion</b>
06:00	5%
08:00	16%
10:00	15%
12:00	11%
14:00	8%
16:00	7%
18:00	11%
20:00	13%
22:00	11%
23:00	3%
<b>Total</b>	<b>100%</b>

Source: Bourke & Bansal, 2010:1771

The outcome was as follows (Dreyer, 2011):

**Table 4.2: Electricity usage of a conventional geyser**

Water consumption	Size of household	Average temperature	Electricity usage per day	Electricity usage per month
[litre/day]	# persons	[°C]	[kWh]	[kWh]
60	1	69.733	12.410	372.30
120	2	68.688	15.438	463.15
180	3	69.660	17.327	519.80
240	4	69.839	20.371	611.12
300	5	69.826	24.044	721.32
360	6	69.903	26.517	795.50
420	7	69.925	29.296	878.87
480	8	69.940	32.329	969.87
540	9	70.039	34.803	1044.10
600	10	69.923	38.306	1149.17

Source: Dreyer, 2011

It will be difficult to determine what the average number of days is that the occupants in the household will be away from home. Therefore, the monthly electricity usage will be multiplied by 12 to determine the annual electricity usage.

#### **4.5.4 Cost of annual electricity usage**

Eskom charges block rates dependent on the kWh used; the more kWh one uses, the higher the rate charged (Eskom, 2010b) (par. 2.2). Mr J Dreyer used the block tariffs charged by Eskom for residential users, as can be seen in Table 4.3.

**Table 4.3: Block tariffs**

Eskom block tariffs – Applicable from 1 April 2011*				
Block	Rate	Units	Usage lower limits	Usage Upper limit
Block 1	0.6572	[R/kWh]	> 0 kWh	<= 50 kWh
Block 2	0.7542	[R/kWh]	> 50 kWh	<= 350 kWh
Block 3	1.095	[R/kWh]	> 350 kWh	<= 600 kWh
Block 4	1.201	[R/kWh]	> 600 kWh	∞

Source: Dreyer, 2011

After taking the block tariffs into account, Mr J Dreyer calculated the monthly electricity cost and came to the following conclusion (Dreyer, 2011):

**Table 4.4: Electricity cost per month**

Water consumption	Size of household	Average temperature	Electricity usage per day	Electricity usage per month	Cost per month	Percentage increase/decrease
(litre/day)	# persons	(°C)	(kWh)	(kWh)	(R)	(%)
60	1	69.733	12.410	372.30	288.39	Base state
120	2	69.688	15.438	463.15	387.87	Base state
180	3	69.660	17.327	519.80	449.90	Base state
240	4	69.839	20.371	611.12	670.36	Base state
300	5	69.826	24.044	721.32	802.71	Base state
360	6	69.903	26.517	795.50	891.80	Base state
420	7	69.925	29.296	878.87	991.93	Base state
480	8	69.940	32.329	969.87	1101.22	Base state
540	9	70.039	34.803	1044.10	1190.36	Base state
600	10	69.923	38.306	1149.17	1316.56	Base state

Source: Dreyer, 2011

To determine the annual electricity cost, the monthly cost will be multiplied by 12.

By taking inflation into account, the annual electricity cost of a conventional geyser will be calculated by using the annual cost of a conventional geyser, as calculated by Mr J Dreyer in his heat switching model, and then increasing it in 2012 with 25% (par 2.1) and from 2013 onwards by 10%, which is the average inflation rate (par 3.3.2). The annual electricity cost from 2011 onwards will be as follows:

**Table 4.5: Annual cost of a conventional geyser**

Household size	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	R	R	R	R	R	R	R	R	R	R
% increase	Base state	25%	10%	10%	10%	10%	10%	10%	10%	10%
1	3,476.68	4,345.85	4,780.44	5,258.48	5,784.33	6,362.76	6,999.03	7,698.94	8,468.83	9,315.72
2	4,654.44	5,818.05	6,399.86	7,039.84	7,743.82	8,518.21	9,370.03	10,307.03	11,337.73	12,471.51
3	5,398.80	6,748.50	7,423.35	8,165.69	8,982.25	9,880.48	10,868.53	11,955.38	13,150.92	14,466.01
4	8,044.32	10,055.40	11,060.94	12,167.03	13,383.74	14,722.11	16,194.32	17,813.75	19,595.13	21,554.64
5	9,632.52	12,040.65	13,244.72	14,569.19	16,026.11	17,628.72	19,391.59	21,330.75	23,463.82	25,810.20
6	10,701.60	13,377.00	14,714.70	16,186.17	17,804.79	19,585.27	21,543.79	23,698.17	26,067.99	28,674.79
7	11,903.16	14,878.95	16,366.85	18,003.53	19,803.88	21,784.27	23,962.70	26,358.97	28,994.86	31,894.35
8	13,214.64	16,518.30	18,170.13	19,987.14	21,985.86	24,184.44	26,602.89	29,263.18	32,189.49	35,408.44
9	14,284.32	17,855.40	19,640.94	21,605.03	23,765.54	26,142.09	28,756.30	31,631.93	34,795.12	38,274.64
10	15,798.72	19,748.40	21,723.24	23,895.56	26,285.12	28,913.63	31,805.00	34,985.50	38,484.04	42,332.45

Household size	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	R	R	R	R	R	R	R	R	R	R
% increase	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
1	10,247.29	11,272.02	12,399.22	13,639.14	15,003.05	16,503.36	18,153.69	19,969.06	21,965.97	24,162.57
2	13,718.66	15,090.52	16,599.58	18,259.53	20,085.49	22,094.04	24,303.44	26,733.78	29,407.16	32,347.88
3	15,912.61	17,503.87	19,254.26	21,179.68	23,297.65	25,627.42	28,190.16	31,009.18	34,110.09	37,521.10
4	23,710.11	26,081.12	28,689.23	31,558.15	34,713.97	38,185.36	42,003.90	46,204.29	50,824.72	55,907.19
5	28,391.22	31,230.35	34,353.38	37,788.72	41,567.59	45,724.35	50,296.78	55,326.46	60,859.11	66,945.02
6	31,542.27	34,696.49	38,166.14	41,982.76	46,181.03	50,799.14	55,879.05	61,466.95	67,613.65	74,375.01
7	35,083.79	38,592.16	42,451.38	46,696.52	51,366.17	56,502.79	62,153.07	68,368.37	75,205.21	82,725.73
8	38,949.29	42,844.22	47,128.64	51,841.50	57,025.65	62,728.22	69,001.04	75,901.14	83,491.26	91,840.38
9	42,102.10	46,312.31	50,943.54	56,037.89	61,641.68	67,805.85	74,586.44	82,045.08	90,249.59	99,274.55
10	46,565.69	51,222.26	56,344.49	61,978.94	68,176.83	74,994.52	82,493.97	90,743.36	99,817.70	109,799.47

Household size	2031
	R
% increase	10%
1	26,578.83
2	35,582.67
3	41,273.21
4	61,497.91
5	73,639.52
6	81,812.51
7	90,998.30
8	101,024.42
9	109,202.01
10	120,779.42

Source: Dreyer, 2011

#### 4.5.5 Size of the household

As this study will determine which hot water heating system will be the most financially viable for a household with low volume hot water consumption, as well as for a household with high volume hot water consumption, it is important to determine the size of each of the households.

For a household with low volume hot water consumption, the household size will represent four occupants as that was the average lowest according to a study done by Napier, Beghin, Higgs and Powell (FinScope, 2009:2).

For a household with high volume consumption, the household size will represent six people, as the same study by Napier *et al.* (FinShope, 2009:2) showed that the average highest household within South Africa is six people (rounded).

#### 4.6 INVESTMENT APPRAISAL INPUTS

The investment appraisal inputs will be discussed in the order in which they appear in the calculations. Therefore, all the costs will be discussed first and then the savings. Under each section of the investment appraisal, a separate discussion will follow on the inputs of each of the five investment options that will be investigated in this study.

#### 4.6.1 Costs

Costs represent any outflow of cash at the beginning, or during the investment assessment period, which represents the resources used to fund and maintain the investment (Adhikari & Supakankunti, 2010:128-129). These costs include the initial investment costs, the installation costs associated with each investment option, as well as maintenance costs and any additional costs. The rebate receivable from Eskom will also be covered under this section; however, although it is an inflow of cash, for the purpose of this study, it will be seen as part of the investment cost.

VAT will be calculated on the average cost before VAT, as not all suppliers are VAT registered. The South African VAT rate is 14% (SARS, s.a.).

#### ***Investment cost***

The investment cost of each alternative water heating system was determined by calculating the average investment cost from three quotations received. The quotations were gathered from suppliers of hot water heating systems. Included in the quotation is the installation cost associated with the investment as this forms an integral part of the investment appraisal. The investment cost takes place in year 0, as the total amount needs to be paid immediately in order to install the hot water heating system.

#### *Solar geyser*

The three quotations used in this study with regard to a solar geyser were received from the following suppliers:

- Kayema (R14 691.11) (Aspeling, 2011)
- Hudor Solar (R10 860.40) (Botha, 2011)
- Solar Heat Exchangers (Pty) Ltd (R14 200.00) (Russell, 2011)

The average investment cost before VAT (without installation cost) of a solar geyser is calculated as follows:

$$(R14\ 691.11 + R10\ 860.40 + R14\ 200.00)/3 = \mathbf{R13\ 250.50}$$

Investment cost of a solar geyser, including VAT, can therefore be calculated as:

$$R13\ 250.50 \times 1.14 = \mathbf{R15\ 105.57}$$

### Time switch

The three quotations used in this study with regard to a time switch were received from the following suppliers:

- Mr Power (R995.00) (Rossouw, 2011)
- Solar corporation (R995.00) (Cronjé, 2011b)
- FC Mulder Electrical CC (the assumption is made that the time switch will cost R995.00 as the cost of the time switch and the installation cost were not separated in this quotation) (Mulder, 2011a)

The average investment cost before VAT of a time switch is calculated as follows:

$$(R995.00 + R995.00 + R995.00)/3 = \mathbf{R995.00}$$

Investment cost of a time switch, including VAT, can therefore be calculated as:

$$R995.00 \times 1.14 = \mathbf{R1\ 134.30}$$

### Heat pump

The three quotations used in this study with regard to a heat pump were received from the following suppliers:

- ITS Heat Pumps (R15 168.00) (Settas, 2011)
- Solar Corporation (R13 442.00) (Cronjé, 2011a)
- The Eco Surgeon (R11 492.56) (Swanepoel, 2011)

In two of the three quotations, the installation costs were included in the original price and were not shown separately; therefore, the average investment cost for the heat pump will include the installation cost. The third quotation's installation cost is also reflected in the quoted price indicated above. This will not be calculated separately.

The average investment cost before VAT of a heat pump is calculated as follows:

$$(R15\ 158.00 + R13\ 442.00 + R11\ 492.56)/3 = \mathbf{R13\ 365.19}$$

Investment cost of a heat pump, including VAT, can be calculated as:

$$R13\ 367.52 \times 1.14 = \mathbf{R15\ 236.32}$$

### Gas geyser

The three quotations used in this study with regard to a gas geyser were received from the following suppliers:

- The Gas Experts (R11 285.00) (Geysers, 2011)
- Gas 2 U (R6 098.00) (Gas 2 U, 2011)
- Lingro Gas Appliances (R2 692.99 x 2 = R5 385.98) (Curnick, 2011) (The reason why this quote is multiplied by two is because this gas geyser type works on the same principle as an instant heater)

Included in the quotations are two 48kg gas bottles, needed to supply the geyser with gas. Not all the quotations include the price of the gas bottles; therefore, an additional R500 is added to include two 48kg gas bottles as indicated on the quotation received from Gas 2 U. These bottles are fully filled when installation takes place, but after the consumption of the gas included in the quotation, the refill will be seen as operational/additional cost. If the average monthly cost (which will be discussed in detail under additional costs) is taken into account, the gas supplied during installations will last around five months (R1 584.00 to fill up the two bottles, divided by the average monthly cost of R320.26 = 4.95 months).

The average investment cost before VAT of a gas geyser is calculated as follows;

$$(R11\ 285.00 + R6\ 098.00 + R5\ 385.98)/3 = \mathbf{R7\ 589.66}$$

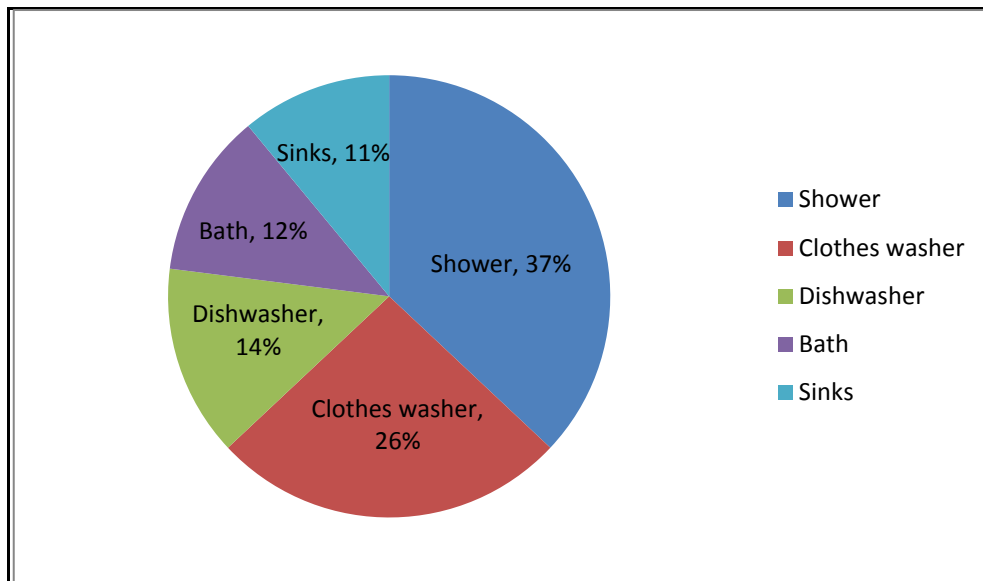
Investment cost of a gas geyser, including VAT, can be calculated as follows:

$$R7\ 589.66 \times 1.14 = \mathbf{R8\ 652.21}$$

### Instant heater

One instant heater can only service one room in a house; therefore, more than one needs to be installed. One will need to install an instant heater in the kitchen and one in the bathroom. This assumption derives from the graph created by Energy Star (2011?) (par 2.3.5.2), where it is shown that most of the hot water usage within a household is in the bathroom and the kitchen (see Figure 4.4). For the purpose of this study, the assumption is made that by installing an instant heater within the bathroom and the kitchen, all the hot water outlets will be covered.

**Figure 4.4: Hot water usage**



Source: Energy star, 2011

Instant water heaters are not used to a great extent in South Africa as yet, thereby making it difficult to find suppliers and installers of instant water heaters.

The quotations for an instant water heater were received from:

- Enintech (R1 930.00 + R2 300.00) = R4 230.00 (Liebenberg, 2011)
- Stiebel Electron (R1 600.00 + R3 600.00) = R5 200.00 (Mocké, 2011)
- Jamison (R2 300.00 + R2 300.00) = R4 600.00 (Jamison, 2011)

The average investment cost before VAT of an instant heater is calculated as follows:

$$(R4\ 230.00 + R5\ 200.00 + R4\ 600.00)/3 = \mathbf{R4\ 676.66}$$

Investment cost of an instant heater, including VAT, can therefore be calculated as:

$$R4\ 676.66 \times 1.14 = \mathbf{R5\ 331.39}$$

### ***Installation cost***

The installation cost for each of the investment options represents the average installation cost calculated from the three quotations received. In most cases, one cannot install the water heating systems without the help of professionals. Therefore, the installation cost

represents an important part of the investment cost. The installation cost will occur at the same time as the initial investment cost, as no benefit will be gained if the hot water systems are not installed properly.

### Solar geyser

The installation costs quoted on each of the three quotations used in this study with regard to a solar geyser were as follows:

- Kayema (R6 722.22) (Aspeling, 2011)
- Hudor Solar (R4 400.00) (Botha, 2011)
- Solar Heat Exchangers (Pty) Ltd (R6 705.00) (Russell, 2011)

The average installation cost before VAT of a solar geyser is calculated as follows:

$$(R6\ 722.22 + R4\ 400.00 + R6\ 705.00)/3 = \mathbf{R5\ 942.41}$$

Installation cost of a solar geyser, including VAT, can be calculated as follows:

$$R5\ 942.41 \times 1.14 = \mathbf{R6\ 774.35}$$

### Time switch

The installation costs quoted on each of the three quotations used in this study with regard to a time switch were as follows:

- Mr Power (R450.00) (Rossouw, 2011)
- Solar Corporation (R390.00) (Cronjé, 2011b)
- FC Mulder Electrical cc (R255.00) (Mulder, 2011a)

The average installation cost before VAT of a time switch is calculated as follows:

$$(R450.00 + R390.00 + R255.00)/3 = \mathbf{R365.00}$$

Installation cost of a time switch, including VAT, can be calculated as follows:

$$R365.00 \times 1.14 = \mathbf{R416.10}$$

### Heat pump

In two of the three quotations, the installation costs were included in the original price and not showed separately, and for the third quote, it was showed separately, but it was added to

the investment cost. Therefore, the average investment cost for the heat pump includes the installation cost. This will not be calculated separately.

### Gas geyser

The installation costs quoted on each of the three quotations used in this study with regard to a gas geyser were as follows:

- The Gas Experts (R2 750.00) (Geysers, 2011)
- Gas 2 U (R3 450.00) (Gas 2 U, 2011)
- Gasin (R3 500.00) (Levesque, 2012)

The average installation cost before VAT of a gas geyser is calculated as follows:

$$(R2\ 750.00 + R3\ 450.00 + R3\ 500.00)/3 = \mathbf{R3\ 233.33}$$

Installation cost of a gas geyser, including VAT, can be calculated as follows:

$$R3\ 233.33 \times 1.14 = \mathbf{R3\ 686.00}$$

### Instant heater

Because instant heaters are not that popular in South Africa as yet, most of the suppliers do not install the instant heaters themselves. According to Grant Mocké from Stiebel-Electron (2011), the instant heater can be installed by a qualified electrician. The following quotes were received for the installation of two instant heaters, one in the kitchen and one in the bathroom:

- FC Mulder Electrical cc ((R1 450.00 x 2) = R2 900.00) (Mulder, 2011b)
- Electrozone Electrical ((R750.00 x 2) = R1 500.00) (Essack, 2012)
- The Electro Surgeon ((R585.00 + R420.00 + R420.00) = R1 425.00) (Jooste, 2012)

The average installation cost before VAT for an instant heater is calculated as follows:

$$(R2\ 900.00 + R1\ 500.00 + R1\ 425.00)/3 = \mathbf{R1\ 941.67}$$

Installation cost for a time switch, including VAT:  $R1\ 941.67 \times 1.14 = \mathbf{R2\ 213.50}$ .

### **Rebate**

Eskom only grants a rebate on the installation of a solar geyser and a heat pump. This rebate is included as a separate line at the bottom of all the quotations received for these

two options, but not taken into account within the investment cost section of this study; therefore, the average rebate will be calculated.

### Solar geyser rebate

The rebates quoted on each of the three quotations used in this study with regard to a solar geyser were as follows:

- Kayema (R3 843.00) (Aspeling, 2011)
- Hudor Solar (R5 904.00) (Botha, 2011)
- Solar Heat Exchangers (Pty) Ltd (R5 332.00) (Russell, 2011)

The average rebate of a solar geyser is calculated as follows:

$$(R3\ 843.00 + R5\ 904.00 + R5\ 332.00)/3 = \mathbf{R5\ 026.33}$$

### Heat pump rebate

The rebates quoted on each of the three quotations used in this study with regard to a heat pump were as follows:

- ITS Heat Pumps (R3 668.00) (Settas, 2011)
- Solar Corporation (R3 668.00) (Cronjé, 2011a)
- The Eco Surgeon (R3 668.00) (Swanepoel, 2011)

The average rebate of a heat pump is calculated as follows:

$$(R3\ 668.00 + R3\ 668.00 + R3\ 668.00)/3 = \mathbf{R3\ 668.00}$$

### ***Maintenance cost***

Any water heating system has maintenance of some kind in order to extend the useful life of the system. These costs seem not to be a significant cash outflow and not of a regular basis. For this reason, maintenance cost will not be included in the investment appraisals as all water heating systems have these costs and it is difficult to calculate an annual value for maintenance cost.

### ***Additional costs***

A gas geyser saves 100% on energy consumption of a conventional geyser, but in order to do this, the electricity is replaced by the use of gas.

#### Gas geyser

In order for a gas geyser to function, two 48kg gas bottles are required to supply the gas to the geyser. To fill the two 48kg gas bottles will cost R1 584.00, calculated at a unit price of R16.50 per kg of gas (Gas 2 U, 2011).

According to Solien Energy Solutions (2007) and Geyser (2011), the average cost of gas used on a monthly basis adds up to around R320.26. Therefore, the annual operating cost for a gas geyser is  $R320.26 \times 12 = \mathbf{R3\ 843.12}$ .

This cost is an average, of which the number of occupants in the household is not known, and therefore this average will be used in both investment appraisals. It is important to remember that this cost can be more or even less than the amount stated above. This annual cost will be multiplied by the average inflation rate for each year.

### **4.6.2 Cost savings**

Cost saving represent the return that will be generated in the future if the investment takes place (Correia *et al.*, 2010:8-17).

#### ***Energy saving***

Within this study, the cost savings will mainly be the savings generated due to the reduction in electricity consumption by each of the five investment options. This will represent a percentage of the electricity consumption of a conventional geyser. These savings are as follows:

#### *Energy saving on a solar geyser*

By installing a solar geyser, the monthly electricity cost of a conventional geyser can be reduced by as much as 40% (Nyatsanza *et al.*, 2008) (par 2.3.1.2). However, according to Home Comfort (s.a.), a solar geyser supplier, a solar geyser can save up to 80% of the energy consumption of a conventional geyser.

For the purpose of this study, a solar geyser will save 40% of the energy used by a conventional geyser.

Energy saving on a time switch

Mr J Dreyer (2011) calculated the impact on energy consumption in a household if a time switch was installed (par. 2.3.2.2). Table 4.5 indicates the percentage saving created by a time switch for the different numbers of people living in the household.

**Table 4.6: Percentage saving from a time switch**

Water consumptions	Size of household	Average temperature	Electricity usage per day	Electricity usage per month	Cost per month	Percentage increase/decrease
[litre/day]	# persons	[°C]	[kWh]	[kWh]	[R]	[%]
60	1	62.902	8.243	247.30	181.66	- 37.01
120	2	60.783	9.510	285.30	210.32	- 45.77
180	3	59.031	10.693	320.80	237.10	- 47.30
240	4	58.145	13.200	396.00	314.34	- 53.11
300	5	57.160	13.200	396.00	314.34	- 60.84
360	6	55.812	13.641	409.22	328.82	- 63.13
420	7	54.523	13.998	419.95	340.57	- 65.67
480	8	53.415	14.302	429.05	350.53	- 68.17
540	9	52.407	14.567	437.02	359.26	- 69.82
600	10	51.504	14.807	444.22	367.35	- 72.11

Source: Dreyer, 2011

The relevant percentage will be used in the investment appraisals, depending on the size of the household.

Energy saving on a heat pump

According to Fardoun *et al.* (2001:330) and GEO plus (2006?), the use of an air source heat pump can reduce 70% of the electricity usage on a conventional geyser (par. 2.3.3.2).

Therefore, for the purpose of this study, the energy saving generated by the installation of a heat pump will add up to 70% of the energy consumption of a conventional geyser.

### Energy saving on a gas geyser

By installing a gas geyser, one eliminates the total electricity usage of a conventional geyser as the electricity is replaced by gas (par. 2.3.4.2). The cost of the gas needed per month forms part of the additional cost indicated above, and will not represent a percentage of the electricity cost used.

Therefore, for the purpose of this study, the cost saving on a gas geyser will be 100% of the electricity consumption of a conventional geyser as the gas cost will be covered in a separate section.

### Energy saving on an instant heater

Instant heaters can generate an energy saving of between 27 and 50% of the total cost associated with a conventional geyser if installed on each hot water outlet in a household in the United States (United States Department of Energy, 2011) (par. 2.3.5.2). This is the best indication of the energy saving generated by an instant water heater as these systems are not yet that well established in South Africa.

For the purpose of this study, only two instant water heaters will be installed in the household, one in the kitchen and one in the bathroom. By taking the hot water usage spread within a household into consideration, the saving will be generated in two areas, which contribute 51% of the total hot water consumption within the household. Therefore, if the maximum energy saving generated if instant water heaters were installed on all hot water outlets is 50% of the total energy cost of a conventional geyser, the energy saving for the purposes of this study will be 25% (50% of 51%). This is because the instant heaters will only serve hot water outlets that supply 51% of the total hot water consumption.

### **4.6.3 Useful life**

The useful life represents the expected time it will take before the hot water heating systems will need replacement. Each of the five hot water heating systems evaluated in this study has different useful lives. Each investment option will be evaluated over its useful life, and not at a set number of years.

### ***Useful life of a solar geyser***

The useful life of a solar geyser is expected to be between 15 and 25 years (PDC Solar, 2008; Home comfort, s.a.).

