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An analysis of the feasibility of using a Solar Water Heating system in a hotel:

A Case Study

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DISCLAIMER

Except where otherwise stated and acknowledged, I certify that this dissertation is my sole and unaided work

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ABSTRACT

The use of solar energy to heat water will not only contribute to the mitigation of global climate change due to the reduced combustion of fossil fuels, but it will also reduce the demand on South Africa's strained electricity supply infrastructure. The hotel industry is particularly energy intensive and the production of hot water makes up a significant portion of its electricity consumption. Furthermore, South Africa boasts one of the world's most abundant solar radiation resources. Thus far, however, the use of large-scale solar water heating (SWH) systems in South African hotels is limited, with the lack of economic feasibility likely to be the core reason.

A case study was thus carried out at a local hotel to assess the feasibility of implementing a solar water heating (SWH) system, taking into account the recent electricity tariff hikes, as well the impact of the proposed Standard Offer Incentive Scheme (SOIC) developed by the Department of Energy (DoE). Furthermore, data from an additional 16 hotels was investigated to ascertain whether the results of this analysis could be extrapolated over the local hotel industry.

It was found that a SWH system is currently a poor investment for the hotel, based on the assessment of Net Present Value (NPV) and Internal Rate of Return (IRR), as well as on the project cash flow analysis. However, the introduction of the SOIC would improve the feasibility significantly. This will allow the system to be paid off completely within 5 years without the hotel incurring any costs over and above that of business as usual. Moreover, it was found that total and Hot Water Cylinder (HWC) electricity use in the hotel industry is too inconsistent for the results of this case study analysis to be representative of the whole local industry.

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ACRONYMS

DME	- Department of Minerals and Energy
DoE	- Department of Energy
EEC	- European Energy Commission
EI	- Energy Intensity
EIA	- Energy Information Administration
EREC	- European Renewable Energy Council
ETC	- Evacuated Tube Collectors
EU	- European Union
FNB	- First National Bank
FPC	- Flat Plate Collectors
GHG	- Greenhouse Gas
HTF	- Heat Transfer Fluid
HWC	- Hot Water Cylinder
IRR	- Internal Rate of Return
kWh	- kilo Watt hour
NERSA	- National Energy Regulator of South Africa
NPV	- Net Present Value
RET	- Renewable Energy Technologies
SANS	- South African National Standards
SAT	- South African Tourism
SWH	- Solar Water Heating

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GLOSSARY OF TERMS

Ambient temperature – outside air temperature

Collector intercept efficiency (C_0) – the optical efficiency of the collector, namely without taking heat losses in to account

Current Transformer (CT) – a device which proportionality scales down the current in a circuit to allow for the connection of a measurement device

Energy intensity (EI) – the typical convention for describing the extent of use of energy in a facility, measured in kWh/m^2/year

Glazing – The transparent cover of a flat plate collector

Heat loss coefficient (U_L) – the heat loss experienced by a solar collector to the atmosphere, in W/m^2, determined by the material and geometry characteristics of the collector

Heat removal factor (F_R) - the ratio of the heat actually delivered to that delivered if the collector plate were at uniform temperature equal to that of the entering fluid

Inlet water temperature – the temperature of the water entering the inlet of a solar collector

Low iron glass – glass with a low iron (Fe) content, which increases the amount of sunlight which can penetrate

Negative of the first-order coefficient of the efficiency (C_1) – the heat loss experienced by the collector, which differs to Heat Loss Coefficient in that it takes into account the variable nature of the inlet water temperature.

Panel Aperture area (A_C) – the surface area of the flat plate collector minus the area of the outer frame

Potable water – water fit for human consumption and use

Selective coating – a coating, typically a paint, which are optically designed to reflect particular wavelengths of sunlight but remain transparent to others, to increase the amount of heat being absorbed by the coated surface

Solar radiation – the electromagnetic radiation and particles emitted by the sun

Time stamped – a term to describe measured data which has the exact time and date of the measurement attached

1 INTRODUCTION

1.1 BACKGROUND INFORMATION

Our sun is an almost limitless supply of energy and mankind's use of this energy dates back centuries. More recently, solar energy has been harnessed to heat swimming pools, to cool buildings, to desalinate water, to generate electricity and to heat water for domestic consumption.

The use of solar energy is growing steadily. In 2008, installed Solar Water Heating (SWH) systems increased by 15%, reaching an estimated 145 GW_{th} globally – double the capacity in 2004 (REN21 2009). South Africa contributed slightly more than 613 MW_{th} (0.4%) to the global capacity at the end of 2007, made up primarily of small-scale household SWH and swimming pool heating systems (Weiss 2009). This contribution is small, considering that South Africa is among the countries with the best solar resources. Daily solar radiation levels vary between 4.5 kWh/m^2 and 6.5 kWh/m^2, compared to 3.6 kWh/m^2 and 2.5 kWh/m^2 for the USA and Europe respectively (Department of Minerals and Energy [DME] 2003).

SWH systems have been used successfully around the world for decades in a variety of sectors, including hotels (European Energy Commission [EEC] 2002). Over 800 hotels in Greece currently make use of SWH systems (Karagiorgas *et al*. 2006). In Australia, some systems supplying hot water to hotels have been operating since the 1960's (Sustainability Victoria 2010). Locally, though, only two hotels could be found with large-scale SWH systems, namely the Southern Sun Stay Easy Emalahleni in Nelspruit and the Da Vinci Hotel in Johannesburg . This finding was based on preliminary research into the local hotel industry, comprising contact with personnel at three of South Africa's largest hotel chain groups, as well as telephonic conversations with 71 Cape Town based hotels. The poor uptake of SWH systems was found to be based primarily on perceptions of unattractive economic feasibility and a lack of understanding of the technology.

Hotels are among the most energy intensive of all building categories and can have a major environmental impact, especially in popular tourist destinations (Rajagopalan *et al*. 2009; Santamouris et al. 1996). This is consistent with the findings of the EEC, which states that the hotel industry is among the most energy intensive sectors of the tourism industry (EEC 2002). Furthermore, the high energy intensity of hotels in South Africa is recognised by the

South African National Standards (SANS). The recently published SANS 204-1 standard for Energy Efficiency in Buildings consequently lists hotels as the most energy intensive of all buildings, more than double that of shopping malls and more than triple that of office blocks (SANS 2008). The production of hot water is a large contributor to the high energy intensity in hotels.

Furthermore, global tourism has been growing at a steady rate during the last two decades. A similar trend is evident in South Africa, with consistent growth since 2001 (South African Tourism [SAT] 2008). South Africa recorded the highest number of foreign arrivals ever in 2008, an increase of 5.5% from 2007. This is significantly higher than the global average of 1.8% for the same period (SAT 2008).

The need for the tourism industry to employ more environmentally sustainable technologies and policy has been recognized by international organisations. Examples are the United Nations' Agenda 21 Program and the European Renewable Energy Council's " Excellence in Energy for the Tourism Industry" program (United Nations 1992; EREC 2008). Furthermore, the World Tourism Organisation (WTO) also recognises that environmental impact of tourism is severe and provides support to member organisations to reduce this impact. The development of these programs highlights the global trend of governments of developed countries and international organisations to promote and enforce a more environmentally friendly tourism industry.

Some developing countries have also implemented strategies to reduce energy consumption in the tourism industry. India recently enacted nationwide energy conservation codes for hotels[1] with centralized hot water systems, requiring that at least 20 % of water heating capacity must come from SWH systems (REN21 2007). China's National Development and Reform Commission issued its "Plan on Enforcement of Utilization of Solar Energy Heating Nationwide" in 2007, which applies to hotels (Martinot and Li 2008).

Hotels themselves are also becoming more aware of the need to implement environmentally friendly technologies. A study comprising 200 European hotels revealed that many are willing to invest in renewable energy technologies (RET) due to the upcoming "eco-labelling" scheme expected to be implemented in Europe, as well as the increased social status associated with having environmentally friendly technologies in place (Karagiorgas *et*

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[1] This code includes hospitals and residential buildings.

al. 2006). A survey in Australia highlighted that more than half of the participants believed the adoption of RET would be beneficial as a marketing tool.

Furthermore, the growing awareness among tourists of climate change and environmental degradation is affecting the way in which they travel and the locations at which they choose to stay (Schendler 2003; Karagiorgas *et al*. 2006). Eco-sensitive tourists prefer to stay in hotels that operate environmental programs and that have implemented RET.