For the purpose of this study, the average will be used. Therefore, the expected useful life of a solar geyser will be 20 years.

### ***Useful life of a time switch***

The useful life of a time switch depends on the quality of the time switch installed, as well as the type of time switch (mechanical or electrical) (Otto, 2012). A cheap time switch may last around five years, whereas a better quality time switch can give you a useful life of between 15 and 20 years (Otto, 2012).

The quotations used for the purposes of this study with regard to a time switch are for a standard time switch, which is of good quality, but does not represent the state-of-the-art time switches; therefore, the useful life will be 10 years – the average between a cheap and good quality time switch.

### ***Useful life of a heat pump***

The expected useful life of a heat pump is around 14 to 15 years (The Consortium for Energy Efficiency, 2009; Manczyk, 2003).

For the purpose of this study, the useful life of a heat pump will be 15 years.

### ***Useful life of a gas geyser***

A gas geyser's useful life is expected to be around 12 years (Kablan, 2004:1071; Audet, 2009).

Therefore, for the purpose of this study, the useful life of a gas geyser will be 12 years.

### ***Useful life of an instant heater***

The useful life of an instant heater is expected to be around 20 years (United States Department of Energy, 2011).

For the purpose of this study, the useful life of an instant heater will be 20 years.

#### **4.6.4 Inflation rate and the electricity cost of a conventional geyser**

Inflation will be taken into account for the purpose of this study. The inflation rate will be used to determine the price increase of electricity from 2013 onwards. The reason for this is that up to this point Eskom only has permission to increase electricity charges by 25% until 2012 (Nersa, 2009). No indication is available of what will happen from 2013 onwards; therefore, the inflation rate seems to be the realistic view.

The rate that will be used to take inflation into account is 10%, which represents the average inflation rate between 1981 and 2010 (Trading Economist, 2011).

#### **4.6.5 Discount rate**

Calculating the discount rate for individuals can be a difficult task. The discount rate will differ from person to person, depending on his/her financing preference. If the individual decided to use a bank loan to cover the investment cost, the discount rate will be the interest charged on the bank loan; if the individual decided to cover the investment cost using savings, the discount rate will be the interest rate received on a personal savings account.

Foltyn-Zarychta (2010:290) states that the market discount rate must be used to evaluate investments for private investors. For the purposes of this study, the assumption is made that in South Africa the prime rate represents the market discount rate. The current prime rate in South Africa is at 9% (Absa, 2012).

For the purpose of this study, a discount rate of 9% will be used, as the interest rates received on savings accounts are generally lower, and the rates charged on bank loans are slightly higher than the prime rate.

#### **4.6.6 Net present value (NPV)**

In order to calculate the NPV of each of the different investment options, the table method will be used where all the cashflows for each year will be indicated in detail, summed and then discounted at an appropriate discount rate by using the correct discount factors in the present value table. The totals of each of the years will then be summed to determine the NPV.

Because these investment options are mutually exclusive, and have different useful lives, the equivalent annual annuity will also be calculated by making use of the following formula (par. 3.3.6):

$$EAA = NPV / \text{present value factor of annuity for the useful life of the investment}$$

Where:

EAA = equivalent annual annuity

NPV = the NPV calculated over the expected life time

#### **4.6.7 Internal rate of return (IRR)**

The IRR will be calculated by using an Excel spreadsheet. All the inputs to the table method used to calculate the NPV will be entered into an Excel spreadsheet. From there, the following Excel formula will be used to determine the IRR:

$$=IRR(\text{values}, [\text{guess}])$$

Within this formula, the *values* represent the totals of each of the years reviewed, and *[guess]* represents an estimate of what the IRR is expected to be.

It is important to note that the total for each year should represent the totals before discounted to the present value.

#### **4.6.8 Modified internal rate of return (MIRR)**

The MIRR will also be calculated by using an Excel spread sheet. All the inputs will be the same as for the IRR calculation, with only the formula changing. The Excel formula for calculating the MIRR is as follows:

$$=MIRR(\text{values}, \text{finance\_rate}, \text{reinvest\_rate})$$

*Values* represent the sum of the total of all the years reviewed, the *finance rate* the discount rate, and the *reinvest rate* the cost of capital.

Again, the sum of the total of all the years represents the totals before discounting it to the present value.

#### **4.6.9 Accounting rate of return (ARR)**

The ARR will be calculated by making use of the following formula:

$$\text{Accounting rate of return} = \frac{\text{Average annual profits}}{\text{Average investment}} \times 100$$

It is important to note that the average investment cost will be the initial investment cost divided by two.

#### **4.6.10 Discounted payback period**

The discounted payback period will be calculated by adding up the discounted total of each year until the initial investment cost is covered by the inflows. When the total of a year is more than the outstanding investment cost, the appropriate percentage will be calculated in order to give the correct payback period. This will not be done using Excel, but it will be calculated from the NPV calculation tables.

#### **4.6.11 Economic Value Added (EVA)**

The EVA will be calculated by making use of the following formula:

$$EVA = NOPAT - (CE \times WACC)$$

Where:

NOPAT = Net operating profit

CE = Capital employed

WACC = Weighted average cost of capital

#### **4.6.12 Sensitivity analysis**

A sensitivity analysis will be performed at the end of all the calculations to determine what the impact on the appraisal outcomes will be if some of the inputs were to change. This will be done by changing some of the key inputs of the investment appraisal. Some of the inputs

that will be tested include the discount rate, the inflation rate as well as the percentage savings generated by each of the alternatives.

#### **4.7 SUMMARY**

This chapter outlines the objective of this study, as well as how this study was conducted. The design and method of this study were indicated. Each of the inputs to the investment appraisal was calculated in order to determine the outcome of this study. The inputs include the investment cost, the installation cost, the rebate from Eskom, the cost saving, and the discount rate. Other factors affecting the outcome of this study were also discussed, such as the size of the household, the geyser temperature, the energy usage of a conventional geyser as well as the household size. Furthermore, all the formulas and methods of calculating all the investment appraisals that will be used in this study are also mentioned. These formulas and methods include the NPV, IRR, MIRR, ARR, the discounted payback period as well as the EVA.

In Chapter 5, the results of this study will be calculated.

## **5. CHAPTER 5: RESULTS**

### **5.1 INTRODUCTION**

The goal of this study is to determine what the most financially viable investment will be to reduce electricity cost when it comes to water heating systems for households (par. 1.4.1).

This chapter covers the results of the empirical study to determine the financial viability of five water heating systems identified to replace a conventional geyser in order to save on electricity usage. There is certain information that will be relevant for all alternatives as mentioned and calculated in Chapter 4. These include the electricity cost of a conventional geyser, of which each alternative will save a certain percentage, as well as the assumption that the maintenance costs for all systems are the same, as all water heating systems have these costs and it is difficult to calculate an annual value for maintenance cost.

There will be two investment appraisals for each alternative, one for a household with low volume hot water consumption (four people, as determined by Napier *et al.* (Finscope, 2009:2) (par. 4.5.5), and one for a household with high volume hot water consumptions (six people, as determined by Napier *et al.* (Finscope, 2009:2) (par. 4.5.5).

Several specific objectives were formulated in order to reach the goal of this study. This chapter addresses the third specific objective of this study by performing investment appraisal on the five alternative water heating systems.

*Please note that a Compact Disc (CD) is included in this study, containing an Excel spreadsheet in which each person can determine the financial viability of the water heating system alternatives by inputting the size of their household as well as their own discount rate.*

### **5.2 INVESTMENT APPRAISALS**

Below follows the ten investment appraisals to determine the financial viability of each of the hot water heating systems.

#### **5.2.1 Solar geyser**

The first investment appraisal for a solar geyser will be done on a household with low volume hot water consumption, followed by the investment appraisal for a household with high volume hot water consumption.

### ***Low volume hot water consumption (solar geyser)***

The inputs to this investment appraisal are as follows:

The investment cost (par. 4.6.1), installation cost (par. 4.6.1) and rebate (par. 4.6.1) are based on the quotations received from three suppliers.

A solar geyser can contribute up to a 40% saving on the energy usage of a conventional geyser, as stated by Nyatsanza *et al.* (2008) (par. 4.6.2). The saving is calculated on the energy cost as shown in paragraph 4.5.4. The quotations received from suppliers of solar geysers were gathered in 2011; therefore, for the purpose of this study, the assumption is made that the solar geyser will start generating savings from 2012 (year 1) onwards. The calculation of the saving generated by a solar geyser can be seen in Table 5.1.

The discount rate of an individual, for the purpose of this study, will be 9%, which is the prime rate in South Africa (par. 4.6.5).

### **NPV**

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The NPV of an investment in a solar geyser for a household with low hot water consumption, as calculated in Table 5.2, amounts to R63 750.

The NPV of a solar geyser for a household with low volume hot water consumption is positive, making the investment worthwhile.

### **Equivalent annual annuity**

The equivalent annual annuity is determined by using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R63\ 750 / 9.1285$$

$$= R6\ 984$$

The equivalent annual annuity for a solar geyser for a household with low hot water consumption amounts to R6 984. The equivalent annual annuity is also positive, but must be compared with the EAA of the other investment options to see if a solar geyser is the better investment option for a household with low volume hot water consumption.

### IRR and MIRR

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following are the results for the IRR and MIRR:

The IRR is calculated in Table 5.2 and amounts to 33%, while the MIRR amounts to 18%. Both the IRR and MIRR are higher than the discount rate used.

### ARR

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(4.02+4.42+4.87+5.35+5.89+6.48+7.13+7.84+8.62+9.48+10.43+11.48+12.62+13.89+15.27+16.80+18.48+20.33+22.36+24.60)/20}{16.85/2} \times 100 \\ &= \frac{\text{R}11.52}{\text{R}8.43} \times 100 \\ &= 137\% \end{aligned}$$

The ARR for a solar geyser in a household with low volume hot water consumption is 137%, which indicates that the expected accounting return for this investment is high above the cost of capital.

### Discounted payback period

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

$$\text{Discounted payback period} = 16.85 - 3.69 - 3.72 - 3.76 - 3.79 - (1.89/3.83)$$

$$\text{Discounted payback period} = 4.49 \text{ years}$$

The discounted payback period amounts to 4.49 years.

The discounted payback period of a solar geyser in a household with low volume hot water consumption is over four years. This is a long time for an investment looking to cut costs as quickly as possible.

### EVA

The EVA is calculated as follows (par. 4.6.11):

$$\text{EVA} = \text{NOPAT} - (\text{CE} \times \text{WACC})$$

This calculation is done in Table 5.3. The EVA represents the sum of the discounted EVAs and amounts to R66 760.

The economic value that will be added over the lifetime of a solar geyser, to a household with low volume hot water consumption, is R66 750.

**Table 5.1: Energy saving for low volume hot water consumption (solar geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	10.06	11.06	12.17	13.38	14.72	16.19	17.81	19.60	21.55	23.71	26.08	28.69	31.56	34.71	38.19	42.00	46.20	50.82	55.91	61.50
Saving	0%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
<b>Total saving</b>	-	<b>4.02</b>	<b>4.42</b>	<b>4.87</b>	<b>5.35</b>	<b>5.89</b>	<b>6.48</b>	<b>7.13</b>	<b>7.84</b>	<b>8.62</b>	<b>9.48</b>	<b>10.43</b>	<b>11.48</b>	<b>12.62</b>	<b>13.89</b>	<b>15.27</b>	<b>16.80</b>	<b>18.48</b>	<b>20.33</b>	<b>22.36</b>	<b>24.60</b>

**Table 5.2: Low volume hot water consumption (solar geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>																					
Investment cost	-15.11																				
Installation cost	-6.77																				
Rebate	5.03																				
<b>Savings</b>																					
Energy saving (40%)		4.02	4.42	4.87	5.35	5.89	6.48	7.13	7.84	8.62	9.48	10.43	11.48	12.62	13.89	15.27	16.80	18.48	20.33	22.36	24.60
<b>Total cash flows</b>	-16.85	4.02	4.42	4.87	5.35	5.89	6.48	7.13	7.84	8.62	9.48	10.43	11.48	12.62	13.89	15.27	16.80	18.48	20.33	22.36	24.60
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted cash flows</b>	<b>-16.85</b>	<b>3.69</b>	<b>3.72</b>	<b>3.76</b>	<b>3.79</b>	<b>3.83</b>	<b>3.86</b>	<b>3.90</b>	<b>3.93</b>	<b>3.97</b>	<b>4.01</b>	<b>4.04</b>	<b>4.08</b>	<b>4.12</b>	<b>4.15</b>	<b>4.19</b>	<b>4.23</b>	<b>4.27</b>	<b>4.31</b>	<b>4.35</b>	<b>4.39</b>

NPV 63.75  
IRR 33%  
MIRR 18%

**Table 5.3: EVA calculation for low volume hot water consumption (solar geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		4.02	4.42	4.87	5.35	5.89	6.48	7.13	7.84	8.62	9.48	10.43	11.48	12.62	13.89	15.27	16.8	18.48	20.33	22.36	24.6
Capital charges (R16.85 x 9%)		-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52
<b>EVA</b>		2.50	2.90	3.35	3.83	4.37	4.96	5.61	6.32	7.10	7.96	8.91	9.96	11.10	12.37	13.75	15.28	16.96	18.81	20.84	23.08
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted EVA</b>		2.30	2.44	2.59	2.72	2.84	2.96	3.07	3.17	3.27	3.36	3.45	3.54	3.62	3.70	3.78	3.85	3.92	3.99	4.05	4.12

EVA 66.75

### ***High volume hot water consumption (solar geyser)***

The inputs to this investment appraisal are as follows:

The investment cost (par. 4.6.1), installation cost (par. 4.6.1) and rebate (par. 4.6.1) are based on the quotations received from three suppliers.

A solar geyser can contribute up to a 40% saving on the energy usage of a conventional geyser, as stated in the literature by Nyatsanza *et al.* (2008) (par. 4.6.2). The saving is calculated on the energy cost as shown in paragraph 4.5.4. The quotations received from suppliers of solar geysers were gathered in 2011; therefore, for the purpose of this study, the assumption is made that the solar geyser will start to generate savings from 2012 (year 1) onwards. The calculation of the savings generated by a solar geyser can be seen in Table 5.4.

The discount rate of an individual, for the purpose of this study, will be 9%, which is the prime rate in South Africa (par. 4.6.5).

### **NPV**

The NPV is the sum of all the discounted cashflows (par. 4.6.6). The net present value of a solar geyser for a household with high hot water consumption amounts to R90 370, as calculated in Table 5.5.

The NPV for a solar geyser in a household with high volume hot water consumption is positive, making the investment worthwhile to consider.

### **Equivalent annual annuity**

The equivalent annual annuity is determined using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R90\,370 / 9.1285$$

$$= R9\,900$$

The equivalent annual annuity is also positive, but must be compared with the EAA of the other investment options to see if a solar geyser is a better investment option for a household with low volume hot water consumption.

### IRR and MIRR

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following are the results for the IRR and MIRR, as calculated in Table 5.5:

IRR = 42%

MIRR = 20%

The IRR and MIRR are higher than the discount rate, indicating the investor will get a positive return on investment.

### ARR

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(5.35+5.89+6.47+7.12+7.83+8.62+9.48+10.43+11.47+12.62+13.88+15.27+16.79+18.47+20.32+22.35+24.59+27.05+29.75+32.73)/20}{16.85/2} \times 100 \\ &= \frac{\text{R}15.32}{\text{R}8.43} \times 100 \\ &= 182\% \end{aligned}$$

The accounting return on investment is expected to be around 182% when a solar geyser is installed in a household with high volume hot water consumption. This is well above the cost of capital.

### Discounted payback period

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

$$\text{Discounted payback period} = 16.85 - 4.91 - 4.95 - 5.00 - (1.99/5.05)$$

$$\text{Discounted payback period} = 3.39 \text{ years}$$

A household with high volume hot water consumption can expect to pay back a solar geyser within 3.39 years. This is better than the years it will take to pay back the same investment for a household with low volume hot water consumption.

### EVA

The EVA is calculated as follows (par. 4.6.11):

$$EVA = NOPAT - (CE \times WACC)$$

This formula is applied in Table 5.6, and the EVA represents the sum of the discounted EVAs.

The economic value that will be added to a household with high volume hot water consumption when installing a solar geyser amounts to R93 380.

**Table 5.4: Energy saving for high volume hot water consumption (solar geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	13.38	14.71	16.19	17.80	19.59	21.54	23.70	26.07	28.67	31.54	34.70	38.17	41.98	46.18	50.80	55.88	61.47	67.61	74.38	81.81
Saving	0%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
<b>Total saving</b>	-	<b>5.35</b>	<b>5.89</b>	<b>6.47</b>	<b>7.12</b>	<b>7.83</b>	<b>8.62</b>	<b>9.48</b>	<b>10.43</b>	<b>11.47</b>	<b>12.62</b>	<b>13.88</b>	<b>15.27</b>	<b>16.79</b>	<b>18.47</b>	<b>20.32</b>	<b>22.35</b>	<b>24.59</b>	<b>27.05</b>	<b>29.75</b>	<b>32.73</b>

**Table 5.5: High volume hot water consumption (solar geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>																					
Investment cost	-15.11																				
Installation cost	-6.77																				
Rebate	5.03																				
<b>Savings</b>																					
Energy saving (40%)		5.35	5.89	6.47	7.12	7.83	8.62	9.48	10.43	11.47	12.62	13.88	15.27	16.79	18.47	20.32	22.35	24.59	27.05	29.75	32.73
<b>Total cash flows</b>	-16.85	5.35	5.89	6.47	7.12	7.83	8.62	9.48	10.43	11.47	12.62	13.88	15.27	16.79	18.47	20.32	22.35	24.59	27.05	29.75	32.73
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted cash flows</b>	<b>-16.85</b>	<b>4.91</b>	<b>4.95</b>	<b>5.00</b>	<b>5.05</b>	<b>5.09</b>	<b>5.14</b>	<b>5.19</b>	<b>5.23</b>	<b>5.28</b>	<b>5.33</b>	<b>5.38</b>	<b>5.43</b>	<b>5.48</b>	<b>5.53</b>	<b>5.58</b>	<b>5.63</b>	<b>5.68</b>	<b>5.73</b>	<b>5.79</b>	<b>5.84</b>

NPV 90.37  
 IRR 42%  
 MIRR 20%

**Table 5.6: EVA calculation for high volume hot water consumption (solar geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		5.35	5.89	6.47	7.12	7.83	8.62	9.48	10.43	11.47	12.62	13.88	15.27	16.79	18.47	20.32	22.35	24.59	27.05	29.75	32.73
Capital charges (R16.85 x 9%)		-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52
<b>EVA</b>		<b>3.83</b>	<b>4.37</b>	<b>4.95</b>	<b>5.60</b>	<b>6.31</b>	<b>7.10</b>	<b>7.96</b>	<b>8.91</b>	<b>9.95</b>	<b>11.10</b>	<b>12.36</b>	<b>13.75</b>	<b>15.27</b>	<b>16.95</b>	<b>18.80</b>	<b>20.83</b>	<b>23.07</b>	<b>25.53</b>	<b>28.23</b>	<b>31.21</b>
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted EVA</b>		<b>3.52</b>	<b>3.68</b>	<b>3.83</b>	<b>3.97</b>	<b>4.10</b>	<b>4.24</b>	<b>4.36</b>	<b>4.47</b>	<b>4.58</b>	<b>4.69</b>	<b>4.79</b>	<b>4.89</b>	<b>4.98</b>	<b>5.07</b>	<b>5.16</b>	<b>5.25</b>	<b>5.33</b>	<b>5.41</b>	<b>5.49</b>	<b>5.57</b>

EVA 93.38

## 5.2.2 Time switch

The first investment appraisal for a time switch will be done on a household with low volume hot water consumption, followed by the investment appraisal for a household with high volume hot water consumption.

### ***Low volume hot water consumption (time switch)***

The inputs to this investment appraisal are as follows:

The investment cost (par. 4.6.1) and installation cost (par. 4.6.1) of a time switch are based on the quotations received from three suppliers.

A time switch can contribute up to a 53% saving on the energy usage of a conventional geyser, as calculated by J Dreyer (2009) (par. 4.6.2). The saving is calculated on the energy cost as shown in paragraph 4.5.4. The quotations received from suppliers of time switches were gathered in 2011; therefore, for the purpose of this study, the assumption is made that the time switch will start to generate savings from 2012 (year 1) onwards. The calculation of the savings generated by a time switch can be seen in Table 5.7.

The discount rate of an individual, for the purpose of this study, will be 9%, which is the prime rate in South Africa (par. 4.6.5).

### NPV

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value for a time switch in a household with low hot water consumption is calculated in Table 5.8 and amounts to R49 410.

The NPV is positive, again making this a good investment for a household with low volume hot water consumption.

### Equivalent annual annuity

The equivalent annual annuity is determined by using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R49\ 410 / 6.4177$$

= R7 699

The equivalent annual annuity will always be positive if the NPV is positive; therefore the EAA must be compared with the EAA of the other investment options in order to determine if a time switch will be the better investment option for a household with low volume hot water consumption.

### IRR and MIRR

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following are the results for the IRR and MIRR calculations in Table 5.8:

IRR = 354%

MIRR = 55%

The IRR is significantly higher than the discount rate. The MIRR is also more than the discount rate.

### ARR

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(5.33+5.86+6.45+7.09+7.80+8.58+9.44+10.39+11.42+12.57)/10}{1.55/2} \\ &= \frac{\text{R}8.49}{\text{R}0.78} \times 100 \\ &= 1\,008\% \end{aligned}$$

The accounting return on the investment is also very high, indicating that this investment option will be worthwhile to consider.

### Discounted payback period

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

Discounted payback period =  $1.55/4.89$

Discounted payback period = 0.3 years

The discounted payback period of a time switch within a household with low volume hot water consumption is less than one year. This is very quick, indicating that this investment will pay for itself within a couple of months.

### EVA

The EVA is calculated as follows (par. 4.6.11):

$EVA = NOPAT - (CE \times WACC)$

This formula is applied in Table 5.9. The EVA represents the sum of the discounted EVAs and amounts to R50 070.

The time switch will add value of R50 070 over its expected life.

**Table 5.7: Energy for low volume hot water consumption (time switch)**

	0	1	2	3	4	5	6	7	8	9	10
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	10.06	11.06	12.17	13.38	14.72	16.19	17.81	19.60	21.55	23.71
Saving	0%	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%
<b>Total saving</b>	-	<b>5.33</b>	<b>5.86</b>	<b>6.45</b>	<b>7.09</b>	<b>7.80</b>	<b>8.58</b>	<b>9.44</b>	<b>10.39</b>	<b>11.42</b>	<b>12.57</b>

**Table 5.8: Low volume hot water consumption (time switch)**

	0	1	2	3	4	5	6	7	8	9	10
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>											
Investment cost	-1.13										
Installation cost	-0.42										
Rebate											
<b>Savings</b>											
Energy saving (53%)		5.33	5.86	6.45	7.09	7.80	8.58	9.44	10.39	11.42	12.57
<b>Total cash flows</b>	-1.55	5.33	5.86	6.45	7.09	7.80	8.58	9.44	10.39	11.42	12.57
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224
<b>Discounted cash flows</b>	<b>-1.55</b>	<b>4.89</b>	<b>4.93</b>	<b>4.98</b>	<b>5.02</b>	<b>5.07</b>	<b>5.12</b>	<b>5.16</b>	<b>5.21</b>	<b>5.26</b>	<b>5.31</b>

NPV 49.41  
 IRR 354%  
 MIRR 55%

**Table 5.9: EVA calculation for low volume hot water consumption (time switch)**

	0	1	2	3	4	5	6	7	8	9	10
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		5.33	5.86	6.45	7.09	7.80	8.58	9.44	10.39	11.42	12.57
Capital charges (R1.55 x 9%)		-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14
<b>EVA</b>		5.19	5.72	6.31	6.95	7.66	8.44	9.30	10.25	11.28	12.43
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224
<b>Discounted EVA</b>		4.76	4.82	4.87	4.93	4.98	5.03	5.09	5.14	5.20	5.25

EVA 50.07

### ***High volume hot water consumption (time switch)***

The inputs to this investment appraisal are as follows:

The investment cost (par. 4.6.1) and installation cost (par. 4.6.1) of a time switch are based on the quotations received from three suppliers.

A time switch can contribute up to a 63% saving on the energy usage of a conventional geyser within a household with high volume hot water consumption, as calculated by J Dreyer (2009) (par. 4.6.2). The saving is calculated on the energy cost as shown in paragraph 4.5.4. The quotations received from suppliers of time switches were gathered in 2011; therefore, for the purpose of this study, the assumption is made that the time switch will start to generate savings from 2012 (year 1) onwards. The calculation of the saving generated by a time switch can be seen in Table 5.10.

The discount rate of an individual, for the purpose of this study, will be 9%, which is the prime rate in South Africa (par. 4.6.5).

### **NPV**

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value as calculated in Table 5.11 amounts to R79 040.

The NPV of a time switch in a household with high volume hot water consumption is also positive, indicating that this is a good investment option.

### **Equivalent annual annuity**

The equivalent annual annuity is determined using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R79\ 040 / 6.4177$$

$$= R12\ 316$$

The equivalent annual annuity is also positive, but must be compared with the EAA of other investment options in order to determine if a time switch is a better investment option for a household with high volume hot water consumption.

### IRR and MIRR

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following results for the IRR and MIRR are calculated in Table 5.11:

IRR = 554%

MIRR = 62%

Again, the IRR and MIRR are much higher than the discount rate used of 9%.

### ARR

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(8.43+9.27+10.20+11.22+12.34+13.57+14.93+16.42+18.07+19.87)/10}{1.55/2} \times 100 \\ &= \frac{\text{R}13.43}{\text{R}0.78} \times 100 \\ &= 1\,721\% \end{aligned}$$

The ARR for a time switch in a household with high volume hot water consumption is extremely high, indicating that this is a viable investment option.

### Discounted payback period

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

Discounted payback period = 1.55/7.73

Discounted payback period = 0.20 years

The discounted payback period of a time switch within a household with high volume hot water consumption is 2.4 months (12 months x 0.20).

## EVA

The EVA is calculated as follows (par. 4.6.11):

$$\text{EVA} = \text{NOPAT} - (\text{CE} \times \text{WACC})$$

This formula is applied in Table 5.12. The EVA represents the sum of the discounted EVAs and amounts to R79 690.

The time switch will add economic value of R79 690 over its expected life in a household with high volume hot water consumption.

**Table 5.10: Energy saving for high volume hot water consumption (time switch)**

	0	1	2	3	4	5	6	7	8	9	10
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	13.38	14.71	16.19	17.80	19.59	21.54	23.70	26.07	28.67	31.54
Saving	0%	63%	63%	63%	63%	63%	63%	63%	63%	63%	63%
<b>Total saving</b>	-	<b>8.43</b>	<b>9.27</b>	<b>10.20</b>	<b>11.22</b>	<b>12.34</b>	<b>13.57</b>	<b>14.93</b>	<b>16.42</b>	<b>18.07</b>	<b>19.87</b>

**Table 5.11: High volume hot water consumption (time switch)**

	0	1	2	3	4	5	6	7	8	9	10
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>											
Investment cost	-1.13										
Installation cost	-0.42										
Rebate											
<b>Savings</b>											
Energy saving (63%)		8.43	9.27	10.20	11.22	12.34	13.57	14.93	16.42	18.07	19.87
<b>Total cash flows</b>	-1.55	8.43	9.27	10.20	11.22	12.34	13.57	14.93	16.42	18.07	19.87
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224
<b>Discounted cash flows</b>	<b>-1.55</b>	<b>7.73</b>	<b>7.80</b>	<b>7.87</b>	<b>7.95</b>	<b>8.02</b>	<b>8.09</b>	<b>8.17</b>	<b>8.24</b>	<b>8.32</b>	<b>8.39</b>

NPV 79.04  
 IRR 554%  
 MIRR 62%

**Table 5.12: EVA calculation for high volume hot water consumption (time switch)**

	0	1	2	3	4	5	6	7	8	9	10
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		8.43	9.27	10.20	11.22	12.34	13.57	14.93	16.42	18.07	19.87
Capital charges (R1.55 x 9%)		-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14	-0.14
<b>EVA</b>		8.29	9.13	10.06	11.08	12.20	13.43	14.79	16.28	17.93	19.73
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224
<b>Discounted EVA</b>		7.60	7.69	7.77	7.85	7.93	8.01	8.09	8.17	8.25	8.33

EVA 79.69

### 5.2.3 Heat pump

Below follows the two investment appraisals to determine the financial viability of a heat pump.

#### ***Low volume hot water consumption (heat pump)***

The inputs to this investment appraisal are as follows:

The investment cost (par. 4.6.1), installation cost (par. 4.6.1) and rebate (par. 4.6.1) of a heat pump are based on the quotations received from three suppliers.

A heat pump can contribute up to a 70% saving on the energy usage of a conventional geyser, as indicated by Fardoun *et al.* (2001:330) (par. 4.6.2). The saving is calculated on the energy cost as shown in paragraph 4.5.4. The quotations received from suppliers of heat pumps were gathered in 2011; therefore, for the purpose of this study, the assumption is made that the heat pump will start to generate savings from 2012 (year 1) onwards. The calculation of the saving generated by a heat pump can be seen in Table 5.13.

The discount rate of an individual, for the purpose of this study, will be 9%, which is the prime rate in South Africa (par. 4.6.5).

#### NPV

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value is calculated in Table 5.14 and amounts to R91 770.

The NPV for a heat pump in a household with low volume hot water consumption is positive, making this a good investment option.

#### Equivalent annual annuity

The equivalent annual annuity is determined using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R91\ 770 / 8.0607$$

$$= R11\ 385$$

The equivalent annual annuity amounts to R11 385 and is also positive. The EAA must be compared with the EAA of other investment options in order to determine if a heat pump is the better investment option for a household with low volume hot water consumption.

IRR and MIRR

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following result for the IRR and MIRR are calculated in Table 5.14:

IRR = 71%

MIRR = 26%

The IRR and MIRR are higher than the discount rate, making this a worthwhile investment option.

ARR

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned}
 \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\
 &= \frac{(7.04+7.74+8.52+9.37+10.31+11.34+12.47+13.72+15.09+16.60+18.26+20.08+22.09+24.30+26.73)/15}{11.57/2} \times 100 \\
 &= \frac{\text{R18.64}}{\text{R5.79}} \times 100 \\
 &= 322\%
 \end{aligned}$$

The accounting rate of return is high, and significantly higher than the cost of capital.

Discounted payback period

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

Discounted payback period =  $11.57 - 6.46 - (5.11/6.52)$

Discounted payback period = 1.78 years

The discounted payback period of a heat pump in a household with low volume hot water consumption is just under two years.

### EVA

The EVA is calculated as follows (par. 4.6.11):

$$\text{EVA} = \text{NOPAT} - (\text{CE} \times \text{WACC})$$

This formula is applied in Table 5.15. The EVA represents the sum of the discounted EVAs and amounts to R94 940.

The economic value that will be added by this investment will be R94 940 over its expected life.

**Table 5.13: Energy saving for low volume hot water consumption (heat pump)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	10.06	11.06	12.17	13.38	14.72	16.19	17.81	19.60	21.55	23.71	26.08	28.69	31.56	34.71	38.19
Saving	0%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
<b>Total saving</b>	-	<b>7.04</b>	<b>7.74</b>	<b>8.52</b>	<b>9.37</b>	<b>10.31</b>	<b>11.34</b>	<b>12.47</b>	<b>13.72</b>	<b>15.09</b>	<b>16.60</b>	<b>18.26</b>	<b>20.08</b>	<b>22.09</b>	<b>24.30</b>	<b>26.73</b>

**Table 5.14: Low volume hot water consumption (heat pump)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>																
Investment cost	-15.24															
Installation cost	-															
Rebate	3.67															
<b>Savings</b>																
Energy saving (70%)		7.04	7.74	8.52	9.37	10.31	11.34	12.47	13.72	15.09	16.60	18.26	20.08	22.09	24.30	26.73
<b>Total cash flows</b>	-11.57	7.04	7.74	8.52	9.37	10.31	11.34	12.47	13.72	15.09	16.60	18.26	20.08	22.09	24.30	26.73
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745
<b>Discounted cash flows</b>	<b>-11.57</b>	<b>6.46</b>	<b>6.52</b>	<b>6.58</b>	<b>6.64</b>	<b>6.70</b>	<b>6.76</b>	<b>6.82</b>	<b>6.88</b>	<b>6.95</b>	<b>7.01</b>	<b>7.07</b>	<b>7.14</b>	<b>7.21</b>	<b>7.27</b>	<b>7.34</b>

NPV 91.77  
 IRR 71%  
 MIRR 26%

**Table 5.15: EVA calculation for low volume hot water consumption (heat pump)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		7.04	7.74	8.52	9.37	10.31	11.34	12.47	13.72	15.09	16.60	18.26	20.08	22.09	24.30	26.73
Capital charges (R11.57 x 9%)		-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04
<b>EVA</b>		<b>6.00</b>	<b>6.70</b>	<b>7.48</b>	<b>8.33</b>	<b>9.26</b>	<b>10.29</b>	<b>11.43</b>	<b>12.68</b>	<b>14.05</b>	<b>15.56</b>	<b>17.22</b>	<b>19.04</b>	<b>21.05</b>	<b>23.26</b>	<b>25.69</b>
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745
<b>Discounted EVA</b>		<b>5.50</b>	<b>5.64</b>	<b>5.77</b>	<b>5.90</b>	<b>6.02</b>	<b>6.14</b>	<b>6.25</b>	<b>6.36</b>	<b>6.47</b>	<b>6.57</b>	<b>6.67</b>	<b>6.77</b>	<b>6.87</b>	<b>6.96</b>	<b>7.05</b>

EVA 94.94

### ***High volume hot water consumption (heat pump)***

The inputs to this investment appraisal are as follows:

The investment cost (par. 4.6.1), installation cost (par. 4.6.1) and rebate (par. 4.6.1) of a heat pump are based on the quotations received from three suppliers.

A heat pump can contribute up to a 70% saving on the energy usage of a conventional geyser, as indicated by Fardoun *et al.* (2001:330) (par. 4.6.2). The saving is calculated on the energy cost as shown in paragraph 4.5.4. The quotations received from suppliers of heat pumps were gathered in 2011; therefore, for the purpose of this study, the assumption is made that the heat pump will start to generate savings from 2012 (year 1) onwards. The calculation of the savings generated by a heat pump can be seen in Table 5.16.

The discount rate of an individual, for the purpose of this study, will be 9%, which is the prime rate in South Africa (par. 4.6.5).

### NPV

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value was calculated in Table 5.17 and amounts to R125 900.

The NPV is also positive and therefore indicates that this is a good investment option.

### Equivalent annual annuity

The equivalent annual annuity is determined using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R125\,900 / 8.0607$$

$$= R15\,619$$

The equivalent annual annuity is positive, indicating that this is a viable investment option.

### IRR and MIRR

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following results for the IRR and MIRR are calculated in Table 5.17:

IRR = 91%

MIRR = 29%

The IRR and MIRR are higher than the discount rate, making this a good investment option.

### ARR

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(9.36+10.30+11.33+12.46+13.71+15.08+16.59+18.25+20.07+22.08+24.29+26.72+29.39+32.33+35.56)/15}{11.57/2} \times 100 \\ &= \frac{\text{R}19.83}{\text{R}5.79} \times 100 \\ &= 342\% \end{aligned}$$

The accounting return rate expected from this investment option is significantly higher than the cost of capital.

### Discounted payback period

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

$$\text{Discounted payback period} = 11.57 - 8.59 - (2.98/8.67)$$

$$\text{Discounted payback period} = 1.34 \text{ years}$$

The discounted payback period is under two years, making this a good investment option.

### EVA

The EVA is calculated as follows (par. 4.6.11):

$$\text{EVA} = \text{NOPAT} - (\text{CE} \times \text{WACC})$$

This formula is applied in Table 5.18. The EVA represents the sum of the discounted EVAs and amounts to R129 080.

The economic value that will be added to a household with high volume hot water consumption when this investment option is installed is expected to be R129 080.

**Table 5.16: Energy saving for high volume hot water consumption (heat pump)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	13.38	14.71	16.19	17.80	19.59	21.54	23.70	26.07	28.67	31.54	34.70	38.17	41.98	46.18	50.80
Saving	0%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%	70%
<b>Total saving</b>	-	<b>9.36</b>	<b>10.30</b>	<b>11.33</b>	<b>12.46</b>	<b>13.71</b>	<b>15.08</b>	<b>16.59</b>	<b>18.25</b>	<b>20.07</b>	<b>22.08</b>	<b>24.29</b>	<b>26.72</b>	<b>29.39</b>	<b>32.33</b>	<b>35.56</b>

**Table 5.17: High volume hot water consumption (heat pump)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>																
Investment cost	-15.24															
Installation cost	-															
Rebate	3.67															
<b>Savings</b>																
Energy saving (70%)		9.36	10.30	11.33	12.46	13.71	15.08	16.59	18.25	20.07	22.08	24.29	26.72	29.39	32.33	35.56
<b>Total cash flows</b>	-11.57	9.36	10.30	11.33	12.46	13.71	15.08	16.59	18.25	20.07	22.08	24.29	26.72	29.39	32.33	35.56
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745
<b>Discounted cash flows</b>	<b>-11.57</b>	<b>8.59</b>	<b>8.67</b>	<b>8.75</b>	<b>8.83</b>	<b>8.91</b>	<b>8.99</b>	<b>9.07</b>	<b>9.16</b>	<b>9.24</b>	<b>9.33</b>	<b>9.41</b>	<b>9.50</b>	<b>9.59</b>	<b>9.67</b>	<b>9.76</b>

NPV 125.90  
 IRR 91%  
 MIRR 29%

**Table 5.18: EVA calculation for high volume hot water consumption (heat pump)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		9.36	10.30	11.33	12.46	13.71	15.08	16.59	18.25	20.07	22.08	24.29	26.72	29.39	32.33	35.56
Capital charges (R11.57 x 9%)		-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04	-1.04
<b>EVA</b>		8.32	9.26	10.29	11.42	12.67	14.04	15.55	17.21	19.03	21.04	23.25	25.67	28.35	31.29	34.52
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745
<b>Discounted EVA</b>		7.64	7.79	7.95	8.09	8.23	8.37	8.50	8.64	8.76	8.89	9.01	9.13	9.25	9.36	9.48

EVA 129.08

#### **5.2.4 Gas geyser**

Below follows the two investment appraisals to determine the financial viability of a gas geyser.

##### ***Low volume hot water consumption (gas geyser)***

The inputs to this investment appraisal for a gas geyser are as follows:

The investment cost (par. 4.6.1) and installation cost (par. 4.6.1) of a time switch are based on the quotations received from three suppliers.

A gas geyser can contribute up to a 100% saving on the energy usage of a conventional geyser (par. 4.6.2). The saving is calculated on the energy cost as shown in paragraph 4.5.4. The quotations received from suppliers of gas geysers were gathered in 2011; therefore, for the purpose of this study, the assumption is made that the gas geyser will start to generate savings from 2012 (year 1) onwards. The calculation of the savings generated by a gas geyser can be seen in Table 5.19.

Additional costs arise when installing a gas geyser, as gas replaces the energy usage of the conventional geyser. These costs add up to an average annual cost of R3 843.12, as calculated by Solien Energy Solutions (2007) (par. 4.6.1). This annual cost will be multiplied by the inflation rate of 10% (par. 3.3.2) to determine the annual cost.

The discount rate of an individual, for the purpose of this study, will be 9%, which is the prime rate in South Africa (par. 4.6.5).

##### **NPV**

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value was calculated in Table 5.20 and amounts to R59 610.

The NPV of a gas geyser in a household with low volume hot water consumption is positive, making it a good investment.

##### **Equivalent annual annuity**

The equivalent annual annuity is determined using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R59\ 610 / 7.1607$$

$$= R8\ 325$$

The equivalent annual annuity is also positive. This is in line with the NPV.

### IRR and MIRR

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following results for the IRR and MIRR are calculated in Table 5.20:

$$\text{IRR} = 60\%$$

$$\text{MIRR} = 26\%$$

The IRR and MIRR are higher than the discount rate, indicating that investors would earn a return higher than their initial investment.

### ARR

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(6.21+6.83+7.52+8.27+9.10+10.01+11.01+12.11+13.32+14.65+16.11+17.72)/12}{12.34/2} \times 100 \\ &= \frac{R11.07}{R6.17} \times 100 \\ &= 179\% \end{aligned}$$

The ARR for a gas geyser in a household with low volume hot water consumption is fairly high.

### Discounted payback period

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

$$\text{Discounted payback period} = 12.34 - 5.70 - 5.75 - (0.89/5.80)$$

$$\text{Discounted payback period} = 2.15 \text{ years}$$

The discounted payback period is just over two years.

### EVA

The EVA is calculated as follows (par. 4.6.11):

$$\text{EVA} = \text{NOPAT} - (\text{CE} \times \text{WACC})$$

This formula is applied in Table 5.21. The EVA represents the sum of the discounted EVAs and amounts to R64 000.

The expected economic value that will be added to the household over the lifespan of a gas geyser is R64 000.

**Table 5.19: Energy saving for low volume hot water consumption (gas geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	10.06	11.06	12.17	13.38	14.72	16.19	17.81	19.60	21.55	23.71	26.08	28.69
Saving	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
<b>Total saving</b>	<b>-</b>	<b>10.06</b>	<b>11.06</b>	<b>12.17</b>	<b>13.38</b>	<b>14.72</b>	<b>16.19</b>	<b>17.81</b>	<b>19.60</b>	<b>21.55</b>	<b>23.71</b>	<b>26.08</b>	<b>28.69</b>

**Table 5.20: Low volume hot water consumption (gas geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>													
Investment cost	-8.65												
Installation cost	-3.69												
Additional cost		-3.84	-4.23	-4.65	-5.12	-5.63	-6.19	-6.81	-7.49	-8.24	-9.06	-9.97	-10.96
<b>Savings</b>													
Energy saving (100%)		10.06	11.06	12.17	13.38	14.72	16.19	17.81	19.60	21.55	23.71	26.08	28.69
<b>Total cash flows</b>	<b>-12.34</b>	<b>6.21</b>	<b>6.83</b>	<b>7.52</b>	<b>8.27</b>	<b>9.10</b>	<b>10.01</b>	<b>11.01</b>	<b>12.11</b>	<b>13.32</b>	<b>14.65</b>	<b>16.11</b>	<b>17.72</b>
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555
<b>Discounted cash flows</b>	<b>-12.34</b>	<b>5.70</b>	<b>5.75</b>	<b>5.80</b>	<b>5.86</b>	<b>5.91</b>	<b>5.97</b>	<b>6.02</b>	<b>6.08</b>	<b>6.13</b>	<b>6.19</b>	<b>6.24</b>	<b>6.30</b>

NPV 59.61  
IRR 60%  
MIRR 26%

**Table 5.21: EVA calculation for low volume hot water consumption (gas geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		6.21	6.83	7.52	8.27	9.10	10.01	11.01	12.11	13.32	14.65	16.11	17.72
Capital charges (R12.34 x 9%)		-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11
<b>EVA</b>		<b>5.10</b>	<b>5.72</b>	<b>6.41</b>	<b>7.16</b>	<b>7.98</b>	<b>8.89</b>	<b>9.90</b>	<b>11.00</b>	<b>12.21</b>	<b>13.54</b>	<b>15.00</b>	<b>16.61</b>
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555
<b>Discounted EVA</b>		<b>4.68</b>	<b>4.82</b>	<b>4.95</b>	<b>5.07</b>	<b>5.19</b>	<b>5.30</b>	<b>5.41</b>	<b>5.52</b>	<b>5.62</b>	<b>5.72</b>	<b>5.81</b>	<b>5.91</b>

EVA 64.00

### ***High volume hot water consumption (gas geyser)***

The inputs to this investment appraisal for a gas geyser are as follows:

The investment cost (par. 4.6.1) and installation cost (par. 4.6.1) of a gas geyser are based on the quotations received from three suppliers.

A gas geyser can contribute up to a 100% saving on the energy usage of a conventional geyser (par. 4.6.2). The saving is calculated on the energy cost, as shown in paragraph 4.5.4. The quotations received from suppliers of gas geysers were gathered in 2011; therefore, for the purpose of this study, the assumption is made that the gas geyser will start to generate savings from 2012 (year 1) onwards. The calculation of the savings generated by a gas geyser can be seen in Table 5.22.

Additional costs arise when installing a gas geyser, as gas replaces the energy usage of the conventional geyser. These costs add up to an average annual cost of R3 843.12, as calculated by Solien Energy Solutions (2007) (par. 4.6.1). This annual cost will be multiplied by the inflation rate of 10% (par. 3.3.2) to determine the annual cost.

The discount rate of an individual, for the purpose of this study, will be 9%, which is the prime rate in South Africa (par. 4.6.5).

### **NPV**

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value was calculated in Table 5.23 and amounts to R98 080.

The NPV of a gas geyser in a household with high volume hot water consumption is positive, indicating that it is a worthwhile investment.

### **Equivalent annual annuity**

The equivalent annual annuity will be determined using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R98\ 080 / 7.1607$$

$$= R13\ 697$$

The equivalent annual annuity is also positive, and also fairly high.

### IRR and MIRR

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following results for the IRR and MIRR are calculated in Table 5.23:

$$\text{IRR} = 87\%$$

$$\text{MIRR} = 31\%$$

The IRR and MIRR are both higher than the discount rate, indicating that the investor will earn a return higher than the initial investment.

### ARR

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(9.53+10.49+11.54+12.69+13.96+15.35+16.89+18.58+20.44+22.48+24.73+27.20)/12}{12.34/2} \times 100 \\ &= \frac{\text{R}16.99}{\text{R}6.17} \times 100 \\ &= 275\% \end{aligned}$$

The ARR of a gas geyser in a household with high volume hot water consumption is high in comparison with the discount rate.

### Discounted payback period

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

$$\text{Discounted payback period} = 12.34 - 8.75 - (3.59/8.83)$$

$$\text{Discounted payback period} = 1.41 \text{ years}$$

The discounted payback period is less than two years, making this a viable option to install.

## EVA

The EVA is calculated as follows (par. 4.6.11):

$$\text{EVA} = \text{NOPAT} - (\text{CE} \times \text{WACC})$$

This formula is applied in Table 5.24. The EVA represents the sum of the discounted EVAs and amounts to R102 470.

The expected economic value that will be added to a household with high volume hot water consumption over the expected life of a gas geyser is R102 470. The EVA ranks the gas geyser as the second best investment option for a household with high volume hot water consumption.

**Table 5.22: Energy saving for high volume hot water consumption (gas geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	13.38	14.71	16.19	17.80	19.59	21.54	23.70	26.07	28.67	31.54	34.70	38.17
Saving	0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
<b>Total saving</b>	<b>-</b>	<b>13.38</b>	<b>14.71</b>	<b>16.19</b>	<b>17.80</b>	<b>19.59</b>	<b>21.54</b>	<b>23.70</b>	<b>26.07</b>	<b>28.67</b>	<b>31.54</b>	<b>34.70</b>	<b>38.17</b>

**Table 5.23: High volume hot water consumption (gas geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>													
Investment cost	-8.65												
Installation cost	-3.69												
Additional cost		-3.84	-4.23	-4.65	-5.12	-5.63	-6.19	-6.81	-7.49	-8.24	-9.06	-9.97	-10.96
<b>Savings</b>													
Energy saving (100%)		13.38	14.71	16.19	17.80	19.59	21.54	23.70	26.07	28.67	31.54	34.70	38.17
<b>Total cash flows</b>	<b>-12.34</b>	<b>9.53</b>	<b>10.49</b>	<b>11.54</b>	<b>12.69</b>	<b>13.96</b>	<b>15.35</b>	<b>16.89</b>	<b>18.58</b>	<b>20.44</b>	<b>22.48</b>	<b>24.73</b>	<b>27.20</b>
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555
<b>Discounted cash flows</b>	<b>-12.34</b>	<b>8.75</b>	<b>8.83</b>	<b>8.91</b>	<b>8.99</b>	<b>9.07</b>	<b>9.16</b>	<b>9.24</b>	<b>9.32</b>	<b>9.41</b>	<b>9.50</b>	<b>9.58</b>	<b>9.67</b>

NPV 98.08  
 IRR 87%  
 MIRR 31%

**Table 5.24: EVA calculation for high volume hot water consumption (gas geyser)**

	0	1	2	3	4	5	6	7	8	9	10	11	12
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		9.53	10.49	11.54	12.69	13.96	15.35	16.89	18.58	20.44	22.48	24.73	27.20
Capital charges (R12.34 x 9%)		-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11	-1.11
<b>EVA</b>		<b>8.42</b>	<b>9.38</b>	<b>10.43</b>	<b>11.58</b>	<b>12.85</b>	<b>14.24</b>	<b>15.78</b>	<b>17.47</b>	<b>19.33</b>	<b>21.37</b>	<b>23.62</b>	<b>26.09</b>
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555
<b>Discounted EVA</b>		<b>7.73</b>	<b>7.89</b>	<b>8.05</b>	<b>8.20</b>	<b>8.35</b>	<b>8.49</b>	<b>8.63</b>	<b>8.77</b>	<b>8.90</b>	<b>9.03</b>	<b>9.15</b>	<b>9.28</b>

EVA 102.47

### 5.2.5 Instant heaters

The financial viability of an instant heater is calculated as follows:

#### ***Low volume hot water consumption (instant heater)***

The inputs to this investment appraisal are as follows:

The investment cost (par. 4.6.1) and installation cost (par. 4.6.1) of an instant heater are based on the quotations received from three suppliers.

An instant heater can contribute up to a 25% saving on the energy usage of a conventional geyser as the instant heaters will only serve 51% of the total hot water outlet within the household (par. 4.6.2). The saving is calculated on the energy cost, as shown in paragraph 4.5.4. The quotations received from suppliers of instant heaters were gathered in 2011; therefore, for the purpose of this study, the assumption is made that the instant heater will start to generate savings from 2012 (year 1) onwards. The calculation of the saving generated by an instant heater can be seen in Table 5.25.