In summary, it is believed that SWH systems in South African hotels are a much underutilized method of reducing the environmental impacts of climate change due to fossil fuel use, as well as reducing the demand on our electricity supply. Hotels are very energy intensive and a significant portion of their energy use is for hot water production. In South Africa, the primary means of producing such hot water is by using fossil fuel based electricity. Furthermore, South Africa has abundant solar resources and SWH systems have been proven to be effective in the large-scale production of hot water in regions with solar radiation that is inferior to that of South Africa. Moreover, tourism in South Africa is growing steadily, which will result in rising electricity consumption in hotels. The environmental awareness of tourists themselves is also on the rise, which should act as an incentive for hotel owners to employ more environmentally friendly technologies as marketing initiatives.

The combination of the issues discussed above should place hotels at the forefront of the implementation of SWH systems; in practice, however, the market remains relatively untapped. The lack of implementation is suspected to be due to the economic viability of such systems. Electricity prices in South Africa have historically been relatively low when compared to the rest of the world (Eberhard 2005). However, the National Energy Regulator of South Africa (NERSA) has recently approved electricity tariff increases over the next three years (NERSA 2010a), which are likely to have a positive effect on the economic viability of large-scale SWH systems.

It is therefore believed that a study to evaluate the economic viability of a large-scale SWH system in a hotel, taking into account current electricity prices and increases would prove valuable for hotel owners and governmental decision makers.

1.2 RESEARCH OBJECTIVES

The objective of this study is to provide evidence to support the *thesis statement*:

A Solar Water Heating system is currently a good investment for a South African hotel, and it will significantly reduce the hotel's total electricity consumption.

This objective will be achieved by evaluating:

- how much electricity a hotel uses
- what proportion of the total use is attributed to hot water production
- how occupancy levels influence hot water use
- the performance of a SWH system under local conditions
- what proportion of electricity attributed to hot water production can be displaced
- the economic feasibility of the SWH system

1.3 CHAPTER OVERVIEWS

The remainder of this report comprises the literature review, methodology, results, discussion of results, conclusions and recommendations for further research.

The *Literature Review* chapter discusses the literature covered to i) evaluate the current status of SWH in the hotel industry, ii) investigate the economic feasibility of existing SWH systems, iii) understand energy use in the hotel industry and the typical contribution of hot water production to a hotel's total energy requirements, iv) ascertain what the most appropriate SWH system design and solar collector would be for this study. The *Methodology* chapter discusses the chosen research design and describes the method used in this study to attain the research objectives. The *Results* chapter presents the research results and analyses those results. This comprises a discussion of i) the electricity use in hotels and an analysis of the effect of occupancy, ii) the design and performance of the proposed SWH system and iii) the costs and economic feasibility of such a system. The *Discussion of results* chapter highlights the analysis of the findings obtained during this study and the *Conclusion* chapter summarises the conclusion which were drawn from the study. This is followed by the *Further Research* chapter, which outlines potential areas in which more research is needed. .

2 LITERATURE REVIEW

This chapter reviews the literature relating to the following topics:

- i) energy use in the hotel industry to understand how much energy is used by hotels, how hotels typically use this energy and what factors affect its use
- ii) the economic feasibility of installed systems to assess whether they are typically good investments and to identify and understand the factors affecting such feasibility
- iii) the typical contribution of hot water production is to a hotel's total energy requirements
- iv) large-scale SWH systems and solar collectors to determine which systems would be the most appropriate for this study.

2.1 ENERGY USE IN THE HOTEL INDUSTRY

Hotel buildings are unique in their consumption of energy when compared to other commercial buildings. Furthermore, hotels themselves can also have very different energy use patterns, depending on the types of facilities offered. To evaluate the potential for a large-scale SWH system in a hotel, it is essential to understand the underlying energy use of such hotel. There are many studies that evaluate energy use in the hotel industry in general, which can offer valuable insight. What these studies reveal is that the Energy Intensity (EI) of the hotels, typically measured in energy use per unit floor area per year (kWh/m^2/year), varied considerably and that many factors can influence the final energy usage. These factors can include hotel class, i.e. its star rating, size and occupancy levels, all of which are discussed briefly below.