The discount rate of an individual, for the purpose of this study, will be 9%, which is the prime rate in South Africa (par. 4.6.5).

#### NPV

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value was calculated in Table 5.26 and amounts to R42 840.

The NPV of an instant heater in a household with low volume hot water consumption is positive.

#### Equivalent annual annuity

The equivalent annual annuity is determined using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R42\ 840 / 9.1285$$

$$= R4\ 693$$

The equivalent annual annuity is also positive.

### IRR and MIRR

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following results for the IRR and MIRR are calculated:

$$\text{IRR} = 43\%$$

$$\text{MIRR} = 20\%$$

The IRR and MIRR are higher than the discount rate, making it a viable investment option.

### ARR

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(2.51+2.77+3.04+3.35+3.68+4.05+4.45+4.90+5.39+5.93+6.52+7.17+7.89+8.68+9.55+10.50+11.55+12.71+13.98+15.37)/20}{7.54/2} \times 100 \\ &= \frac{\text{R}7.20}{\text{R}3.77} \times 100 \\ &= 191\% \end{aligned}$$

The ARR is higher than the cost of capital.

### Discounted payback period

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

$$\text{Discounted payback period} = 7.54 - 2.31 - 2.33 - 2.35 - (0.55/2.37)$$

$$\text{Discounted payback period} = 3.23 \text{ years}$$

The discounted payback period of an instant heater in a household with low volume hot water consumption is just over three years.

### EVA

The EVA is calculated as follows (par. 4.6.11):

$$EVA = NOPAT - (CE \times WACC)$$

This formula is applied in Table 5.27. The EVA represents the sum of the discounted EVAs and amounts to R44 180.

The expected economic value that will be added to a household with low volume hot water consumption is R44 180.

**Table 5.25: Energy saving for low volume hot water consumption (instant heater)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	10.06	11.06	12.17	13.38	14.72	16.19	17.81	19.60	21.55	23.71	26.08	28.69	31.56	34.71	38.19	42.00	46.20	50.82	55.91	61.50
Saving	0%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
<b>Total saving</b>	-	<b>2.51</b>	<b>2.77</b>	<b>3.04</b>	<b>3.35</b>	<b>3.68</b>	<b>4.05</b>	<b>4.45</b>	<b>4.90</b>	<b>5.39</b>	<b>5.93</b>	<b>6.52</b>	<b>7.17</b>	<b>7.89</b>	<b>8.68</b>	<b>9.55</b>	<b>10.50</b>	<b>11.55</b>	<b>12.71</b>	<b>13.98</b>	<b>15.37</b>

**Table 5.26: Low volume hot water consumption (instant heater)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>																					
Investment cost	-5.33																				
Installation cost	-2.21																				
Rebate																					
<b>Savings</b>																					
Energy saving (25%)		2.51	2.77	3.04	3.35	3.68	4.05	4.45	4.90	5.39	5.93	6.52	7.17	7.89	8.68	9.55	10.50	11.55	12.71	13.98	15.37
<b>Total cash flows</b>	-7.54	2.51	2.77	3.04	3.35	3.68	4.05	4.45	4.90	5.39	5.93	6.52	7.17	7.89	8.68	9.55	10.50	11.55	12.71	13.98	15.37
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted cash flows</b>	<b>-7.54</b>	<b>2.31</b>	<b>2.33</b>	<b>2.35</b>	<b>2.37</b>	<b>2.39</b>	<b>2.41</b>	<b>2.44</b>	<b>2.46</b>	<b>2.48</b>	<b>2.50</b>	<b>2.53</b>	<b>2.55</b>	<b>2.57</b>	<b>2.60</b>	<b>2.62</b>	<b>2.65</b>	<b>2.67</b>	<b>2.69</b>	<b>2.72</b>	<b>2.74</b>

NPV 42.84  
IRR 43%  
MIRR 20%

**Table 5.27: EVA calculation for low volume hot water consumption (instant heater)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		2.51	2.77	3.04	3.35	3.68	4.05	4.45	4.90	5.39	5.93	6.52	7.17	7.89	8.68	9.55	10.50	11.55	12.71	13.98	15.37
Capital charges (R7.54 x 9%)		-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68
<b>EVA</b>		1.84	2.09	2.36	2.67	3.00	3.37	3.77	4.22	4.71	5.25	5.84	6.49	7.21	8.00	8.87	9.82	10.87	12.03	13.30	14.70
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted EVA</b>		1.68	1.76	1.82	1.89	1.95	2.01	2.06	2.12	2.17	2.22	2.26	2.31	2.35	2.39	2.43	2.47	2.51	2.55	2.59	2.62

EVA 44.18

### ***High volume hot water consumption (instant heater)***

The inputs to this investment appraisal are as follows:

The investment cost (par. 4.6.1) and installation cost (par. 4.6.1) of an instant heater are based on the quotations received from three suppliers.

An instant heater can contribute up to a 25% saving on the energy usage of a conventional geyser, as the instant heaters will only serve 51% of the total hot water outlet within the household (par. 4.6.2). The saving is calculated on the energy cost, as shown in paragraph 4.5.4. The quotations received from suppliers of instant heaters were gathered in 2011; therefore, for the purpose of this study, the assumption is made that the instant heater will start to generate savings from 2012 (year 1) onwards. The calculation of the saving generated by an instant heater can be seen in Table 5.28.

The discount rate of an individual, for the purpose of this study, will be 9%, which is the prime rate in South Africa (par. 4.6.5).

### **NPV**

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value was calculated in Table 5.29 and amounted to R59 480.

The NPV is positive for an instant heater in a household with high volume hot water consumption. This indicates that it is a financially viable investment option.

### **Equivalent annual annuity**

The equivalent annual annuity is determined using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R59\,480 / 9.1285$$

$$= R6\,516$$

The equivalent annual annuity is also positive.

### IRR and MIRR

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following results for the IRR and MIRR are calculated in Table 5.29:

$$\text{IRR} = 54\%$$

$$\text{MIRR} = 22\%$$

The IRR and MIRR are higher than the discount rate; therefore, the return on investment is more than the cost of capital.

### ARR

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(3.34+3.68+4.05+4.45+4.90+5.39+5.92+6.52+7.17+7.89+8.67+9.54+10.50+11.55+12.70+13.97+15.37+16.90+18.59+20.45)/20}{7.54/2} \times 100 \\ &= \frac{\text{R}9.58}{\text{R}3.77} \times 100 \\ &= 254\% \end{aligned}$$

The ARR is higher than the cost of capital.

### Discounted payback period

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

$$\text{Discounted payback period} = 7.54 - 3.07 - 3.10 - (1.37/3.12)$$

$$\text{Discounted payback period} = 2.44 \text{ years}$$

The discounted payback period is almost two and a half years.

## EVA

The EVA is calculated as follows (par. 4.6.11):

$$\text{EVA} = \text{NOPAT} - (\text{CE} \times \text{WACC})$$

This formula is applied in Table 5.30. The EVA represents the sum of the discounted EVAs and amounts to R60 820.

The expected economic value that will be added by this investment option for a household with high volume hot water consumption is R60 820.

**Table 5.28: Energy saving for high volume hot water consumption (instant heater)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	13.38	14.71	16.19	17.80	19.59	21.54	23.70	26.07	28.67	31.54	34.70	38.17	41.98	46.18	50.80	55.88	61.47	67.61	74.38	81.81
Saving	0%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
<b>Total saving</b>	-	<b>3.34</b>	<b>3.68</b>	<b>4.05</b>	<b>4.45</b>	<b>4.90</b>	<b>5.39</b>	<b>5.92</b>	<b>6.52</b>	<b>7.17</b>	<b>7.89</b>	<b>8.67</b>	<b>9.54</b>	<b>10.50</b>	<b>11.55</b>	<b>12.70</b>	<b>13.97</b>	<b>15.37</b>	<b>16.90</b>	<b>18.59</b>	<b>20.45</b>

**Table 5.29: High volume hot water consumption (instant heater)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>																					
Investment cost	-5.33																				
Installation cost	-2.21																				
Rebate																					
<b>Savings</b>																					
Energy saving (25%)		3.34	3.68	4.05	4.45	4.90	5.39	5.92	6.52	7.17	7.89	8.67	9.54	10.50	11.55	12.70	13.97	15.37	16.90	18.59	20.45
<b>Total cash flows</b>	-7.54	3.34	3.68	4.05	4.45	4.90	5.39	5.92	6.52	7.17	7.89	8.67	9.54	10.50	11.55	12.70	13.97	15.37	16.90	18.59	20.45
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted cash flows</b>	<b>-7.54</b>	<b>3.07</b>	<b>3.10</b>	<b>3.12</b>	<b>3.15</b>	<b>3.18</b>	<b>3.21</b>	<b>3.24</b>	<b>3.27</b>	<b>3.30</b>	<b>3.33</b>	<b>3.36</b>	<b>3.39</b>	<b>3.42</b>	<b>3.45</b>	<b>3.49</b>	<b>3.52</b>	<b>3.55</b>	<b>3.58</b>	<b>3.62</b>	<b>3.65</b>

NPV 59.48  
IRR 54%  
MIRR 22%

**Table 5.30: EVA calculation for high volume hot water consumption (instant heater)**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		3.34	3.68	4.05	4.45	4.90	5.39	5.92	6.52	7.17	7.89	8.67	9.54	10.50	11.55	12.70	13.97	15.37	16.90	18.59	20.45
Capital charges (R7.54 x 9%)		-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68	-0.68
<b>EVA</b>		2.67	3.00	3.37	3.77	4.22	4.71	5.25	5.84	6.49	7.21	8.00	8.86	9.82	10.87	12.02	13.29	14.69	16.22	17.92	19.77
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted EVA</b>		2.45	2.53	2.60	2.67	2.74	2.81	2.87	2.93	2.99	3.04	3.10	3.15	3.20	3.25	3.30	3.35	3.39	3.44	3.48	3.53

EVA 60.82

## 5.2.6 Summary of investment appraisals

**Table 5.31: Summary of investment appraisals for a household with low volume hot water consumption**

	<b>Solar geyser</b>	<b>Time switch</b>	<b>Heat pump</b>	<b>Gas geyser</b>	<b>Instant heater</b>
<b>NPV</b>	R63 750	R49 410	R91 770	R59 610	R42 840
<b>EAA</b>	R6 984	R7 699	R11 385	R8 325	R4 693
<b>IRR</b>	33%	354%	71%	60%	43%
<b>MIRR</b>	18%	55%	26%	26%	20%
<b>ARR</b>	137%	1 008%	332%	179%	191%
<b>Discounted payback period</b>	4.49 years	0.30 years	1.78 years	2.15 years	3.23 years
<b>EVA</b>	R66 760	R50 070	R94 940	R64 000	R44 180

**Table 5.32: Summary of investment appraisals for a household with high volume hot water consumption**

	<b>Solar geyser</b>	<b>Time switch</b>	<b>Heat pump</b>	<b>Gas geyser</b>	<b>Instant heater</b>
<b>NPV</b>	R90 370	R79 040	R125 900	R98 080	R59 480
<b>EAA</b>	R9 900	R12 316	R15 619	R13 697	R6 516
<b>IRR</b>	42%	554%	91%	87%	54%
<b>MIRR</b>	20%	62%	29%	31%	22%
<b>ARR</b>	182%	1 721%	342%	275%	254%
<b>Discounted payback period</b>	3.39 years	0.20 years	1.34 years	1.41 years	2.44 years
<b>EVA</b>	R93 380	R79 690	R129 080	R102 470	R60 820

### 5.3 SENSITIVITY ANALYSIS

The sensitivity analysis will determine what the impact will be on the outcome of the analysis if one of the inputs to the investment appraisal were to change (par 4.6.12). To determine the impact, variables within one of the investment appraisals will be changed.

The investment appraisal on which the sensitivity analysis will be conducted will be the investment appraisal for a solar geyser within a household with high volume hot water consumption (par. 5.2.1). This investment appraisal was randomly selected.

#### 5.3.1 Change in discount rate

If the discount rates were to be different, and were to increase from 9% to 10%, the impact will be as follows:

##### ***NPV***

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value is calculated in Table 5.34 and amounts to R80 430. At a discount rate of 9%, it amounted to R90 370.

The change in the discount rate from 9% to 10% decreased the NPV by almost R10 000. Therefore, it can be said that the NPV is sensitive to a change in the discount rate.

##### ***Equivalent annual annuity***

The equivalent annual annuity is determined by using the following formula (par. 4.6.6):

EAA = NPV/ present value factor of annuity for the useful life of the investment

$$= R90\,430 / 9.1285$$

$$= R8\,811$$

The equivalent annual annuity amounts to R8 811 if the discount rate changes to 10%. The equivalent annual annuity at a discount rate of 9% amounts to R9 900. It is evident that the equivalent annual annuity is also sensitive to a change in the discount rate.

### ***IRR and MIRR***

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following results for the IRR and MIRR are calculated in Table 5.34:

IRR = 42%

MIRR = 20%

The IRR and MIRR are unchanged, as the discount rate is not used for this calculation.

### ***ARR***

There will be no impact on the ARR as the discount rate will not affect accounting profit made by the investment. The discount rate only has an affect on the discounted cashflows.

### ***Discounted payback period***

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

Discounted payback period = 16.85 - 4.86 - 4.86 - 4.86 - (2.27/4.86)

Discounted payback period = 3.47 years

The discount rate changed from 3.39 years at a discount rate of 9% to 3.47 years at a discount rate of 10%. The discounted payback period increased slightly, but the effect was not significant; therefore, the discounted payback period is not that sensitive to a change in discount rate.

### ***EVA***

The EVA is calculated as follows (par. 4.6.11):

EVA = NOPAT – (CE X WACC)

This formula is applied in Table 5.37. The EVA represents the sum of the discounted EVAs and amounts to R84 370.

The change in the EVA amounts to R9 010 (the EVA was R93 380 at a discount rate of 9%); therefore, it can be concluded that the EVA is sensitive to discount rate changes.

**Table 5.33: Energy saving for a change in discount rate**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	13.38	14.71	16.19	17.80	19.59	21.54	23.70	26.07	28.67	31.54	34.70	38.17	41.98	46.18	50.80	55.88	61.47	67.61	74.38	81.81
Saving	0%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
<b>Total saving</b>	-	<b>5.35</b>	<b>5.89</b>	<b>6.47</b>	<b>7.12</b>	<b>7.83</b>	<b>8.62</b>	<b>9.48</b>	<b>10.43</b>	<b>11.47</b>	<b>12.62</b>	<b>13.88</b>	<b>15.27</b>	<b>16.79</b>	<b>18.47</b>	<b>20.32</b>	<b>22.35</b>	<b>24.59</b>	<b>27.05</b>	<b>29.75</b>	<b>32.73</b>

**Table 5.34: Change in discount rate**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>																					
Investment cost	-15.11																				
Installation cost	-6.77																				
Rebate	5.03																				
<b>Savings</b>																					
Energy saving (40%)		5.35	5.89	6.47	7.12	7.83	8.62	9.48	10.43	11.47	12.62	13.88	15.27	16.79	18.47	20.32	22.35	24.59	27.05	29.75	32.73
<b>Total cash flows</b>	-16.85	5.35	5.89	6.47	7.12	7.83	8.62	9.48	10.43	11.47	12.62	13.88	15.27	16.79	18.47	20.32	22.35	24.59	27.05	29.75	32.73
Discount factor (10%)	1.0000	0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241	0.3855	0.3505	0.3186	0.2897	0.2633	0.2394	0.2176	0.1978	0.1799	0.1635	0.1486
<b>Discounted cash flows</b>	<b>-16.85</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.86</b>	<b>4.87</b>	<b>4.86</b>	<b>4.86</b>

NPV 80.43  
 IRR 42%  
 MIRR 20%

**Table 5.35: EVA calculation for a change in discount rate**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		5.35	5.89	6.47	7.12	7.83	8.62	9.48	10.43	11.47	12.62	13.88	15.27	16.79	18.47	20.32	22.35	24.59	27.05	29.75	32.73
Capital charges (R7.54 x 9%)		-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52
<b>EVA</b>		3.83	4.37	4.96	5.61	6.32	7.10	7.96	8.91	9.95	11.10	12.36	13.75	15.28	16.96	18.80	20.84	23.07	25.53	28.23	31.21
Discount factor		0.9091	0.8264	0.7513	0.6830	0.6209	0.5645	0.5132	0.4665	0.4241	0.3855	0.3505	0.3186	0.2897	0.2633	0.2394	0.2176	0.1978	0.1799	0.1635	0.1486
<b>Discounted EVA</b>		3.49	3.61	3.72	3.83	3.92	4.01	4.09	4.16	4.22	4.28	4.33	4.38	4.43	4.46	4.50	4.53	4.56	4.59	4.62	4.64

EVA 84.37

### **5.3.2 Change in inflation rate**

If the inflation rate increased from 10% to 11%, the impacts are as follows (the discount rate is 9%):

#### ***NPV***

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value is calculated in Table 5.37 and amounts to R100 480. This changed from R90 370 at an inflation rate of 10%.

The NPV increases by R9 750 when the inflation rate increases from 10% to 11%; therefore, the NPV is affected if the inflation rate changes.

#### ***Equivalent annual annuity***

The equivalent annual annuity is determined using the following formula (par. 4.6.6):

EAA = NPV / present value factor of annuity for the useful life of the investment

$$= R100\,480 / 9.1285$$

$$= R11\,007$$

The equivalent annual annuity changes from R9 900 to R11 007, and therefore is sensitive to a change in the inflation rate.

#### ***IRR and MIRR***

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following results for the IRR and MIRR are calculated in Table 5.37:

$$\text{IRR} = 43\%$$

$$\text{MIRR} = 20\%$$

The IRR slightly increases by 1% (from 42% to 43%) and the MIRR remains unchanged. It can be concluded that the IRR and MIRR are not that much affected by a change in the inflation rate.

## **ARR**

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(5.35+5.94+6.59+7.32+8.12+9.02+10.01+11.11+12.33+13.69+15.19+16.86+18.72+20.78+23.06+25.60+28.42+31.54+35.01+38.86)/20}{16.85/2} \times 100 \\ &= \frac{R17.18}{R8.43} \times 100 \\ &= 204\% \end{aligned}$$

The ARR increases with 22% (from 182% to 204%). This indicates that the ARR is, to some degree, sensitive to a change in the inflation rate.

## ***Discounted payback period***

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

$$\text{Discounted payback period} = 16.85 - 4.91 - 5.00 - 5.09 - (1.85/5.18)$$

$$\text{Discounted payback period} = 3.36 \text{ years}$$

The discounted payback period changes from 3.39 years at an inflation rate of 10% to 3.36 years at an inflation rate of 11%, and therefore does not change significantly. It can be said that the discounted payback period is not sensitive to a slight change in the inflation rate.

## **EVA**

The EVA is calculated as follows (par. 4.6.11):

$$\text{EVA} = \text{NOPAT} - (\text{CE} \times \text{WACC})$$

This formula was applied in Table 5.38. The EVA represents the sum of the discounted EVAs and amounts to R103 490.

The EVA increased by around R10 000.00 as it changed from R93 380 at an inflation rate of 10% to R103 490 at an inflation rate of 11%. It can be concluded that the EVA is sensitive to a change in the inflation rate.

**Table 5.36: Energy saving for a change in inflation rate**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	13.38	14.85	16.48	18.29	20.31	22.54	25.02	27.77	30.83	34.22	37.98	42.16	46.80	51.95	57.66	64.00	71.04	78.86	87.53	97.16
Saving	0%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
<b>Total saving</b>	-	<b>5.35</b>	<b>5.94</b>	<b>6.59</b>	<b>7.32</b>	<b>8.12</b>	<b>9.02</b>	<b>10.01</b>	<b>11.11</b>	<b>12.33</b>	<b>13.69</b>	<b>15.19</b>	<b>16.86</b>	<b>18.72</b>	<b>20.78</b>	<b>23.06</b>	<b>25.60</b>	<b>28.42</b>	<b>31.54</b>	<b>35.01</b>	<b>38.86</b>

**Table 5.37: Change in inflation rate**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>																					
Investment cost	-15.11																				
Installation cost	-6.77																				
Rebate	5.03																				
<b>Savings</b>																					
Energy saving (40%)		5.35	5.94	6.59	7.32	8.12	9.02	10.01	11.11	12.33	13.69	15.19	16.86	18.72	20.78	23.06	25.60	28.42	31.54	35.01	38.86
<b>Total cash flows</b>	-16.85	5.35	5.94	6.59	7.32	8.12	9.02	10.01	11.11	12.33	13.69	15.19	16.86	18.72	20.78	23.06	25.60	28.42	31.54	35.01	38.86
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted cash flows</b>	<b>-16.85</b>	<b>4.91</b>	<b>5.00</b>	<b>5.09</b>	<b>5.18</b>	<b>5.28</b>	<b>5.38</b>	<b>5.47</b>	<b>5.58</b>	<b>5.68</b>	<b>5.78</b>	<b>5.89</b>	<b>6.00</b>	<b>6.11</b>	<b>6.22</b>	<b>6.33</b>	<b>6.45</b>	<b>6.57</b>	<b>6.69</b>	<b>6.81</b>	<b>6.93</b>

NPV 100.48  
 IRR 43%  
 MIRR 20%

**Table 5.38: EVA calculation for a change is inflation rate**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		5.35	5.94	6.59	7.32	8.12	9.02	10.01	11.11	12.33	13.69	15.19	16.86	18.72	20.78	23.06	25.60	28.42	31.54	35.01	38.86
Capital charges (R7.54 x 9%)		-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52
<b>EVA</b>		<b>3.83</b>	<b>4.42</b>	<b>5.08</b>	<b>5.80</b>	<b>6.61</b>	<b>7.50</b>	<b>8.49</b>	<b>9.59</b>	<b>10.81</b>	<b>12.17</b>	<b>13.68</b>	<b>15.35</b>	<b>17.20</b>	<b>19.26</b>	<b>21.55</b>	<b>24.08</b>	<b>26.90</b>	<b>30.03</b>	<b>33.50</b>	<b>37.35</b>
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted EVA</b>		<b>3.52</b>	<b>3.72</b>	<b>3.92</b>	<b>4.11</b>	<b>4.29</b>	<b>4.47</b>	<b>4.64</b>	<b>4.81</b>	<b>4.98</b>	<b>5.14</b>	<b>5.30</b>	<b>5.46</b>	<b>5.61</b>	<b>5.76</b>	<b>5.91</b>	<b>6.07</b>	<b>6.22</b>	<b>6.37</b>	<b>6.52</b>	<b>6.66</b>

EVA 103.49

### **5.3.3 Percentage change in energy saving**

If the percentage saving generated by a solar geyser changed from 40% to 30% (the discount rate is 9% and the inflation rate is 10%):

#### ***NPV***

The NPV is the sum of all the discounted cashflows (par. 4.6.6).

The net present value is calculated in Table 5.40 and amounts to R63 570.

The NPV decreased by around R25 000, as is evident in the change in NPV from R90 370 to R63 570. Therefore, the NPV is very sensitive to a change in the energy saving generated by the water heating system.

#### ***Equivalent annual annuity***

The equivalent annual annuity is determined using the following formula (par. 4.6.6):

EAA = NPV / present value factor of annuity for the useful life of the investment

$$= R63\ 570 / 9.1285$$

$$= R6\ 964$$

The equivalent annual annuity also decreases significantly from R9 900 to R6 964, and therefore it is very sensitive to a change in the energy saving of a water heating system.

#### ***IRR and MIRR***

The IRR (par. 4.6.7) and MIRR (par. 4.6.8) are determined using Excel and the following results for the IRR and MIRR are calculated in Table 5.40:

$$\text{IRR} = 33\%$$

$$\text{MIRR} = 18\%$$

There is a decrease in the IRR and MIRR. The IRR decreases from 42% to 33% and the MIRR decreases from 20% to 18%. It is evident that the IRR is sensitive to a change in the energy saving, but the change in the MIRR is not that significant.

## **ARR**

The ARR is calculated as follows (par. 4.6.9):

$$\begin{aligned} \text{ARR} &= \frac{\text{Average annual profits}}{\text{Average investment}} \times 100 \\ &= \frac{(4.01+4.41+4.86+5.34+5.88+6.46+7.11+7.82+8.60+9.46+10.41+11.45+12.59+13.85+15.24+16.76+18.44+20.28+22.31+24.54)/20}{16.85/2} \times 100 \\ &= \frac{R11.49}{R8.43} \times 100 \\ &= 136\% \end{aligned}$$

The ARR decreases from 182% to 136%, therefore it is clear that the ARR is sensitive to a change in the energy saving of a water heating system.

## ***Discounted payback period***

The discounted payback period represents the number of years it will take for the discounted cash inflows to cover the initial investment (par. 4.6.10).

The discounted payback period is calculated as follows:

$$\text{Discounted payback period} = 16.85 - 3.68 - 3.72 - 3.75 - 3.78 - (1.92/3.82)$$

$$\text{Discounted payback period} = 4.50 \text{ years}$$

The discounted payback period changes from 3.39 years to 4.50 years. This is a significant change and therefore it can be said that the discounted payback period is sensitive to a change in the energy saving.