It should be intuitive that higher class hotels (4- and 5-star) use more energy than the more modest 2- and 3-star hotels. They tend to have a higher number of energy intensive facilities, such as heated swimming pools and health spas, as well as larger rooms. However, no consistency was found in the literature accessed for this review. A study by Rajagopalan *et al.* highlighted a difference in energy intensity per class of hotel, finding that 4- and 5-star hotels are fairly similar, with EI ranging from about 300 kWh/m^2/day to 600 kWh/m^2/day. 3-star hotels were found to be generally less energy intensive, typically below 300 kWh/m^2/day (Rajagopalan *et al.* 2009). Deng and Burnett's study failed to find any clear relationship between class and EI, and even found that 3-star hotels could be more energy intensive than their 5-star counterparts (Deng and Burnett 2000). Onut's and Soner's investigation of only 5-star hotels revealed a vast difference in EI, which ranged from 129 kWh/m^2/year to 646.3 kWh/m^2/year (Onut & Soner 2006).

The physical size of a hotel has also been shown to affect EI. The EEC study of the tourism sector revealed that a typical EI for a large hotel (>150 rooms) is between 365 and 440 kWh/m^2/year. The EI in a medium hotel (50 – 150 rooms) ranges from 260 to 320 kWh/m^2/year (EEC 2002). This study does not however make any distinction between hotel class.

Furthermore, it should be expected that, as the hotel occupancy increases, the total energy consumption should increase accordingly, since there are more guests using the facilities and thus hot water. However, this is not always the case. Rajagopalan *et al.* found no correlation between occupancy levels and EI using Pearson's Coefficients and suggests that a simple proportional relationship is unlikely (Rajagopalan *et al.* 2009). This was also recognised by Bohdanowicz and Martinac. Their study attempted to create benchmarks for energy consumption using linear regression and it concluded that many factors influence energy use (Bohdanowicz and Martinac 2007). They concluded further that, in order to compare hotels, one would need to categorise the hotels into sub-groups with similar properties for it to be realistic. Papamarcou and Kalogirou postulated an exponential relationship between occupancy and energy consumption, but this was only based on a single hotel and is thus insufficient evidence to draw any general conclusions (Papamarcou and Kalogirou 2001). Onut and Soner's study, however, found a strong correlation between occupancy and energy consumption using linear programming techniques (Onut and Soner 2006).

None of the studies discussed above assessed the relationship between occupancy and energy use related to hot water production. It is more likely that a clearer relationship exists between occupancy and hot water energy use than between occupancy and total facility EI. Deng, for instance, found that in hotels without laundries, the correlation between hot water use and occupancy was strong (Deng 2003). In contrast, an analysis of hotels *with* laundries failed to show similar correlations.

Sources of information were found that estimate the contribution of hot water production to final energy use in hotels. These too, however, varied considerably. According to the EEC, energy consumed in the production of hot water in a medium rated hotel (3- to 4-star) makes up as much as 15% of the hotel's total energy consumption and can be as much as 24% for 5-

star hotels (EEC 2002). The Energy Information Administration (EIA) states that water heating accounts for 31.4% of total energy consumption in the USA hotel industry (EIA 2008).

Although these studies discussed above provide valuable insight into energy consumption in hotels, as well as into the factors affecting it, it was found that energy use could vary significantly from hotel to hotel, regardless of hotel class, size and occupancy. Consequently, it is believed that any studies relating to energy use in the local hotel industry would be more reliable if based on actual measurements and that the analysis of relationships between energy use and hotel operation should be carried out with caution.

2.2 ECONOMIC FEASIBILITY OF INTERNATIONAL SWH SYSTEMS

International studies related to the economic viability of RET systems in the hotel industry, including SWH systems, have also been reviewed. Karagiorgas *et al.*'s (2006) study concluded that SWH can be economically viable with payback periods as low as 1.7 years. However, this study also showed that payback periods could be as high as 19 years, due to the combination of high hardware prices and low electricity prices. This highlights the fact that the costs of components and the electricity price will have a significant effect on the economic feasibility of such systems. According to a presentation by solar thermal system manufacturer Emmvee Solar Systems in December 2009, the common payback period of solar thermal systems in Indian hotels ranges between two and three years (Baerbel 2010). The recent installations at Best Western and the JP Siddharta Hotel in India showed good economic viability with payback periods of 2.1 and 1.7 years respectively (Baerbel 2010).