## **EVA**

The EVA is calculated as follows (par. 4.6.11):

$$\text{EVA} = \text{NOPAT} - (\text{CE} \times \text{WACC})$$

This formula is applied in Table 5.41. The EVA represents the sum of the discounted EVAs and amounts to R66 580.

The EVA drops significantly from R93 380 to R66 580, and is therefore very sensitive to a change in the energy saving of a water heating system.

**Table 5.39: Energy saving for a change in energy saving**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Energy cost	-	13.38	14.71	16.19	17.80	19.59	21.54	23.70	26.07	28.67	31.54	34.70	38.17	41.98	46.18	50.80	55.88	61.47	67.61	74.38	81.81
Saving	0%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
<b>Total saving</b>	-	<b>4.01</b>	<b>4.41</b>	<b>4.86</b>	<b>5.34</b>	<b>5.88</b>	<b>6.46</b>	<b>7.11</b>	<b>7.82</b>	<b>8.60</b>	<b>9.46</b>	<b>10.41</b>	<b>11.45</b>	<b>12.59</b>	<b>13.85</b>	<b>15.24</b>	<b>16.76</b>	<b>18.44</b>	<b>20.28</b>	<b>22.31</b>	<b>24.54</b>

**Table 5.40: Change in energy saving**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
<b>Costs</b>																					
Investment cost	-15.11																				
Installation cost	-6.77																				
Rebate	5.03																				
<b>Savings</b>																					
Energy saving (30%)		4.01	4.41	4.86	5.34	5.88	6.46	7.11	7.82	8.60	9.46	10.41	11.45	12.59	13.85	15.24	16.76	18.44	20.28	22.31	24.54
<b>Total cash flows</b>	-16.85	4.01	4.41	4.86	5.34	5.88	6.46	7.11	7.82	8.60	9.46	10.41	11.45	12.59	13.85	15.24	16.76	18.44	20.28	22.31	24.54
Discount factor (9%)	1.0000	0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted cash flows</b>	<b>-16.85</b>	<b>3.68</b>	<b>3.72</b>	<b>3.75</b>	<b>3.78</b>	<b>3.82</b>	<b>3.85</b>	<b>3.89</b>	<b>3.93</b>	<b>3.96</b>	<b>4.00</b>	<b>4.03</b>	<b>4.07</b>	<b>4.11</b>	<b>4.15</b>	<b>4.18</b>	<b>4.22</b>	<b>4.26</b>	<b>4.30</b>	<b>4.34</b>	<b>4.38</b>

NPV 63.57  
IRR 33%  
MIRR 18%

**Table 5.41: EVA calculation for a change is inflation rate**

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000	R'000
Total cash flows		4.01	4.41	4.86	5.34	5.88	6.46	7.11	7.82	8.60	9.46	10.41	11.45	12.59	13.85	15.24	16.76	18.44	20.28	22.31	24.54
Capital charges (R7.54 x 9%)		-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52	-1.52
<b>EVA</b>		2.50	2.90	3.34	3.82	4.36	4.95	5.59	6.30	7.09	7.95	8.89	9.93	11.08	12.34	13.72	15.25	16.92	18.77	20.80	23.03
Discount factor		0.9174	0.8417	0.7722	0.7084	0.6499	0.5963	0.5470	0.5019	0.4604	0.4224	0.3875	0.3555	0.3262	0.2992	0.2745	0.2519	0.2311	0.2120	0.1945	0.1784
<b>Discounted EVA</b>		2.29	2.44	2.58	2.71	2.83	2.95	3.06	3.16	3.26	3.36	3.45	3.53	3.61	3.69	3.77	3.84	3.91	3.98	4.04	4.11

EVA 66.58

### 5.3.4 Summary of sensitivity analysis

**Table 5.42: Summary of the sensitivity analysis**

	<b>Baseline</b>	<b>Change in discount rate (9% to 10%)</b>	<b>Change in inflation rate (10% to 11%)</b>	<b>Change in % saving (40% to 30%)</b>
	<b>R'000</b>	<b>R'000</b>	<b>R'000</b>	<b>R'000</b>
<b>NPV</b>	R90 370	R80 430	R100 480	R63 570
<b>EAA</b>	R9 900	R8 811	R11 007	R6 964
<b>IRR</b>	42%	42%	43%	33%
<b>MIRR</b>	20%	20%	20%	18%
<b>ARR</b>	182%	182%	204%	136%
<b>Discounted payback period</b>	3.39 years	3.47 years	3.36 years	4.50 years
<b>EVA</b>	R93 380	R84 370	R103 490	R66 580

## 5.4 SUMMARY

This chapter contains all the investment appraisals needed to come to a conclusion in this study. Ten investment appraisals were done. The summary of the investment appraisals performed for a household with low volume hot water consumption can be seen in Table 5.31, and the summary of the investment appraisal performed for a household with high volume hot water consumption can be seen in Table 5.32. The outcome of the sensitivity analysis is summarised in Table 5.42.

This chapter generated the results for this study. With this, the third specific objective was achieved, namely to consider, within the context of both high and low volume consumption households, the investment cost, net present value, IRR, MIRR, ARR, payback period and EVA for a solar water heating system, a time switch on a conventional geyser, a heat pump, a gas geyser and an instant heater.

In Chapter 6, conclusions and recommendations will be made based on the outcomes of this study.

## **6. CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS**

### **6.1 BACKGROUND**

As stated in Chapter 1 (par. 1.4.1), the general objective of this study is to determine the most financially viable investment with regard to water heating systems in order to reduce electricity costs within a household.

The specific objectives (par. 1.4.2) in order to reach the general objective were as follows:

- To conceptualise, from the literature, the financial impact of the conventional geyser with regard to the average electricity bill, as well as the different options as alternatives to reduce the electricity usage in order to generate hot water.
- To conceptualise from the literature the relevance of different investment appraisal techniques in deciding on the most financially viable option as alternative to the conventional geyser to reduce electricity usage in order to generate hot water.
- To consider, within the context of both high and low volume consumption households, the investment cost, net present value, IRR, MIRR, ARR, payback period and EVA for a solar water heating system, a time switch on a conventional geyser, a heat pump, a gas geyser and an instant heater.
- To provide recommendations regarding the most financially viable water heating system for a household, depending on the volume of hot water consumption.

The objective of this final chapter of this study is to comply with the last objective of making recommendations regarding the most financially viable water heating system for a household, depending on the volume of hot water consumption. Firstly, conclusions will be drawn on the other three objectives covered in Chapter 2, Chapter 3 and Chapter 4, and then recommendations will be made, where applicable.

Finally, the chapter will state the limitations of this research, the value of this research, as well as possible areas to research further.

### **6.2 CONCLUSIONS**

The conclusions will be discussed in the order of the specific objectives of this study.

### **6.2.1 Conclusion regarding the financial impact of a conventional geyser and alternative water heating options**

This objective was covered in Chapter 2 of this study. It was found that a conventional geyser adds up to 50% of the total electricity usage of a South African Household (par. 2.2). Alternative water heating systems were identified.

### **6.2.2 The investment appraisal methods to use for all investment options for both high and low volume hot water consumption households**

In order to address the second specific objective of this study, a literature review had to be done on investment appraisal methods. Several investment appraisal methods were identified and discussed in Chapter 3.

### **6.2.3 Conclusions on objectives based on the empirical results**

In order to address the third and last objective of this study the objectives based on the empirical study can be concluded by referring to Table 5.31 and Table 5.32. Table 5.31 is a summary of all the investment appraisals done for a household with low volume hot water consumption. Table 5.32 is a summary of all investment appraisals done for a household with high volume hot water consumption.

## **6.3 RECOMMENDATIONS**

In order to achieve the fourth and last specific objective of this study, recommendations are made based on the research and conclusions made in this study. As mentioned in the conclusions above, the different alternatives to replace a conventional geyser in order to reduce energy consumption and reduce electricity cost were identified and discussed by means of a literature review. The different investment appraisal methods were also discussed by means of a literature review to identify the most appropriate methods for the purpose of the study.

From the empirical study, the following recommendations can be made:

### **6.3.1 Recommendations for a household with low volume hot water consumption**

For a household with low volume hot water consumption, the most financially viable alternative water heating system is a time switch on a conventional geyser. Although the NPV and equivalent annual annuity of this investment option are not the highest between the options, it renders the best IRR, MIRR, ARR and discounted payback period. The IRR of a time switch is almost five times higher than the investment option with the second highest IRR, the MIRR at 2.12 times, the ARR at 5.5 times and the discounted payback period at 5.9 times quicker.

The second best investment option for a household with low volume hot water consumption will be a heat pump. This investment option has the highest NPV, equivalent annual annuity and EVA, with the second highest IRR, MIRR, ARR and discounted payback period.

A gas geyser will be the third best investment option for a household with low volume hot water consumption.

### **6.3.2 Recommendations for a household with high volume hot water consumption**

For a household with high volume hot water consumption, the most financially viable alternative water heating system is again a time switch, with the highest IRR, MIRR, ARR and discounted payback period. The NPV and equivalent annual annuity for a time switch increased significantly from the investment appraisal for a time switch for a household with low volume hot water consumption, making it more competitive in that area with the other options. The IRR is six times more than the option with the second highest IRR, the MIRR is double that of the second best option, the ARR is 6.3 times and the discounted payback period is 6.7 times quicker.

The second best investment option for a household with high volume hot water consumption is again a heat pump with the highest NPV, equivalent annual annuity and EVA, the second highest IRR, ARR and discounted payback period.

The gas geyser is the third best investment option for a household with high volume hot water consumption.

## **6.4 LIMITATIONS OF THIS STUDY**

The following limitations should be considered:

- Limited literature is available on the different hot water heating systems, which made it difficult to perform a proper literature review on all aspects of these systems.
- No indication could be given on the maintenance costs of a conventional geyser as well as all the other water heating systems. Due to this, the assumption had to be made that the maintenance cost is not significant, and therefore this cost was not included in the investment appraisals.
- The situation differs from individual to individual. The assumption is made that they are mostly in a net lending position, and therefore the prime lending rate was used as a discount rate.

## **6.5 VALUE OF THE RESEARCH**

This research is the first research focusing on all the different types of water heating systems, and not just on a solar geyser or a heat pump. Secondly, this study focuses on South Africa as a country in a time where alternative water heating systems are highly considered due to high tariff increases by Eskom.

The contribution of this study is that it gives a detailed financial analysis of each of the water heating systems, and compares all five water heating systems by considering various investment appraisal methods. Secondly, individuals will be able to calculate the financial viability of each of the water heating systems by inputting their own variables in an Excel spreadsheet included on a CD in this study.

## **6.6 AREAS FOR FURTHER RESEARCH**

The following areas were identified for further research:

- The population of this study can be focused on small businesses and large organisations.
- Research can be done on the most appropriate discount rate for individuals.
- The maintenance cost of water heating systems can also be researched.

## **6.7 FINAL CONCLUSION**

This chapter focussed on concluding on each of the specific objectives set out in Chapter 1 by analysing literature and through empirical results. The goal of this study, as well as the

specific objectives of this study as set out in Chapter 1 paragraph 1.4, was achieved. The first two objectives were addressed in Chapter 2 and Chapter 3. The third objective was addressed in Chapter 5.

The research question was to determine what the household economic implications of key alternative water heating systems within the South African context are. This question was addressed through the specific objectives, which were met. It was found that a conventional geyser contributes to 50% of the total energy consumption of a household, and that a time switch would be the best investment option for both a household with low and high volume hot water consumption.

The chapter ended by making recommendations, stating the limitations experienced within the study, the expected value of the research and areas for further research.

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**ANNEXTURE A**

**TITLE**

HEAT TRANSFER ANALYSIS OF A DOMESTIC GEYSER SYSTEM

**CLIENT**

MRS A PRETORIUS

**DATE**

MARCH 2012

**AUTHOR**

MR J DREYER

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## NOMENCLATURE

Symbol	Units	Full Description
$q_x$	W	Heat flux from region x
$\Delta T$	°C	Differential temperature
$R_x$	$\frac{K}{W}$	Thermal resistance of region x
$\rho$	$\frac{kg}{m^3}$	Density
$P_{ambient}$	kPa	Ambient pressure
$T_{ambient}$	°C	Ambient temperature
$V_x$	$\frac{m}{s}$	Velocity for fluid x
$h_x$	$\frac{W}{m^2 \cdot K}$	Convection coefficient for surface x
$k_x$	$\frac{W}{m \cdot K}$	Conduction coefficient for medium x
$Re_x$	-	Reynolds number for fluid x
$Nu_x$	-	Nusselt number for fluid x
$Pr_x$	-	Prandtl number for fluid x
$\dot{m}$	$\frac{kg}{s}$	Mass flow rate
$\dot{Q}$	$\frac{m^3}{s}$	Volumetric flow rate
$P_x$	W	Power consumption / output of x
$\mu_x$	$\frac{kg}{m \cdot s}$	Viscosity of fluid x



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## 1 INTRODUCTION

A heat transfer analysis of a domestic geyser system was requested. The objective of the analysis is to investigate the efficiency of different energy conservation strategies. In this investigation the following conservation strategies were analysed:

- Reducing the average temperature of the water in the geyser.
- Installing a time switch to energise the geyser during specified intervals.
- Installing a geyser blanket to increase the insulation thickness around the geyser.

The analysis also incorporated the effect that water usage per day has on the energy cost per household. This was done by assuming an average water consumption of 60 litres per person per day, and expanding the analyses from one to ten persons per household.

The total volume of water used per day was distributed over a 24 hour period by utilising a specific water consumption profile, as documented in section 3.4. The water usage profile was adopted from Bourke & Bansal (2010).

The effect of Eskom's block tariff was also included in the analyses. The aim of the block tariffs is for high energy consumers to pay more, whilst lower end users pay less per kilowatt hour for their energy needs. The detail of the block tariffs can be seen in section 3.1

The results are tabulated and discussed in section 4 & 5.

## 2 EVALUATION APPROACH

### 2.1 REFERENCE GEYSER

For this investigation a Tecron vertically mounted geyser was used as reference with the following technical characteristics:

- Heating element power : 3000 W
- Capacity : 150 litre
- Internal Dimensions : 550 mm (diameter) X 1150 mm (length)
- Internal pressure : 200 kPa
- Reservoir material : Copper
- Insulation material : EPS (Expanded Polystyrene)

In order to determine if any improvement was realised by implementing the various energy conservation strategies, a base configuration need to be established. The base configuration would provide the fundamental heat transfer model on which all scenarios will be based.

The base configuration was calibrated by varying certain unknown parameters used in the analysis. This was done to resemble the amount of heat lost on a real, functional geyser of similar design by comparing the outlet temperature at various intervals.

### 2.2 ENERGY CONSERVATION STRATEGIES

#### 2.2.1 Scenario 1 – Base Configuration

For the base configuration, the analysis start-up temperature was set at 70°C, approximately the mean temperature. The thermostat temperature range was set at 65 - 75°C.

#### 2.2.2 Scenario 2 – Reduced Temperature

For this scenario the analysis start-up temperature was set at 60°C. The thermostat temperature range was set at 55 - 65°C. The lower thermostat setting of 55°C was chosen as any temperature below this set point could result in microbial growth and consequent health implications [9.2].

#### 2.2.3 Scenario 3 – Time Switch

A logical time operator was superimposed over the temperature restriction in this analysis that only allows the heating element to be energised between 05h00 – 08h00 and 17h00 – 20h00. The analysis start-up temperature was set at 70°C, whilst the thermostat temperature range was set at 65 - 75°C.

#### 2.2.4 Scenario 4 – Insulation Blanket

The last scenario that was modelled entails an insulation blanket to be installed over the external surface of the geyser, increasing the thermal resistance of the geyser against heat loss. A 75mm thick insulation layer with a thermal conductivity of 0.03 W/m.K was included in the analysis. The analysis start-up temperature was set at 70°C, whilst the thermostat temperature range was set at 65 - 75°C.

### 2.3 HEAT TRANSFER MODEL

The heat transfer model of the geyser was divided into 3 sections, where after heat transfer equations were solved for each section, as shown in Figure 1.

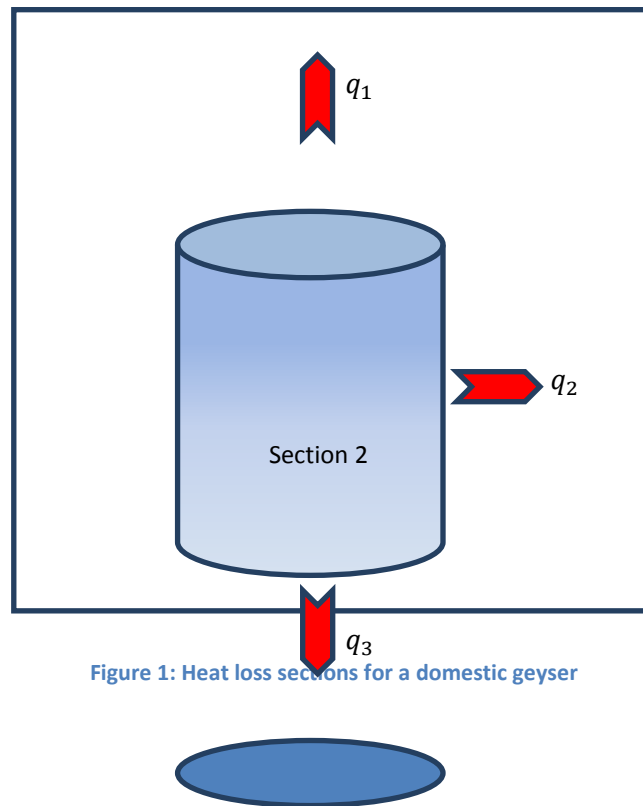


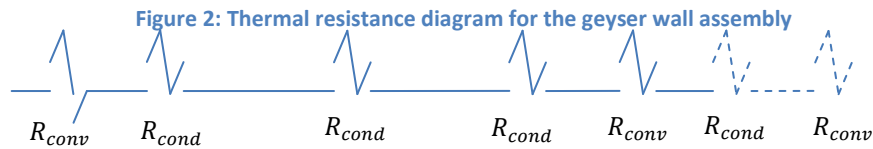
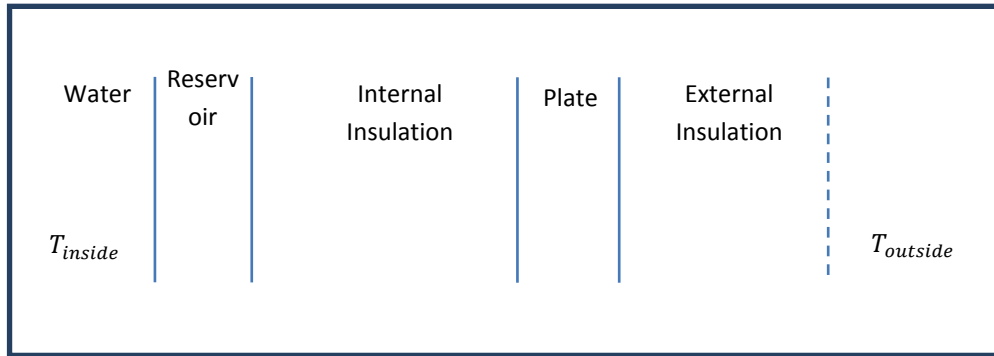
Figure 1: Heat loss sections for a domestic geyser

Heat fluxes  $q_1$  and  $q_3$  refer to the heat loss through the upper and lower circular wall sections of the geyser, while heat flux  $q_2$  is referring to heat loss through the cylindrical wall section. In practice sections 1 & 3 would be tori-spherical, but for the purpose of this analysis a flat approximation would be sufficient.

These three heat fluxes occur in parallel, thus the governing heat transfer equation would be according to Fourier's Law and take the form:

$$q_{total} = q_1 + q_2 + q_3 = \frac{\Delta T}{R_{tot}} = \frac{T_{inside} - T_{outside}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

The thermal resistance diagram for all 3 sections will be the same, and can be seen in Figure 2:



The total resistance will be calculated by totalling the individual convective and conductive resistances. In case of scenario 4 where a geyser blanket is installed on the outside surface, the conductive resistance of the insulation layer is included, and the convective resistance moves to the outer surface, as shown in the following equation:

$$R_{1,2,3} = R_{convection,inside} + R_{conduction,reservoir} + R_{conduction,internal\ insulation} + R_{conduction,plate} + R_{conduction,external\ insulation} + R_{convection,outside}$$

An explicit analysis was compiled within Microsoft Excel, and solved for a 24 hour period. The time interval between analysis steps was set at one second, and at each step the heat transfer equations were solved. The results from a previous step is used as input into the current step, where after the entire analysis is repeated. An extract from the Excel sheet can be seen in Appendix 7.1.

### 3 ASSUMPTIONS

#### 3.1 ESKOM BLOCK TARIFFS

Eskom will be implementing a block tariff scheme from 1 April 2011, as set out in Table 1. These block tariffs were included in the calculations, and can be clearly seen in Figure 4 to Figure 7 at the 400 - 600 kWh per month region.

Eskom Block Tariffs - Applicable from 1 April 2011 <sup>1</sup>				
Block	Rate	Units	Usage Lower Limit	Usage Upper Limit
Block 1	0.6572	[R/kWh]	> 0 kWh	<= 50 kWh
Block 2	0.7542	[R/kWh]	> 50 kWh	<= 350 kWh
Block 3	1.095	[R/kWh]	> 350 kWh	<= 600 kWh
Block 4	1.201	[R/kWh]	> 600 kWh	∞

Table 1: Eskom Block Tariffs

#### 3.2 HEAT TRANSFER CHARACTERISTICS

A number of heat transfer characteristics were required to complete the analysis. Whilst some of these characteristics could be located from literature, others were assumed and varied during the calibration process to obtain results as close as possible to real life data.

Table 2 to Table 4 summarises the characteristics used in the analysis:

Ambient Conditions	Unit	Value
Ambient temperature	°C	25
Ambient pressure	kPa	101.3

Table 2: Ambient Conditions

Geyser Parameter	Unit	Value
Max internal temperature	°C	75

<sup>1</sup> Source: [www.eskom.co.za/tariffs](http://www.eskom.co.za/tariffs). Accessed on the 14<sup>th</sup> September 2011. This energy rate includes VAT and the Environment Levy charge.

Reservoir height (internal)	mm	1020
Reservoir radius (internal)	mm	217
Wall thickness of reservoir	mm	2
Wall thickness of internal insulation	mm	30
Wall thickness of outer casement (plate)	mm	0.8
Total wall thickness of geyser	mm	32.8
Geyser height (external)	mm	1085
Geyser radius (external)	mm	249
Conductivity of reservoir	W/m.K	450
Conductivity of internal insulation	W/m.K	0.1
Conductivity of outer casement (plate)	W/m.K	300
Internal volume	m <sup>3</sup>	0.151
Geyser heating element power output	W	3000
Heating element activation temperature	°C	65

Table 3: Heat transfer characteristics of the reference geyser

Air Properties	Unit	Value
Density	kg/m <sup>3</sup>	1.184
Specific heat at constant pressure	kJ/kg.K	1.005
Conductivity	W/m.K	0.02551
Viscosity	kg/m.s	0.00001849
Prandtl number	-	0.7281
Air velocity	m/s	1
Reynolds number (section 1 & 3)	-	31992
Nusselt number (section 1 & 3)	-	106.844
Convection coefficient (section 1 & 3)	W/m <sup>2</sup> .K	5.45
Convective resistance (section 1 & 3)	K/W	0.935

Reynolds number (section 2)	-	69516
Nusselt number (section 2)	-	157.5
Convection coefficient (section 2)	W/m <sup>2</sup> .K	3.7
Convective resistance (section 2)	K/W	0.1586

Table 4: Air properties at ambient conditions

### 3.3 WATER PROPERTIES

Due to the fact that water's properties are a function of temperature and pressure, a table was populated which contains all necessary data for various temperatures at a constant pressure of 200 kPa. This pressure was used to extract physical properties for water, as the reference geyser is designed to operate at 200 kPa.

Whenever a value was sought that fell between two values in the table, linear interpolation was used to determine the intermediate value. The table containing water's physical properties at 200 kPa for a temperature range of 0 – 80 °C can be seen in Table 5:

P = 200 kPa						
Temperature	Density	C <sub>p</sub>	k	μ	Pr	h
[°C]	[kg/m <sup>3</sup> ]	[kJ/kg.K]	[W/m.K]	[kg/m.s]	[-]	[kJ/kg]
0	1000	4.228	0.5476	0.001792	13.84	0.1621
4.211	1000	4.202	0.5561	0.001557	11.77	17.9
8.421	1000	4.19	0.5644	0.001368	10.16	35.57
12.63	999.5	4.185	0.5725	0.001213	8.867	53.2
16.84	998.9	4.183	0.5804	0.001085	7.817	70.81
21.05	998.1	4.183	0.588	0.0009768	6.948	88.42
25.26	997	4.183	0.5953	0.0008852	6.22	106
29.47	995.9	4.183	0.6022	0.0008067	5.604	123.6
33.68	994.5	4.183	0.6087	0.0007389	5.077	141.3
37.89	993	4.182	0.6149	0.00068	4.625	158.9

42.11	991.4	4.182	0.6207	0.0006283	4.233	176.5
46.32	989.7	4.181	0.6261	0.0005827	3.891	194.1
50.53	987.8	4.181	0.6311	0.0005423	3.593	211.7
54.74	985.9	4.181	0.6358	0.0005063	3.33	229.3
58.95	983.8	4.182	0.64	0.0004741	3.098	246.9
63.16	981.6	4.183	0.6439	0.0004452	2.892	264.5
67.37	979.3	4.185	0.6475	0.0004191	2.709	282.1
71.58	976.9	4.188	0.6507	0.0003955	2.545	299.8
75.79	974.4	4.19	0.6536	0.000374	2.398	317.4
80	971.9	4.194	0.6562	0.0003545	2.266	335

Table 5: Water properties at 200 kPa

### 3.4 WATER USAGE PROFILE

The water usage profile was adopted from Bourke & Bansal (2010) and can be seen in Figure 3. The profile will be the same for all consumption rates – only the absolute values would differ according to the total water consumed per day.

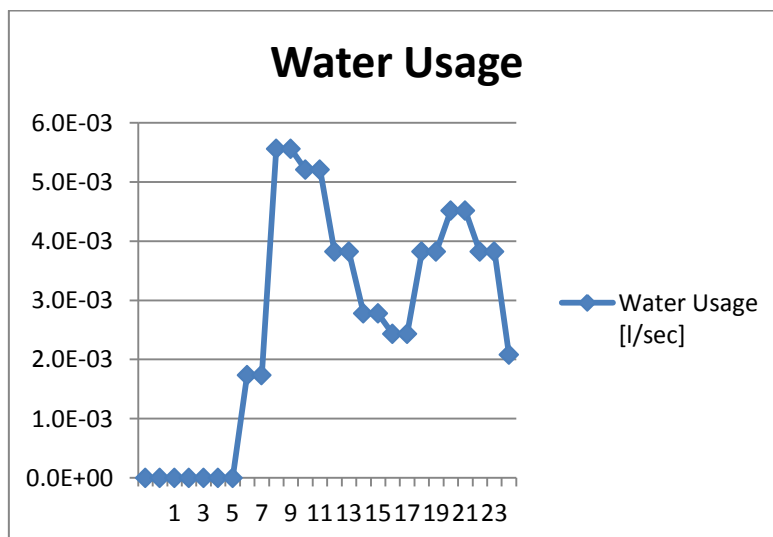


Figure 3: Water usage profile for a 24 hour period and a total of 250 litres consumed per day

## 4 ANALYSIS RESULTS

The objective of this analysis is to compare different energy conservation strategies by comparing energy savings to a base configuration. The indicators that would be included in the final results are the electricity usage per month (in kWh), and the cost per month (in Rands) after Eskom's block tariffs have been applied.

These indicators would ultimately be the deciding factor whether to implement the proposed conservation strategy or not.

The results for scenario 1 to 4 can be seen in Table 6 to Table 9:

Scenario 1						
Water Consumption	Size of household	Average Temperature	Electricity Usage per day	Electricity Usage per month	Cost per month	Percentage increase/decrease
[litre/day]	# persons	[°C]	[kWh]	[kWh]	[R]	[%]
60	1	69.733	12.410	372.30	288.39	Base state
120	2	69.688	15.438	463.15	387.87	Base state
180	3	69.660	17.327	519.80	449.90	Base state
240	4	69.839	20.371	611.12	670.36	Base state
300	5	69.826	24.044	721.32	802.71	Base state
360	6	69.903	26.517	795.50	891.80	Base state
420	7	69.925	29.296	878.87	991.93	Base state
480	8	69.940	32.329	969.87	1101.22	Base state
540	9	70.039	34.803	1044.10	1190.36	Base state
600	10	69.923	38.306	1149.17	1316.56	Base state

Table 6: Electricity usage and associated costs for the base configuration

Scenario 2						
Water Consumption	Size of household	Average Temperature	Electricity Usage per day	Electricity Usage per month	Cost per month	Percentage increase/decrease
[litre/day]	# persons	[°C]	[kWh]	[kWh]	[R]	[%]
60	1	59.585	9.897	296.90	219.07	-24.04
120	2	59.549	10.811	324.32	239.76	-38.19
180	3	59.743	13.139	394.17	312.34	-30.58
240	4	59.766	16.224	486.72	413.68	-38.29
300	5	59.638	17.227	516.80	446.62	-44.36
360	6	59.768	20.876	626.27	688.56	-22.79
420	7	59.802	22.778	683.35	757.10	-23.67
480	8	59.806	24.754	742.62	828.29	-24.78
540	9	59.833	26.915	807.45	906.15	-23.88
600	10	59.948	29.499	884.97	999.25	-24.10

Table 7: Electricity usage and associated costs for the reduced temperature conservation strategy

Scenario 3						
Water Consumption	Size of household	Average Temperature	Electricity Usage per day	Electricity Usage per month	Cost per month	Percentage increase/decrease
[litre/day]	# persons	[°C]	[kWh]	[kWh]	[R]	[%]
60	1	62.902	8.243	247.30	181.66	-37.01
120	2	60.783	9.510	285.30	210.32	-45.77
180	3	59.031	10.693	320.80	237.10	-47.30
240	4	58.145	13.200	396.00	314.34	-53.11
300	5	57.160	13.200	396.00	314.34	-60.84
360	6	55.812	13.641	409.22	328.82	-63.13
420	7	54.523	13.998	419.95	340.57	-65.67
480	8	53.415	14.302	429.05	350.53	-68.17
540	9	52.407	14.567	437.02	359.26	-69.82
600	10	51.504	14.807	444.22	367.15	-72.11

Table 8: Electricity usage and associated costs for the time switch conservation strategy

Scenario 4						
Water Consumption	Size of household	Average Temperature	Electricity Usage per day	Electricity Usage per month	Cost per month	Percentage increase/decrease
[litre/day]	# persons	[°C]	[kWh]	[kWh]	[R]	[%]
60	1	69.829	10.098	302.95	223.63	-22.45
120	2	69.832	12.866	385.97	303.36	-21.79
180	3	69.816	16.155	484.65	411.41	-8.56
240	4	69.679	19.377	581.32	517.27	-22.84
300	5	69.824	21.897	656.92	725.37	-9.64
360	6	69.729	23.905	717.15	797.70	-10.55
420	7	69.783	28.290	848.70	955.69	-3.65
480	8	69.857	29.762	892.87	1008.74	-8.40
540	9	70.033	33.598	1007.95	1146.95	-3.65
600	10	70.146	36.977	1109.32	1268.70	-3.64

Table 9: Electricity usage and associated costs for the geyser blanket conservation strategy

These results are plotted for a visual presentation in Figure 4 to Figure 7.

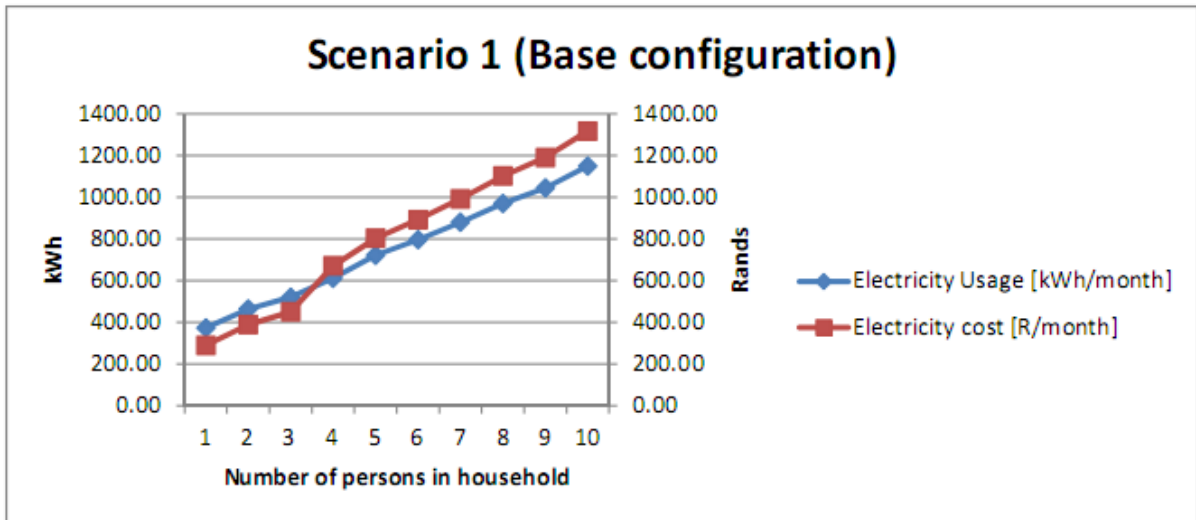


Figure 4: Electricity usage and associated costs for the base configuration

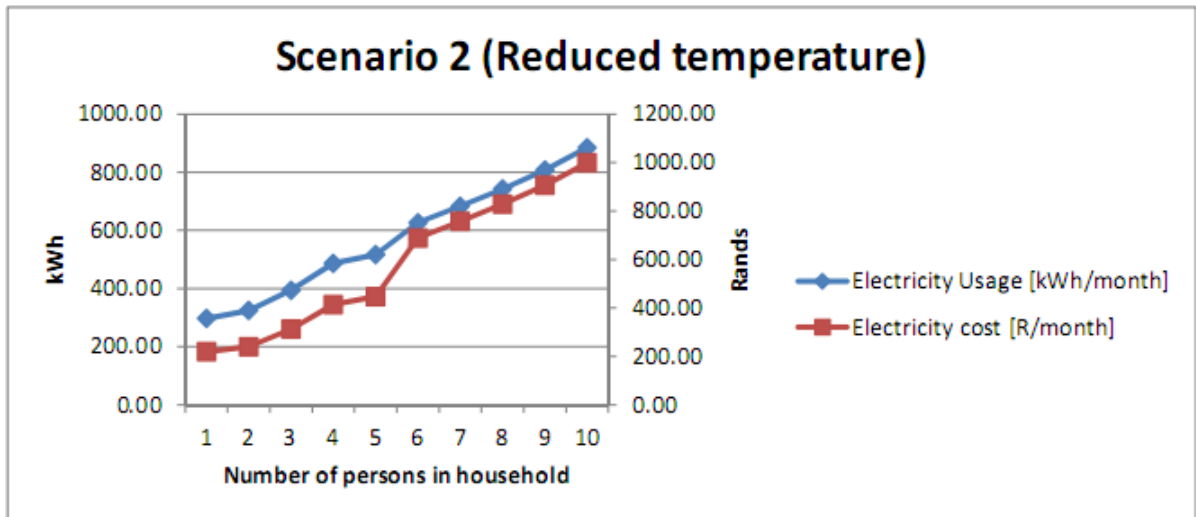


Figure 5: Electricity usage and associated costs for the reduced temperature conservation strategy

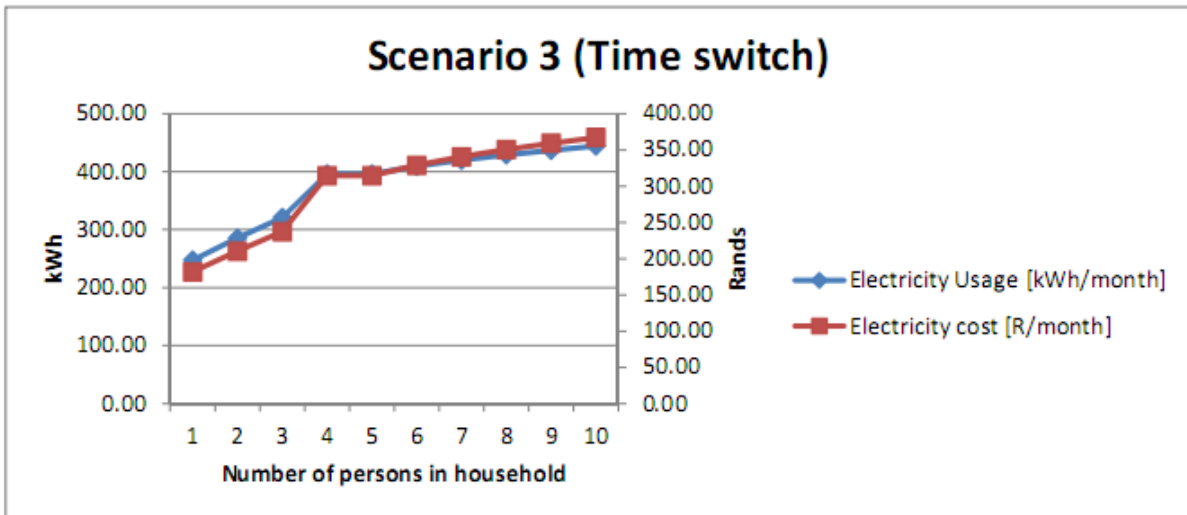


Figure 6: Electricity usage and associated costs for the time switch conservation strategy

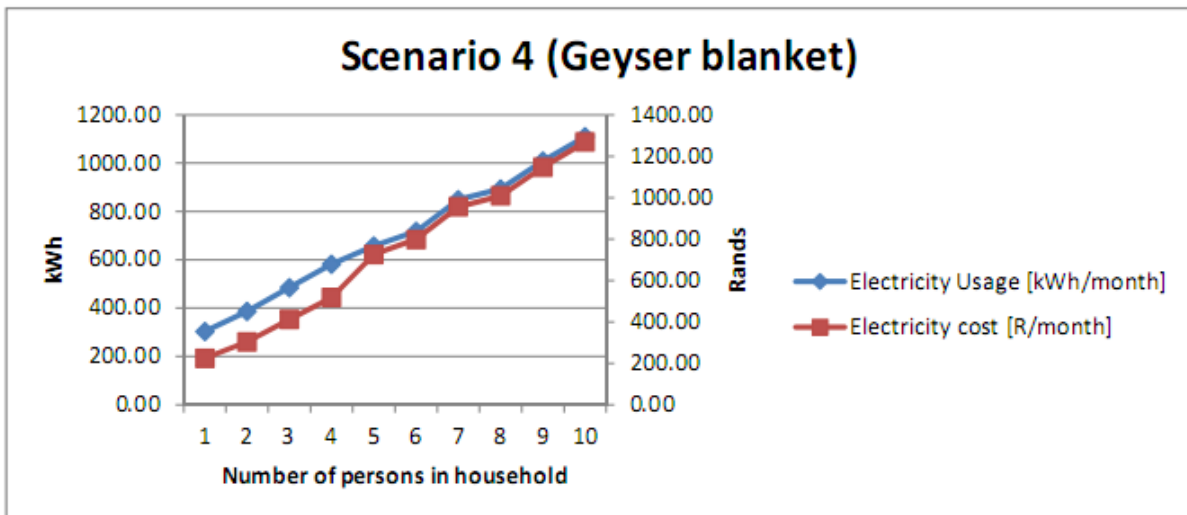


Figure 7: Electricity usage and associated costs for the geyser blanket conservation strategy

## 5 DISCUSSION OF RESULTS

From Scenario 1 (Figure 4) it can be seen that there is a nearly linearly relationship between energy usage and the number of persons in the household. The cost associated with this energy usage profile displays two distinct linear sections, with a ramp in the 400 – 600 kWh per month region. This can be attributed to Eskom's block tariffs, where high end users are billed higher for their energy needs.

In Table 7 and Figure 5 it can be seen that the reduced temperature conservation strategy yields energy savings for all household sizes, with a maximum saving of ~44% for a five person household. It can thus be concluded that this energy saving is highly recommended, as it is easily implemented and the associated savings are considerable. The average water temperature would be slightly lower (~59.5°C), which tends to lead to a higher volume of hot water consumed.

In Table 8 and Figure 6 it can be seen that energy savings can be realised for all household sizes by installing a time switch on the water heating system. The high end users which consume a large volume of hot water will benefit most from this conservation strategy, with a maximum saving of ~72% for a ten person household. It is also evident that the average water temperature decreases from ~63°C for a single person household to ~51.5°C for a ten person house hold.

The final conservation strategy that was modelled is the installation of an insulation layer around the water heating system, generally referred to as a geyser blanket. The results can be seen in Table 9 and Figure 7. From the results it can be seen that low end users would benefit the most from this strategy, with a maximum saving of ~22.5% per a single person household, while a ten person household would only see a saving of ~3.6%.

## 6 REFERENCES

- 9.1 BOURKE, G. & BANSAL, P. 2010. Energy consumption modelling of air source electric heat pump water heaters. *Applied thermal engineering*, 30:1769-1774.
  
- 9.2 ANON. 2008. Energy Saving Tips. Website accessed on: 14 September 2011  
<http://www.savingpower.co.za/index.php?q=con,13,%20Power%20Usage>.

## **7 APPENDIXES**

### **7.1 HEAT TRANSFER MODEL SPREAD SHEET**

Heat Transfer Model										Water Properties				
Time			T_begin	T_end	Q_loss_wall	Q_loss_mix	Q_add	WU Coef	Usage	Power Consumption	T_avg	ρ	C_p	k
[sec]	[min]	[h]	[°C]	[°C]	[W]	[W]	[W]	[1/sec]	[l/s]	[kWh]	[°C]	[kg/m <sup>3</sup> ]	[kJ/kg.K]	[W/m.K]
1			60.000	59.999	289.382	0.0E+00	3000	0.0E+00	0.0E+00	8.3E-04	60	983.8	4.182	0.64
300	5		61.298	61.302	300.111	0.0E+00	3000	0.0E+00	0.0E+00	8.3E-04	61.3	983.8	4.182	0.64
3600	60	1	74.946	74.945	413.205	0.0E+00	0	0.0E+00	0.0E+00	0.0E+00	74.946	976.9	4.188	0.6507
7200	120	2	72.594	72.593	393.743	0.0E+00	0	0.0E+00	0.0E+00	0.0E+00	72.593	976.9	4.188	0.6507
10800	180	3	70.354	70.354	375.148	0.0E+00	0	0.0E+00	0.0E+00	0.0E+00	70.354	979.3	4.185	0.6475
14400	240	4	68.222	68.222	357.512	0.0E+00	0	0.0E+00	0.0E+00	0.0E+00	68.222	979.3	4.185	0.6475
18000	300	5	66.193	66.192	340.656	0.0E+00	0	0.0E+00	0.0E+00	0.0E+00	66.192	981.6	4.183	0.6439
21600	360	6	73.800	73.803	403.727	7.9E+02	3000	6.9E-06	4.2E-03	8.3E-04	73.802	976.9	4.188	0.6507
25200	420	7	69.087	69.086	364.669	7.2E+02	0	6.9E-06	4.2E-03	0.0E+00	69.087	979.3	4.185	0.6475
28800	480	8	67.413	67.413	350.816	2.3E+03	3000	2.2E-05	1.3E-02	8.3E-04	67.413	979.3	4.185	0.6475
32400	540	9	69.401	69.401	367.260	2.3E+03	3000	2.2E-05	1.3E-02	8.3E-04	69.401	979.3	4.185	0.6475
36000	600	10	71.868	71.868	387.740	2.4E+03	3000	2.1E-05	1.3E-02	8.3E-04	71.868	976.9	4.188	0.6507
39600	660	11	73.267	73.267	399.313	2.4E+03	3000	2.1E-05	1.3E-02	8.3E-04	73.267	976.9	4.188	0.6507
43200	720	12	67.300	67.297	349.810	1.4E+03	0	1.5E-05	9.2E-03	0.0E+00	67.298	981.6	4.183	0.6439
46800	780	13	70.105	70.106	373.084	1.6E+03	3000	1.5E-05	9.2E-03	8.3E-04	70.106	979.3	4.185	0.6475
50400	840	14	71.262	71.260	382.659	1.1E+03	0	1.1E-05	6.7E-03	0.0E+00	71.261	979.3	4.185	0.6475
54000	900	15	67.463	67.465	351.233	1.1E+03	3000	1.1E-05	6.7E-03	8.3E-04	67.464	979.3	4.185	0.6475
57600	960	16	73.483	73.481	401.102	1.1E+03	0	9.7E-06	5.8E-03	0.0E+00	73.482	976.9	4.188	0.6507
61200	1020	17	65.512	65.510	335.030	9.1E+02	0	9.7E-06	5.8E-03	0.0E+00	65.511	981.6	4.183	0.6439
64800	1080	18	71.156	71.158	381.781	1.6E+03	3000	1.5E-05	9.2E-03	8.3E-04	71.157	979.3	4.185	0.6475
68400	1140	19	71.870	71.867	387.757	1.7E+03	0	1.5E-05	9.2E-03	0.0E+00	71.868	976.9	4.188	0.6507
72000	1200	20	67.528	67.530	351.774	1.9E+03	3000	1.8E-05	1.1E-02	8.3E-04	67.529	979.3	4.185	0.6475
75600	1260	21	71.869	71.870	387.746	2.1E+03	3000	1.8E-05	1.1E-02	8.3E-04	71.869	976.9	4.188	0.6507
79200	1320	22	70.405	70.402	375.565	1.6E+03	0	1.5E-05	9.2E-03	0.0E+00	70.403	979.3	4.185	0.6475
82800	1380	23	68.419	68.421	359.139	1.6E+03	3000	1.5E-05	9.2E-03	8.3E-04	68.42	979.3	4.185	0.6475
86400	1440	24	72.350	72.348	391.730	9.5E+02	0	8.3E-06	5.0E-03	0.0E+00	72.349	976.9	4.188	0.6507
									600	40.08166667	70.029			

Properties			Top and Bottom Resistance					Cylinder Side Resistance					Total resistance
$\mu$ [kg/m.s]	Pr [-]	h [kJ/kg]	Re [-]	Nu [-]	$h_{inside}$ [W/m <sup>2</sup> .K]	$_{conv\_insi}$ [K/W]	$R_{total}$ [K/W]	Re [-]	Nu [-]	$h_{inside}$ [W/m <sup>2</sup> .K]	$_{conv\_insic}$ [K/W]	$R_{total}$ [K/W]	$R_{total}$ [K/W]
0.000474	3.098	246.9	90059	290.49	428.37	0.0158	0.958	211659	445.3	279.42	0.0026	0.1618	0.1209
0.000474	3.098	246.9	90059	290.49	428.37	0.0158	0.958	211659	445.3	279.42	0.0026	0.1618	0.1209
0.000396	2.545	299.8	107200	296.82	445.03	0.0152	0.957	251944	455.0	290.29	0.0025	0.1617	0.1209
0.000396	2.545	299.8	107200	296.82	445.03	0.0152	0.957	251944	455.0	290.29	0.0025	0.1617	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000445	2.892	264.5	95691	292.64	434.17	0.0156	0.957	224895	448.6	283.21	0.0025	0.1618	0.1209
0.000396	2.545	299.8	107200	296.82	445.03	0.0152	0.957	251944	455.0	290.29	0.0025	0.1617	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000396	2.545	299.8	107200	296.82	445.03	0.0152	0.957	251944	455.0	290.29	0.0025	0.1617	0.1209
0.000396	2.545	299.8	107200	296.82	445.03	0.0152	0.957	251944	455.0	290.29	0.0025	0.1617	0.1209
0.000445	2.892	264.5	95691	292.64	434.17	0.0156	0.957	224895	448.6	283.21	0.0025	0.1618	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000396	2.545	299.8	107200	296.82	445.03	0.0152	0.957	251944	455.0	290.29	0.0025	0.1617	0.1209
0.000445	2.892	264.5	95691	292.64	434.17	0.0156	0.957	224895	448.6	283.21	0.0025	0.1618	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000396	2.545	299.8	107200	296.82	445.03	0.0152	0.957	251944	455.0	290.29	0.0025	0.1617	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000396	2.545	299.8	107200	296.82	445.03	0.0152	0.957	251944	455.0	290.29	0.0025	0.1617	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000419	2.709	282.1	101412	294.77	439.78	0.0154	0.957	238341	451.9	286.86	0.0025	0.1618	0.1209
0.000396	2.545	299.8	107200	296.82	445.03	0.0152	0.957	251944	455.0	290.29	0.0025	0.1617	0.1209



## 7.2 HEAT TRANSFER MODEL EQUATIONS

Time			T_begin
[sec]	[min]	[h]	[°C]
1	=IF(MOD(A3,60)=0,A3/60,"")	=IF(ISNUMBER(B3),IF(MOD(B3,60)=0,B3/60,""),"")	=60
300	=IF(MOD(A302,60)=0,A302/60,"")	=IF(ISNUMBER(B302),IF(MOD(B302,60)=0,B302/60,""),"")	=E301
3600	=IF(MOD(A3602,60)=0,A3602/60,"")	=IF(ISNUMBER(B3602),IF(MOD(B3602,60)=0,B3602/60,""),"")	=E3601
7200	=IF(MOD(A7202,60)=0,A7202/60,"")	=IF(ISNUMBER(B7202),IF(MOD(B7202,60)=0,B7202/60,""),"")	=E7201
10800	=IF(MOD(A10802,60)=0,A10802/60,"")	=IF(ISNUMBER(B10802),IF(MOD(B10802,60)=0,B10802/60,""),"")	=E10801
14400	=IF(MOD(A14402,60)=0,A14402/60,"")	=IF(ISNUMBER(B14402),IF(MOD(B14402,60)=0,B14402/60,""),"")	=E14401
18000	=IF(MOD(A18002,60)=0,A18002/60,"")	=IF(ISNUMBER(B18002),IF(MOD(B18002,60)=0,B18002/60,""),"")	=E18001
21600	=IF(MOD(A21602,60)=0,A21602/60,"")	=IF(ISNUMBER(B21602),IF(MOD(B21602,60)=0,B21602/60,""),"")	=E21601
25200	=IF(MOD(A25202,60)=0,A25202/60,"")	=IF(ISNUMBER(B25202),IF(MOD(B25202,60)=0,B25202/60,""),"")	=E25201
28800	=IF(MOD(A28802,60)=0,A28802/60,"")	=IF(ISNUMBER(B28802),IF(MOD(B28802,60)=0,B28802/60,""),"")	=E28801
32400	=IF(MOD(A32402,60)=0,A32402/60,"")	=IF(ISNUMBER(B32402),IF(MOD(B32402,60)=0,B32402/60,""),"")	=E32401
36000	=IF(MOD(A36002,60)=0,A36002/60,"")	=IF(ISNUMBER(B36002),IF(MOD(B36002,60)=0,B36002/60,""),"")	=E36001
39600	=IF(MOD(A39602,60)=0,A39602/60,"")	=IF(ISNUMBER(B39602),IF(MOD(B39602,60)=0,B39602/60,""),"")	=E39601
43200	=IF(MOD(A43202,60)=0,A43202/60,"")	=IF(ISNUMBER(B43202),IF(MOD(B43202,60)=0,B43202/60,""),"")	=E43201
46800	=IF(MOD(A46802,60)=0,A46802/60,"")	=IF(ISNUMBER(B46802),IF(MOD(B46802,60)=0,B46802/60,""),"")	=E46801
50400	=IF(MOD(A50402,60)=0,A50402/60,"")	=IF(ISNUMBER(B50402),IF(MOD(B50402,60)=0,B50402/60,""),"")	=E50401
54000	=IF(MOD(A54002,60)=0,A54002/60,"")	=IF(ISNUMBER(B54002),IF(MOD(B54002,60)=0,B54002/60,""),"")	=E54001
57600	=IF(MOD(A57602,60)=0,A57602/60,"")	=IF(ISNUMBER(B57602),IF(MOD(B57602,60)=0,B57602/60,""),"")	=E57601
61200	=IF(MOD(A61202,60)=0,A61202/60,"")	=IF(ISNUMBER(B61202),IF(MOD(B61202,60)=0,B61202/60,""),"")	=E61201
64800	=IF(MOD(A64802,60)=0,A64802/60,"")	=IF(ISNUMBER(B64802),IF(MOD(B64802,60)=0,B64802/60,""),"")	=E64801
68400	=IF(MOD(A68402,60)=0,A68402/60,"")	=IF(ISNUMBER(B68402),IF(MOD(B68402,60)=0,B68402/60,""),"")	=E68401
72000	=IF(MOD(A72002,60)=0,A72002/60,"")	=IF(ISNUMBER(B72002),IF(MOD(B72002,60)=0,B72002/60,""),"")	=E72001
75600	=IF(MOD(A75602,60)=0,A75602/60,"")	=IF(ISNUMBER(B75602),IF(MOD(B75602,60)=0,B75602/60,""),"")	=E75601
79200	=IF(MOD(A79202,60)=0,A79202/60,"")	=IF(ISNUMBER(B79202),IF(MOD(B79202,60)=0,B79202/60,""),"")	=E79201
82800	=IF(MOD(A82802,60)=0,A82802/60,"")	=IF(ISNUMBER(B82802),IF(MOD(B82802,60)=0,B82802/60,""),"")	=E82801
86400	=IF(MOD(A86402,60)=0,A86402/60,"")	=IF(ISNUMBER(B86402),IF(MOD(B86402,60)=0,B86402/60,""),"")	=E86401

T_end	Q_loss_wall
[°C]	[W]
=D3-0.001	=(D3-Temperature_Ambient)/(AC3)
=D302+(H301-F301-G301)/(Volume_Internal*M301*N301*1000)	=(D302-Temperature_Ambient)/(AC302)
=D3602+(H3601-F3601-G3601)/(Volume_Internal*M3601*N3601*1000)	=(D3602-Temperature_Ambient)/(AC3602)
=D7202+(H7201-F7201-G7201)/(Volume_Internal*M7201*N7201*1000)	=(D7202-Temperature_Ambient)/(AC7202)
=D10802+(H10801-F10801-G10801)/(Volume_Internal*M10801*N10801*1000)	=(D10802-Temperature_Ambient)/(AC10802)
=D14402+(H14401-F14401-G14401)/(Volume_Internal*M14401*N14401*1000)	=(D14402-Temperature_Ambient)/(AC14402)
=D18002+(H18001-F18001-G18001)/(Volume_Internal*M18001*N18001*1000)	=(D18002-Temperature_Ambient)/(AC18002)
=D21602+(H21601-F21601-G21601)/(Volume_Internal*M21601*N21601*1000)	=(D21602-Temperature_Ambient)/(AC21602)
=D25202+(H25201-F25201-G25201)/(Volume_Internal*M25201*N25201*1000)	=(D25202-Temperature_Ambient)/(AC25202)
=D28802+(H28801-F28801-G28801)/(Volume_Internal*M28801*N28801*1000)	=(D28802-Temperature_Ambient)/(AC28802)
=D32402+(H32401-F32401-G32401)/(Volume_Internal*M32401*N32401*1000)	=(D32402-Temperature_Ambient)/(AC32402)
=D36002+(H36001-F36001-G36001)/(Volume_Internal*M36001*N36001*1000)	=(D36002-Temperature_Ambient)/(AC36002)
=D39602+(H39601-F39601-G39601)/(Volume_Internal*M39601*N39601*1000)	=(D39602-Temperature_Ambient)/(AC39602)
=D43202+(H43201-F43201-G43201)/(Volume_Internal*M43201*N43201*1000)	=(D43202-Temperature_Ambient)/(AC43202)
=D46802+(H46801-F46801-G46801)/(Volume_Internal*M46801*N46801*1000)	=(D46802-Temperature_Ambient)/(AC46802)
=D50402+(H50401-F50401-G50401)/(Volume_Internal*M50401*N50401*1000)	=(D50402-Temperature_Ambient)/(AC50402)
=D54002+(H54001-F54001-G54001)/(Volume_Internal*M54001*N54001*1000)	=(D54002-Temperature_Ambient)/(AC54002)
=D57602+(H57601-F57601-G57601)/(Volume_Internal*M57601*N57601*1000)	=(D57602-Temperature_Ambient)/(AC57602)
=D61202+(H61201-F61201-G61201)/(Volume_Internal*M61201*N61201*1000)	=(D61202-Temperature_Ambient)/(AC61202)
=D64802+(H64801-F64801-G64801)/(Volume_Internal*M64801*N64801*1000)	=(D64802-Temperature_Ambient)/(AC64802)
=D68402+(H68401-F68401-G68401)/(Volume_Internal*M68401*N68401*1000)	=(D68402-Temperature_Ambient)/(AC68402)
=D72002+(H72001-F72001-G72001)/(Volume_Internal*M72001*N72001*1000)	=(D72002-Temperature_Ambient)/(AC72002)
=D75602+(H75601-F75601-G75601)/(Volume_Internal*M75601*N75601*1000)	=(D75602-Temperature_Ambient)/(AC75602)
=D79202+(H79201-F79201-G79201)/(Volume_Internal*M79201*N79201*1000)	=(D79202-Temperature_Ambient)/(AC79202)
=D82802+(H82801-F82801-G82801)/(Volume_Internal*M82801*N82801*1000)	=(D82802-Temperature_Ambient)/(AC82802)
=D86402+(H86401-F86401-G86401)/(Volume_Internal*M86401*N86401*1000)	=(D86402-Temperature_Ambient)/(AC86402)

Q_loss_mix
[W]
=J3*(M3/1000)*(R3-Enthalpy_Water_25deg)*1000
=J302*(M302/1000)*(R302-Enthalpy_Water_25deg)*1000
=J3602*(M3602/1000)*(R3602-Enthalpy_Water_25deg)*1000
=J7202*(M7202/1000)*(R7202-Enthalpy_Water_25deg)*1000
=J10802*(M10802/1000)*(R10802-Enthalpy_Water_25deg)*1000
=J14402*(M14402/1000)*(R14402-Enthalpy_Water_25deg)*1000
=J18002*(M18002/1000)*(R18002-Enthalpy_Water_25deg)*1000
=J21602*(M21602/1000)*(R21602-Enthalpy_Water_25deg)*1000
=J25202*(M25202/1000)*(R25202-Enthalpy_Water_25deg)*1000
=J28802*(M28802/1000)*(R28802-Enthalpy_Water_25deg)*1000
=J32402*(M32402/1000)*(R32402-Enthalpy_Water_25deg)*1000
=J36002*(M36002/1000)*(R36002-Enthalpy_Water_25deg)*1000
=J39602*(M39602/1000)*(R39602-Enthalpy_Water_25deg)*1000
=J43202*(M43202/1000)*(R43202-Enthalpy_Water_25deg)*1000
=J46802*(M46802/1000)*(R46802-Enthalpy_Water_25deg)*1000
=J50402*(M50402/1000)*(R50402-Enthalpy_Water_25deg)*1000
=J54002*(M54002/1000)*(R54002-Enthalpy_Water_25deg)*1000
=J57602*(M57602/1000)*(R57602-Enthalpy_Water_25deg)*1000
=J61202*(M61202/1000)*(R61202-Enthalpy_Water_25deg)*1000
=J64802*(M64802/1000)*(R64802-Enthalpy_Water_25deg)*1000
=J68402*(M68402/1000)*(R68402-Enthalpy_Water_25deg)*1000
=J72002*(M72002/1000)*(R72002-Enthalpy_Water_25deg)*1000
=J75602*(M75602/1000)*(R75602-Enthalpy_Water_25deg)*1000
=J79202*(M79202/1000)*(R79202-Enthalpy_Water_25deg)*1000
=J82802*(M82802/1000)*(R82802-Enthalpy_Water_25deg)*1000
=J86402*(M86402/1000)*(R86402-Enthalpy_Water_25deg)*1000

Q_add [W]
=IF(D3>=Temperature_Max,0,IF(D3<=Temperature_Activation,Element_Power,IF(AND(D3<Temperature_Max,D3>Temperature_Activation,(D3-E3)<0),Element_Power,0)))
=IF(D302>=Temperature_Max,0,IF(D302<=Temperature_Activation,Element_Power,IF(AND(D302<Temperature_Max,D302>Temperature_Activation,(D302-E302)<0),Element_Power,0)))
=IF(D3602>=Temperature_Max,0,IF(D3602<=Temperature_Activation,Element_Power,IF(AND(D3602<Temperature_Max,D3602>Temperature_Activation,(D3602-E3602)<0),Element_Power,0)))
=IF(D7202>=Temperature_Max,0,IF(D7202<=Temperature_Activation,Element_Power,IF(AND(D7202<Temperature_Max,D7202>Temperature_Activation,(D7202-E7202)<0),Element_Power,0)))
=IF(D10802>=Temperature_Max,0,IF(D10802<=Temperature_Activation,Element_Power,IF(AND(D10802<Temperature_Max,D10802>Temperature_Activation,(D10802-E10802)<0),Element_Power,0)))
=IF(D14402>=Temperature_Max,0,IF(D14402<=Temperature_Activation,Element_Power,IF(AND(D14402<Temperature_Max,D14402>Temperature_Activation,(D14402-E14402)<0),Element_Power,0)))
=IF(D18002>=Temperature_Max,0,IF(D18002<=Temperature_Activation,Element_Power,IF(AND(D18002<Temperature_Max,D18002>Temperature_Activation,(D18002-E18002)<0),Element_Power,0)))
=IF(D21602>=Temperature_Max,0,IF(D21602<=Temperature_Activation,Element_Power,IF(AND(D21602<Temperature_Max,D21602>Temperature_Activation,(D21602-E21602)<0),Element_Power,0)))
=IF(D25202>=Temperature_Max,0,IF(D25202<=Temperature_Activation,Element_Power,IF(AND(D25202<Temperature_Max,D25202>Temperature_Activation,(D25202-E25202)<0),Element_Power,0)))
=IF(D28802>=Temperature_Max,0,IF(D28802<=Temperature_Activation,Element_Power,IF(AND(D28802<Temperature_Max,D28802>Temperature_Activation,(D28802-E28802)<0),Element_Power,0)))
=IF(D32402>=Temperature_Max,0,IF(D32402<=Temperature_Activation,Element_Power,IF(AND(D32402<Temperature_Max,D32402>Temperature_Activation,(D32402-E32402)<0),Element_Power,0)))
=IF(D36002>=Temperature_Max,0,IF(D36002<=Temperature_Activation,Element_Power,IF(AND(D36002<Temperature_Max,D36002>Temperature_Activation,(D36002-E36002)<0),Element_Power,0)))
=IF(D39602>=Temperature_Max,0,IF(D39602<=Temperature_Activation,Element_Power,IF(AND(D39602<Temperature_Max,D39602>Temperature_Activation,(D39602-E39602)<0),Element_Power,0)))
=IF(D43202>=Temperature_Max,0,IF(D43202<=Temperature_Activation,Element_Power,IF(AND(D43202<Temperature_Max,D43202>Temperature_Activation,(D43202-E43202)<0),Element_Power,0)))
=IF(D46802>=Temperature_Max,0,IF(D46802<=Temperature_Activation,Element_Power,IF(AND(D46802<Temperature_Max,D46802>Temperature_Activation,(D46802-E46802)<0),Element_Power,0)))
=IF(D50402>=Temperature_Max,0,IF(D50402<=Temperature_Activation,Element_Power,IF(AND(D50402<Temperature_Max,D50402>Temperature_Activation,(D50402-E50402)<0),Element_Power,0)))
=IF(D54002>=Temperature_Max,0,IF(D54002<=Temperature_Activation,Element_Power,IF(AND(D54002<Temperature_Max,D54002>Temperature_Activation,(D54002-E54002)<0),Element_Power,0)))
=IF(D57602>=Temperature_Max,0,IF(D57602<=Temperature_Activation,Element_Power,IF(AND(D57602<Temperature_Max,D57602>Temperature_Activation,(D57602-E57602)<0),Element_Power,0)))
=IF(D61202>=Temperature_Max,0,IF(D61202<=Temperature_Activation,Element_Power,IF(AND(D61202<Temperature_Max,D61202>Temperature_Activation,(D61202-E61202)<0),Element_Power,0)))
=IF(D64802>=Temperature_Max,0,IF(D64802<=Temperature_Activation,Element_Power,IF(AND(D64802<Temperature_Max,D64802>Temperature_Activation,(D64802-E64802)<0),Element_Power,0)))
=IF(D68402>=Temperature_Max,0,IF(D68402<=Temperature_Activation,Element_Power,IF(AND(D68402<Temperature_Max,D68402>Temperature_Activation,(D68402-E68402)<0),Element_Power,0)))
=IF(D72002>=Temperature_Max,0,IF(D72002<=Temperature_Activation,Element_Power,IF(AND(D72002<Temperature_Max,D72002>Temperature_Activation,(D72002-E72002)<0),Element_Power,0)))
=IF(D75602>=Temperature_Max,0,IF(D75602<=Temperature_Activation,Element_Power,IF(AND(D75602<Temperature_Max,D75602>Temperature_Activation,(D75602-E75602)<0),Element_Power,0)))
=IF(D79202>=Temperature_Max,0,IF(D79202<=Temperature_Activation,Element_Power,IF(AND(D79202<Temperature_Max,D79202>Temperature_Activation,(D79202-E79202)<0),Element_Power,0)))
=IF(D82802>=Temperature_Max,0,IF(D82802<=Temperature_Activation,Element_Power,IF(AND(D82802<Temperature_Max,D82802>Temperature_Activation,(D82802-E82802)<0),Element_Power,0)))
=IF(D86402>=Temperature_Max,0,IF(D86402<=Temperature_Activation,Element_Power,IF(AND(D86402<Temperature_Max,D86402>Temperature_Activation,(D86402-E86402)<0),Element_Power,0)))



Usage	Power Consumption	T_avg	$\rho$
[l/s]	[kWh]	[°C]	[kg/m <sup>3</sup> ]
=I3*Water_Usage_2*1000	=(H3/1000)*(1/3600)	=(D3+E3)/2	=VLOOKUP(\$L3,Water_Properties,2,TRUE)
=I302*Water_Usage_2*1000	=(H302/1000)*(1/3600)	=(D302+E302)/2	=VLOOKUP(\$L302,Water_Properties,2,TRUE)
=I3602*Water_Usage_2*1000	=(H3602/1000)*(1/3600)	=(D3602+E3602)/2	=VLOOKUP(\$L3602,Water_Properties,2,TRUE)
=I7202*Water_Usage_2*1000	=(H7202/1000)*(1/3600)	=(D7202+E7202)/2	=VLOOKUP(\$L7202,Water_Properties,2,TRUE)
=I10802*Water_Usage_2*1000	=(H10802/1000)*(1/3600)	=(D10802+E10802)/2	=VLOOKUP(\$L10802,Water_Properties,2,TRUE)
=I14402*Water_Usage_2*1000	=(H14402/1000)*(1/3600)	=(D14402+E14402)/2	=VLOOKUP(\$L14402,Water_Properties,2,TRUE)
=I18002*Water_Usage_2*1000	=(H18002/1000)*(1/3600)	=(D18002+E18002)/2	=VLOOKUP(\$L18002,Water_Properties,2,TRUE)
=I21602*Water_Usage_2*1000	=(H21602/1000)*(1/3600)	=(D21602+E21602)/2	=VLOOKUP(\$L21602,Water_Properties,2,TRUE)
=I25202*Water_Usage_2*1000	=(H25202/1000)*(1/3600)	=(D25202+E25202)/2	=VLOOKUP(\$L25202,Water_Properties,2,TRUE)
=I28802*Water_Usage_2*1000	=(H28802/1000)*(1/3600)	=(D28802+E28802)/2	=VLOOKUP(\$L28802,Water_Properties,2,TRUE)
=I32402*Water_Usage_2*1000	=(H32402/1000)*(1/3600)	=(D32402+E32402)/2	=VLOOKUP(\$L32402,Water_Properties,2,TRUE)
=I36002*Water_Usage_2*1000	=(H36002/1000)*(1/3600)	=(D36002+E36002)/2	=VLOOKUP(\$L36002,Water_Properties,2,TRUE)
=I39602*Water_Usage_2*1000	=(H39602/1000)*(1/3600)	=(D39602+E39602)/2	=VLOOKUP(\$L39602,Water_Properties,2,TRUE)
=I43202*Water_Usage_2*1000	=(H43202/1000)*(1/3600)	=(D43202+E43202)/2	=VLOOKUP(\$L43202,Water_Properties,2,TRUE)
=I46802*Water_Usage_2*1000	=(H46802/1000)*(1/3600)	=(D46802+E46802)/2	=VLOOKUP(\$L46802,Water_Properties,2,TRUE)
=I50402*Water_Usage_2*1000	=(H50402/1000)*(1/3600)	=(D50402+E50402)/2	=VLOOKUP(\$L50402,Water_Properties,2,TRUE)
=I54002*Water_Usage_2*1000	=(H54002/1000)*(1/3600)	=(D54002+E54002)/2	=VLOOKUP(\$L54002,Water_Properties,2,TRUE)
=I57602*Water_Usage_2*1000	=(H57602/1000)*(1/3600)	=(D57602+E57602)/2	=VLOOKUP(\$L57602,Water_Properties,2,TRUE)
=I61202*Water_Usage_2*1000	=(H61202/1000)*(1/3600)	=(D61202+E61202)/2	=VLOOKUP(\$L61202,Water_Properties,2,TRUE)
=I64802*Water_Usage_2*1000	=(H64802/1000)*(1/3600)	=(D64802+E64802)/2	=VLOOKUP(\$L64802,Water_Properties,2,TRUE)
=I68402*Water_Usage_2*1000	=(H68402/1000)*(1/3600)	=(D68402+E68402)/2	=VLOOKUP(\$L68402,Water_Properties,2,TRUE)
=I72002*Water_Usage_2*1000	=(H72002/1000)*(1/3600)	=(D72002+E72002)/2	=VLOOKUP(\$L72002,Water_Properties,2,TRUE)
=I75602*Water_Usage_2*1000	=(H75602/1000)*(1/3600)	=(D75602+E75602)/2	=VLOOKUP(\$L75602,Water_Properties,2,TRUE)
=I79202*Water_Usage_2*1000	=(H79202/1000)*(1/3600)	=(D79202+E79202)/2	=VLOOKUP(\$L79202,Water_Properties,2,TRUE)
=I82802*Water_Usage_2*1000	=(H82802/1000)*(1/3600)	=(D82802+E82802)/2	=VLOOKUP(\$L82802,Water_Properties,2,TRUE)
=I86402*Water_Usage_2*1000	=(H86402/1000)*(1/3600)	=(D86402+E86402)/2	=VLOOKUP(\$L86402,Water_Properties,2,TRUE)
<b>=SUM(J3:J86402)</b>	<b>=SUM(K3:K86402)</b>	<b>=AVERAGE(L3:L86402)</b>	

C <sub>p</sub>	k	μ
[kJ/kg.K]	[W/m.K]	[kg/m.s]
=VLOOKUP(\$L3,Water_Properties,3,TRUE)	=VLOOKUP(\$L3,Water_Properties,4,TRUE)	=VLOOKUP(\$L3,Water_Properties,5,TRUE)
=VLOOKUP(\$L302,Water_Properties,3,TRUE)	=VLOOKUP(\$L302,Water_Properties,4,TRUE)	=VLOOKUP(\$L302,Water_Properties,5,TRUE)
=VLOOKUP(\$L3602,Water_Properties,3,TRUE)	=VLOOKUP(\$L3602,Water_Properties,4,TRUE)	=VLOOKUP(\$L3602,Water_Properties,5,TRUE)
=VLOOKUP(\$L7202,Water_Properties,3,TRUE)	=VLOOKUP(\$L7202,Water_Properties,4,TRUE)	=VLOOKUP(\$L7202,Water_Properties,5,TRUE)
=VLOOKUP(\$L10802,Water_Properties,3,TRUE)	=VLOOKUP(\$L10802,Water_Properties,4,TRUE)	=VLOOKUP(\$L10802,Water_Properties,5,TRUE)
=VLOOKUP(\$L14402,Water_Properties,3,TRUE)	=VLOOKUP(\$L14402,Water_Properties,4,TRUE)	=VLOOKUP(\$L14402,Water_Properties,5,TRUE)
=VLOOKUP(\$L18002,Water_Properties,3,TRUE)	=VLOOKUP(\$L18002,Water_Properties,4,TRUE)	=VLOOKUP(\$L18002,Water_Properties,5,TRUE)
=VLOOKUP(\$L21602,Water_Properties,3,TRUE)	=VLOOKUP(\$L21602,Water_Properties,4,TRUE)	=VLOOKUP(\$L21602,Water_Properties,5,TRUE)
=VLOOKUP(\$L25202,Water_Properties,3,TRUE)	=VLOOKUP(\$L25202,Water_Properties,4,TRUE)	=VLOOKUP(\$L25202,Water_Properties,5,TRUE)
=VLOOKUP(\$L28802,Water_Properties,3,TRUE)	=VLOOKUP(\$L28802,Water_Properties,4,TRUE)	=VLOOKUP(\$L28802,Water_Properties,5,TRUE)
=VLOOKUP(\$L32402,Water_Properties,3,TRUE)	=VLOOKUP(\$L32402,Water_Properties,4,TRUE)	=VLOOKUP(\$L32402,Water_Properties,5,TRUE)
=VLOOKUP(\$L36002,Water_Properties,3,TRUE)	=VLOOKUP(\$L36002,Water_Properties,4,TRUE)	=VLOOKUP(\$L36002,Water_Properties,5,TRUE)
=VLOOKUP(\$L39602,Water_Properties,3,TRUE)	=VLOOKUP(\$L39602,Water_Properties,4,TRUE)	=VLOOKUP(\$L39602,Water_Properties,5,TRUE)
=VLOOKUP(\$L43202,Water_Properties,3,TRUE)	=VLOOKUP(\$L43202,Water_Properties,4,TRUE)	=VLOOKUP(\$L43202,Water_Properties,5,TRUE)
=VLOOKUP(\$L46802,Water_Properties,3,TRUE)	=VLOOKUP(\$L46802,Water_Properties,4,TRUE)	=VLOOKUP(\$L46802,Water_Properties,5,TRUE)
=VLOOKUP(\$L50402,Water_Properties,3,TRUE)	=VLOOKUP(\$L50402,Water_Properties,4,TRUE)	=VLOOKUP(\$L50402,Water_Properties,5,TRUE)
=VLOOKUP(\$L54002,Water_Properties,3,TRUE)	=VLOOKUP(\$L54002,Water_Properties,4,TRUE)	=VLOOKUP(\$L54002,Water_Properties,5,TRUE)
=VLOOKUP(\$L57602,Water_Properties,3,TRUE)	=VLOOKUP(\$L57602,Water_Properties,4,TRUE)	=VLOOKUP(\$L57602,Water_Properties,5,TRUE)
=VLOOKUP(\$L61202,Water_Properties,3,TRUE)	=VLOOKUP(\$L61202,Water_Properties,4,TRUE)	=VLOOKUP(\$L61202,Water_Properties,5,TRUE)
=VLOOKUP(\$L64802,Water_Properties,3,TRUE)	=VLOOKUP(\$L64802,Water_Properties,4,TRUE)	=VLOOKUP(\$L64802,Water_Properties,5,TRUE)
=VLOOKUP(\$L68402,Water_Properties,3,TRUE)	=VLOOKUP(\$L68402,Water_Properties,4,TRUE)	=VLOOKUP(\$L68402,Water_Properties,5,TRUE)
=VLOOKUP(\$L72002,Water_Properties,3,TRUE)	=VLOOKUP(\$L72002,Water_Properties,4,TRUE)	=VLOOKUP(\$L72002,Water_Properties,5,TRUE)
=VLOOKUP(\$L75602,Water_Properties,3,TRUE)	=VLOOKUP(\$L75602,Water_Properties,4,TRUE)	=VLOOKUP(\$L75602,Water_Properties,5,TRUE)
=VLOOKUP(\$L79202,Water_Properties,3,TRUE)	=VLOOKUP(\$L79202,Water_Properties,4,TRUE)	=VLOOKUP(\$L79202,Water_Properties,5,TRUE)
=VLOOKUP(\$L82802,Water_Properties,3,TRUE)	=VLOOKUP(\$L82802,Water_Properties,4,TRUE)	=VLOOKUP(\$L82802,Water_Properties,5,TRUE)
=VLOOKUP(\$L86402,Water_Properties,3,TRUE)	=VLOOKUP(\$L86402,Water_Properties,4,TRUE)	=VLOOKUP(\$L86402,Water_Properties,5,TRUE)

Pr	h	Re
[-]	[kJ/kg]	[-]
=VLOOKUP(\$L3,Water_Properties,6,TRUE)	=VLOOKUP(\$L3,Water_Properties,7,TRUE)	=(M3*Velocity_Water*2*Radius_Internal) / (P3)
=VLOOKUP(\$L302,Water_Properties,6,TRUE)	=VLOOKUP(\$L302,Water_Properties,7,TRUE)	=(M302*Velocity_Water*2*Radius_Internal) / (P302)
=VLOOKUP(\$L3602,Water_Properties,6,TRUE)	=VLOOKUP(\$L3602,Water_Properties,7,TRUE)	=(M3602*Velocity_Water*2*Radius_Internal) / (P3602)
=VLOOKUP(\$L7202,Water_Properties,6,TRUE)	=VLOOKUP(\$L7202,Water_Properties,7,TRUE)	=(M7202*Velocity_Water*2*Radius_Internal) / (P7202)
=VLOOKUP(\$L10802,Water_Properties,6,TRUE)	=VLOOKUP(\$L10802,Water_Properties,7,TRUE)	=(M10802*Velocity_Water*2*Radius_Internal) / (P10802)
=VLOOKUP(\$L14402,Water_Properties,6,TRUE)	=VLOOKUP(\$L14402,Water_Properties,7,TRUE)	=(M14402*Velocity_Water*2*Radius_Internal) / (P14402)
=VLOOKUP(\$L18002,Water_Properties,6,TRUE)	=VLOOKUP(\$L18002,Water_Properties,7,TRUE)	=(M18002*Velocity_Water*2*Radius_Internal) / (P18002)
=VLOOKUP(\$L21602,Water_Properties,6,TRUE)	=VLOOKUP(\$L21602,Water_Properties,7,TRUE)	=(M21602*Velocity_Water*2*Radius_Internal) / (P21602)
=VLOOKUP(\$L25202,Water_Properties,6,TRUE)	=VLOOKUP(\$L25202,Water_Properties,7,TRUE)	=(M25202*Velocity_Water*2*Radius_Internal) / (P25202)
=VLOOKUP(\$L28802,Water_Properties,6,TRUE)	=VLOOKUP(\$L28802,Water_Properties,7,TRUE)	=(M28802*Velocity_Water*2*Radius_Internal) / (P28802)
=VLOOKUP(\$L32402,Water_Properties,6,TRUE)	=VLOOKUP(\$L32402,Water_Properties,7,TRUE)	=(M32402*Velocity_Water*2*Radius_Internal) / (P32402)
=VLOOKUP(\$L36002,Water_Properties,6,TRUE)	=VLOOKUP(\$L36002,Water_Properties,7,TRUE)	=(M36002*Velocity_Water*2*Radius_Internal) / (P36002)
=VLOOKUP(\$L39602,Water_Properties,6,TRUE)	=VLOOKUP(\$L39602,Water_Properties,7,TRUE)	=(M39602*Velocity_Water*2*Radius_Internal) / (P39602)
=VLOOKUP(\$L43202,Water_Properties,6,TRUE)	=VLOOKUP(\$L43202,Water_Properties,7,TRUE)	=(M43202*Velocity_Water*2*Radius_Internal) / (P43202)
=VLOOKUP(\$L46802,Water_Properties,6,TRUE)	=VLOOKUP(\$L46802,Water_Properties,7,TRUE)	=(M46802*Velocity_Water*2*Radius_Internal) / (P46802)
=VLOOKUP(\$L50402,Water_Properties,6,TRUE)	=VLOOKUP(\$L50402,Water_Properties,7,TRUE)	=(M50402*Velocity_Water*2*Radius_Internal) / (P50402)
=VLOOKUP(\$L54002,Water_Properties,6,TRUE)	=VLOOKUP(\$L54002,Water_Properties,7,TRUE)	=(M54002*Velocity_Water*2*Radius_Internal) / (P54002)
=VLOOKUP(\$L57602,Water_Properties,6,TRUE)	=VLOOKUP(\$L57602,Water_Properties,7,TRUE)	=(M57602*Velocity_Water*2*Radius_Internal) / (P57602)
=VLOOKUP(\$L61202,Water_Properties,6,TRUE)	=VLOOKUP(\$L61202,Water_Properties,7,TRUE)	=(M61202*Velocity_Water*2*Radius_Internal) / (P61202)
=VLOOKUP(\$L64802,Water_Properties,6,TRUE)	=VLOOKUP(\$L64802,Water_Properties,7,TRUE)	=(M64802*Velocity_Water*2*Radius_Internal) / (P64802)
=VLOOKUP(\$L68402,Water_Properties,6,TRUE)	=VLOOKUP(\$L68402,Water_Properties,7,TRUE)	=(M68402*Velocity_Water*2*Radius_Internal) / (P68402)
=VLOOKUP(\$L72002,Water_Properties,6,TRUE)	=VLOOKUP(\$L72002,Water_Properties,7,TRUE)	=(M72002*Velocity_Water*2*Radius_Internal) / (P72002)
=VLOOKUP(\$L75602,Water_Properties,6,TRUE)	=VLOOKUP(\$L75602,Water_Properties,7,TRUE)	=(M75602*Velocity_Water*2*Radius_Internal) / (P75602)
=VLOOKUP(\$L79202,Water_Properties,6,TRUE)	=VLOOKUP(\$L79202,Water_Properties,7,TRUE)	=(M79202*Velocity_Water*2*Radius_Internal) / (P79202)
=VLOOKUP(\$L82802,Water_Properties,6,TRUE)	=VLOOKUP(\$L82802,Water_Properties,7,TRUE)	=(M82802*Velocity_Water*2*Radius_Internal) / (P82802)
=VLOOKUP(\$L86402,Water_Properties,6,TRUE)	=VLOOKUP(\$L86402,Water_Properties,7,TRUE)	=(M86402*Velocity_Water*2*Radius_Internal) / (P86402)

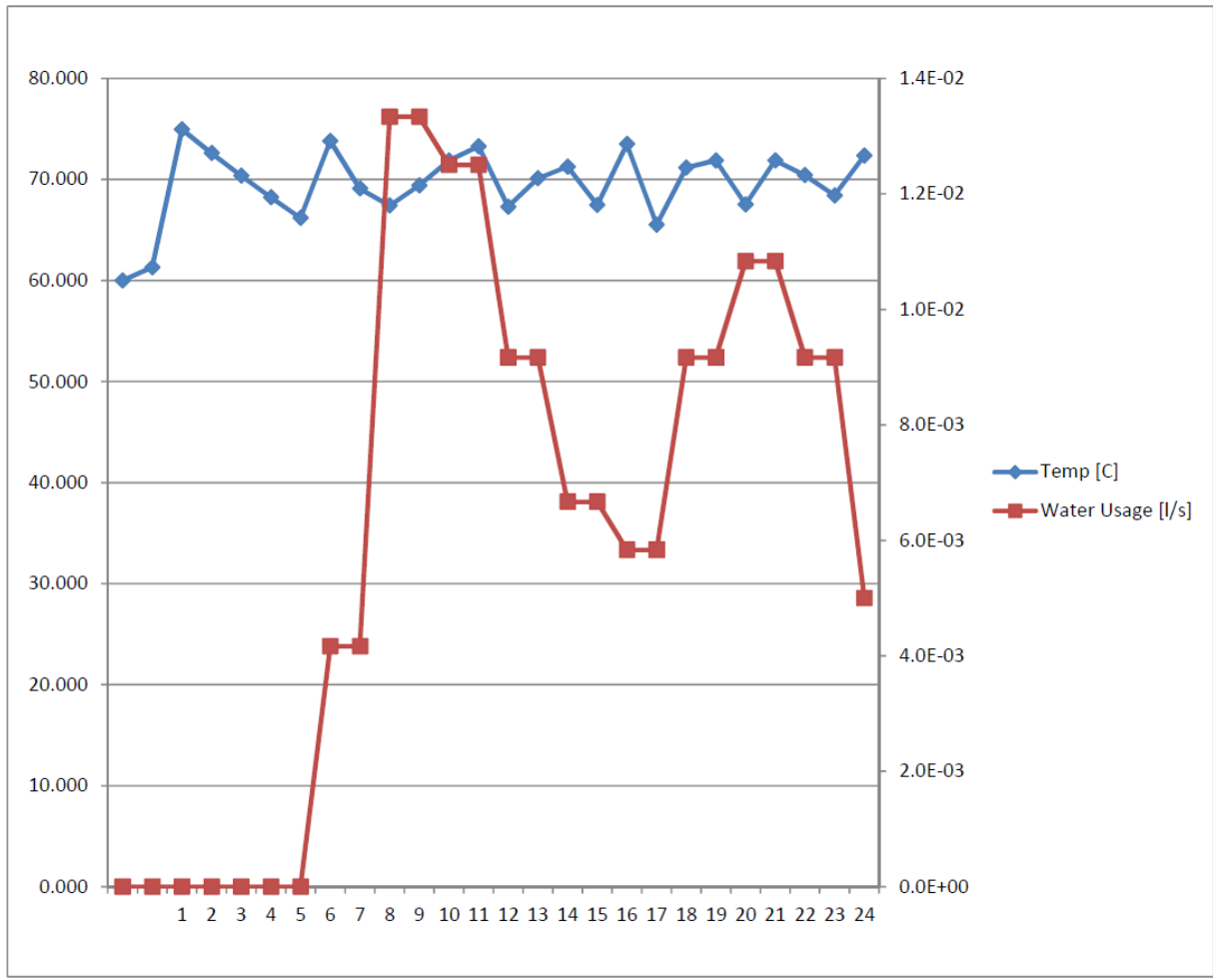
Nu	$h_{\text{inside}}$	$R_{\text{conv\_inside}}$
[-]	[W/m <sup>2</sup> .K]	[K/W]
$=0.664 * S3^{(1/2)} * Q3^{(1/3)}$	$=(T3 * O3) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U3)$
$=0.664 * S302^{(1/2)} * Q302^{(1/3)}$	$=(T302 * O302) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U302)$
$=0.664 * S3602^{(1/2)} * Q3602^{(1/3)}$	$=(T3602 * O3602) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U3602)$
$=0.664 * S7202^{(1/2)} * Q7202^{(1/3)}$	$=(T7202 * O7202) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U7202)$
$=0.664 * S10802^{(1/2)} * Q10802^{(1/3)}$	$=(T10802 * O10802) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U10802)$
$=0.664 * S14402^{(1/2)} * Q14402^{(1/3)}$	$=(T14402 * O14402) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U14402)$
$=0.664 * S18002^{(1/2)} * Q18002^{(1/3)}$	$=(T18002 * O18002) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U18002)$
$=0.664 * S21602^{(1/2)} * Q21602^{(1/3)}$	$=(T21602 * O21602) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U21602)$
$=0.664 * S25202^{(1/2)} * Q25202^{(1/3)}$	$=(T25202 * O25202) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U25202)$
$=0.664 * S28802^{(1/2)} * Q28802^{(1/3)}$	$=(T28802 * O28802) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U28802)$
$=0.664 * S32402^{(1/2)} * Q32402^{(1/3)}$	$=(T32402 * O32402) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U32402)$
$=0.664 * S36002^{(1/2)} * Q36002^{(1/3)}$	$=(T36002 * O36002) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U36002)$
$=0.664 * S39602^{(1/2)} * Q39602^{(1/3)}$	$=(T39602 * O39602) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U39602)$
$=0.664 * S43202^{(1/2)} * Q43202^{(1/3)}$	$=(T43202 * O43202) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U43202)$
$=0.664 * S46802^{(1/2)} * Q46802^{(1/3)}$	$=(T46802 * O46802) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U46802)$
$=0.664 * S50402^{(1/2)} * Q50402^{(1/3)}$	$=(T50402 * O50402) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U50402)$
$=0.664 * S54002^{(1/2)} * Q54002^{(1/3)}$	$=(T54002 * O54002) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U54002)$
$=0.664 * S57602^{(1/2)} * Q57602^{(1/3)}$	$=(T57602 * O57602) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U57602)$
$=0.664 * S61202^{(1/2)} * Q61202^{(1/3)}$	$=(T61202 * O61202) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U61202)$
$=0.664 * S64802^{(1/2)} * Q64802^{(1/3)}$	$=(T64802 * O64802) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U64802)$
$=0.664 * S68402^{(1/2)} * Q68402^{(1/3)}$	$=(T68402 * O68402) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U68402)$
$=0.664 * S72002^{(1/2)} * Q72002^{(1/3)}$	$=(T72002 * O72002) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U72002)$
$=0.664 * S75602^{(1/2)} * Q75602^{(1/3)}$	$=(T75602 * O75602) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U75602)$
$=0.664 * S79202^{(1/2)} * Q79202^{(1/3)}$	$=(T79202 * O79202) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U79202)$
$=0.664 * S82802^{(1/2)} * Q82802^{(1/3)}$	$=(T82802 * O82802) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U82802)$
$=0.664 * S86402^{(1/2)} * Q86402^{(1/3)}$	$=(T86402 * O86402) / (2 * \text{Radius\_Internal})$	$=1 / (\text{PI}() * \text{Radius\_Internal}^2 * U86402)$



Re	Nu	h_inside
[-]	[-]	[W/m <sup>2</sup> .K]
$=(M3*Velocity\_Water*Height\_Internal)/(P3)$	$=0.664*X3^{(1/2)}*Q3^{(1/3)}$	$=(Y3*O3)/(Height\_Internal)$
$=(M302*Velocity\_Water*Height\_Internal)/(P302)$	$=0.664*X302^{(1/2)}*Q302^{(1/3)}$	$=(Y302*O302)/(Height\_Internal)$
$=(M3602*Velocity\_Water*Height\_Internal)/(P3602)$	$=0.664*X3602^{(1/2)}*Q3602^{(1/3)}$	$=(Y3602*O3602)/(Height\_Internal)$
$=(M7202*Velocity\_Water*Height\_Internal)/(P7202)$	$=0.664*X7202^{(1/2)}*Q7202^{(1/3)}$	$=(Y7202*O7202)/(Height\_Internal)$
$=(M10802*Velocity\_Water*Height\_Internal)/(P10802)$	$=0.664*X10802^{(1/2)}*Q10802^{(1/3)}$	$=(Y10802*O10802)/(Height\_Internal)$
$=(M14402*Velocity\_Water*Height\_Internal)/(P14402)$	$=0.664*X14402^{(1/2)}*Q14402^{(1/3)}$	$=(Y14402*O14402)/(Height\_Internal)$
$=(M18002*Velocity\_Water*Height\_Internal)/(P18002)$	$=0.664*X18002^{(1/2)}*Q18002^{(1/3)}$	$=(Y18002*O18002)/(Height\_Internal)$
$=(M21602*Velocity\_Water*Height\_Internal)/(P21602)$	$=0.664*X21602^{(1/2)}*Q21602^{(1/3)}$	$=(Y21602*O21602)/(Height\_Internal)$
$=(M25202*Velocity\_Water*Height\_Internal)/(P25202)$	$=0.664*X25202^{(1/2)}*Q25202^{(1/3)}$	$=(Y25202*O25202)/(Height\_Internal)$
$=(M28802*Velocity\_Water*Height\_Internal)/(P28802)$	$=0.664*X28802^{(1/2)}*Q28802^{(1/3)}$	$=(Y28802*O28802)/(Height\_Internal)$
$=(M32402*Velocity\_Water*Height\_Internal)/(P32402)$	$=0.664*X32402^{(1/2)}*Q32402^{(1/3)}$	$=(Y32402*O32402)/(Height\_Internal)$
$=(M36002*Velocity\_Water*Height\_Internal)/(P36002)$	$=0.664*X36002^{(1/2)}*Q36002^{(1/3)}$	$=(Y36002*O36002)/(Height\_Internal)$
$=(M39602*Velocity\_Water*Height\_Internal)/(P39602)$	$=0.664*X39602^{(1/2)}*Q39602^{(1/3)}$	$=(Y39602*O39602)/(Height\_Internal)$
$=(M43202*Velocity\_Water*Height\_Internal)/(P43202)$	$=0.664*X43202^{(1/2)}*Q43202^{(1/3)}$	$=(Y43202*O43202)/(Height\_Internal)$
$=(M46802*Velocity\_Water*Height\_Internal)/(P46802)$	$=0.664*X46802^{(1/2)}*Q46802^{(1/3)}$	$=(Y46802*O46802)/(Height\_Internal)$
$=(M50402*Velocity\_Water*Height\_Internal)/(P50402)$	$=0.664*X50402^{(1/2)}*Q50402^{(1/3)}$	$=(Y50402*O50402)/(Height\_Internal)$
$=(M54002*Velocity\_Water*Height\_Internal)/(P54002)$	$=0.664*X54002^{(1/2)}*Q54002^{(1/3)}$	$=(Y54002*O54002)/(Height\_Internal)$
$=(M57602*Velocity\_Water*Height\_Internal)/(P57602)$	$=0.664*X57602^{(1/2)}*Q57602^{(1/3)}$	$=(Y57602*O57602)/(Height\_Internal)$
$=(M61202*Velocity\_Water*Height\_Internal)/(P61202)$	$=0.664*X61202^{(1/2)}*Q61202^{(1/3)}$	$=(Y61202*O61202)/(Height\_Internal)$
$=(M64802*Velocity\_Water*Height\_Internal)/(P64802)$	$=0.664*X64802^{(1/2)}*Q64802^{(1/3)}$	$=(Y64802*O64802)/(Height\_Internal)$
$=(M68402*Velocity\_Water*Height\_Internal)/(P68402)$	$=0.664*X68402^{(1/2)}*Q68402^{(1/3)}$	$=(Y68402*O68402)/(Height\_Internal)$
$=(M72002*Velocity\_Water*Height\_Internal)/(P72002)$	$=0.664*X72002^{(1/2)}*Q72002^{(1/3)}$	$=(Y72002*O72002)/(Height\_Internal)$
$=(M75602*Velocity\_Water*Height\_Internal)/(P75602)$	$=0.664*X75602^{(1/2)}*Q75602^{(1/3)}$	$=(Y75602*O75602)/(Height\_Internal)$
$=(M79202*Velocity\_Water*Height\_Internal)/(P79202)$	$=0.664*X79202^{(1/2)}*Q79202^{(1/3)}$	$=(Y79202*O79202)/(Height\_Internal)$
$=(M82802*Velocity\_Water*Height\_Internal)/(P82802)$	$=0.664*X82802^{(1/2)}*Q82802^{(1/3)}$	$=(Y82802*O82802)/(Height\_Internal)$
$=(M86402*Velocity\_Water*Height\_Internal)/(P86402)$	$=0.664*X86402^{(1/2)}*Q86402^{(1/3)}$	$=(Y86402*O86402)/(Height\_Internal)$



R_total
[K/W]
$=((1/W3)+(1/W3)+(1/AB3))^{-1}$
$=((1/W302)+(1/W302)+(1/AB302))^{-1}$
$=((1/W3602)+(1/W3602)+(1/AB3602))^{-1}$
$=((1/W7202)+(1/W7202)+(1/AB7202))^{-1}$
$=((1/W10802)+(1/W10802)+(1/AB10802))^{-1}$
$=((1/W14402)+(1/W14402)+(1/AB14402))^{-1}$
$=((1/W18002)+(1/W18002)+(1/AB18002))^{-1}$
$=((1/W21602)+(1/W21602)+(1/AB21602))^{-1}$
$=((1/W25202)+(1/W25202)+(1/AB25202))^{-1}$
$=((1/W28802)+(1/W28802)+(1/AB28802))^{-1}$
$=((1/W32402)+(1/W32402)+(1/AB32402))^{-1}$
$=((1/W36002)+(1/W36002)+(1/AB36002))^{-1}$
$=((1/W39602)+(1/W39602)+(1/AB39602))^{-1}$
$=((1/W43202)+(1/W43202)+(1/AB43202))^{-1}$
$=((1/W46802)+(1/W46802)+(1/AB46802))^{-1}$
$=((1/W50402)+(1/W50402)+(1/AB50402))^{-1}$
$=((1/W54002)+(1/W54002)+(1/AB54002))^{-1}$
$=((1/W57602)+(1/W57602)+(1/AB57602))^{-1}$
$=((1/W61202)+(1/W61202)+(1/AB61202))^{-1}$
$=((1/W64802)+(1/W64802)+(1/AB64802))^{-1}$
$=((1/W68402)+(1/W68402)+(1/AB68402))^{-1}$
$=((1/W72002)+(1/W72002)+(1/AB72002))^{-1}$
$=((1/W75602)+(1/W75602)+(1/AB75602))^{-1}$
$=((1/W79202)+(1/W79202)+(1/AB79202))^{-1}$
$=((1/W82802)+(1/W82802)+(1/AB82802))^{-1}$
$=((1/W86402)+(1/W86402)+(1/AB86402))^{-1}$



<b>Constants</b>	<b>Value</b>	<b>Units</b>
<b>Ambient conditions</b>		
Ambient temperature	25	°C
Ambient pressure	101.3	kPa
Air velocity over outside surface	1	m/s
<b>Geyser paramaters</b>		
Maximum temperature	75	°C
Internal pressure	300	kPa
Water velocity over inside surface	0.1	m/s
Height (internal)	1.02	m
Radius (internal)	0.217	m
Wall thickness of tank	0.002	m
Wall thickness of insulation	0.03	m
Wall thickness of outer casement	0.0008	m
Total wall thickness of geyser	0.0328	m
Height (external)	1.0856	m
Radius (external)	0.2498	m
Conductivity of tank material (copper)	450	W/m.K
Conductivity of insulation (SAGE EP)	30	W/m.K
Conductivity of outer casement	300	W/m.K
Internal volume	0.1509	m <sup>3</sup>
Conductive resistance of tank material (Top & Bottom)	3.004E-05	K/W
Conductive resistance of insulation (Top & Bottom)	0.007	K/W
Conductive resistance of casement (Top & Bottom)	1.803E-05	K/W
Conductive resistance of tank material (Side)	3.181E-06	K/W
Conductive resistance of insulation (Side)	0.001	K/W
Conductive resistance of casement (Side)	1.668E-06	K/W
Geyser element power output	3000	W
Element activation temperature	65	°C
<b>Air properties at ambient conditions</b>		
Density	1.184	kg/m <sup>3</sup>
Specific heat @ constant pressure	1.005	kJ/kg.K
Conductivity	0.02551	W/m.K
Viscosity	1.8490E-05	kg/m.s
Prandtl number	0.7281	-
Reynolds number (Top & Bottom)	31991.693	-
Nusselt number (Top & Bottom)	106.844	-
Convection coefficient (Top & Bottom)	5.4555	W/m <sup>2</sup> .K
Convective resistance (Top & Bottom)	0.9350	K/W
Reynolds number (Cylinder Side)	69515.976	-
Nusselt number (Cylinder Side)	157.498	-
Convection coefficient (Cylinder Side)	3.7010	W/m <sup>2</sup> .K
Convective resistance (Cylinder Side)	0.1586	K/W
<b>Water Usage Assumptions</b>		
Water usage of household 1 => 100 litre per day	0.06	m <sup>3</sup> /day
Water usage of household 2 => 1000 litre per day	0.6	m <sup>3</sup> /day

**Water Usage Profile**

06h00	5	%
08h00	16	%
10h00	15	%
12h00	11	%
14h00	8	%
16h00	7	%
18h00	11	%
20h00	13	%
22h00	11	%
23h00	3	%
	<hr/>	<hr/>
	100	Total