There are studies that evaluate the cost breakdown of SWH systems; however, they are conducted overseas and are not recent, both of which make the results irrelevant to locally conducted feasibility studies (Fisch *et al.* 1998; Mahjouri and Nunez 2003). Some studies also only evaluate the costs of domestic systems and thus are not relevant to large-scale systems (Bakos and Tsagas 2002). There are also studies that consider industrial systems, but load patterns and operations for the hotel sector are different to domestic and commercial buildings and therefore are not representative (Bohdanowicz and Martinac 2005). This affirms the need for a local study to be undertaken to assess conditions and evaluate costs in order to gain an understanding of the potential in a local context.

That said, Karagiorgas *et al.*'s (2006) survey of 200 European hotels in five countries revealed that economics have not been the core barriers to RET in EU hotels, since there are typically sufficient budgets for renovation and environmental improvements. This study also revealed that there is a vast selection of RET being applied in hotels in the EU and that the performance and viability of each is very much dependent on local conditions.

2.3 SOLAR WATER HEATING SYSTEMS

SWH systems make use of a solar thermal collector array, which absorbs solar radiation and converts it into heat. This heat is absorbed by a heat transfer fluid (HTF), such as water, anti-freeze or air, which passes through the collectors and is then used or stored for later use (Kalogirou 2004). The storage tank would typically have an auxiliary heater to provide the required hot water at times when solar radiation is not readily available.

SWH systems can be broadly categorised into *direct* and *indirect* systems. In *direct* systems, the HTF is potable water, which is heated *directly* in the collector array. In *indirect* systems, the HTF remains in a closed loop and heats the potable water *indirectly* via a heat exchanger (Kalogirou 2004). The choice between a direct or indirect system is typically based on the location of the site. The advantage of direct systems is that no heat exchanger is necessary, which reduces both the costs and the thermal losses associated with transferring the heat from one medium to another. The disadvantage, however, is that the HTF is water and therefore susceptible to freezing in regions that experience below zero temperatures. Water freezing within the system can cause extensive damage. Indirect systems are more suitable in these regions, since the HTF is typically a fluid with anti-freeze properties and damage is avoided. Direct systems can however have freeze protection built into the system. During a period of very low temperatures, hot water from the storage can be re-circulated through the system to prevent freezing, or the system can be drained completely (Kalogirou 2004). Another concern often raised about direct systems is the scaling and corrosion of the pipes due to using water as the HTF. It is therefore suggested that these types of systems are not used in regions that have very hard or acidic water; however, the use of copper piping, although more expensive, can often reduce these effects.

The HTF is transported either by natural convection mechanisms, called passive or thermosyphon circulation, or through forced circulation facilitated by a pump, called active circulation. Large-scale SWH systems normally have a series of collectors positioned some distance from the storage or end use. These typically make use of a pump and are active systems. In order to collect and deliver heat generated in the collector field effectively and efficiently, a control system is required to regulate the flow of the HTF. Normally, differential, or proportional, controllers are used in large-scale SWH systems (Sustainability Victoria 2010). A differential controller calculates the difference between the collector inlet temperature and the collector outlet temperature. If the difference is positive, then the pump is activated to collect the useful heat.

2.4 SOLAR THERMAL COLLECTORS

There are two types of solar thermal collectors, which are usually classified as concentrating and non-concentrating collectors. Concentrating collectors typically have concave reflecting surfaces, which concentrate the solar radiation onto a smaller receiving area (Kalogirou 2004). These types of systems often have tracking systems to track the movement of the sun and are typically used in applications where water temperatures in excess of 100°C are required, such as process heat or electricity generation (Sustainability Victoria 2010).

Non-concentrating collectors can be divided into flat plate collectors (FPC) and evacuated tube collectors (ETC). In 2007, it was estimated that 209.7 million m^2 of non-concentrating solar thermal collectors were in operation around the world, with glazed FPCs and ETCs making up 82% of this (Weiss *et al*. 2007). FPCs are the most commonly used solar collector worldwide (Sustainability Victoria 2010). They can be made from a variety of materials and can have a variety of designs, which affect their final performance and costs (Kalogirou 2004). Glazed FPCs produce water at temperatures up to 80°C, and they are therefore suitable for domestic hot water production. Both FPCs and ETCs are used for hot water production. Since ETCs are more efficient in converting solar radiation to useful heat, they are often more suitable in cold and rainy climates. They are, however, more expensive and are normally only used when higher efficiency or higher temperatures are necessary. FPCs are slightly cheaper and suitable for domestic hot water production in warmer climates, such as South Africa.

2.5 SUMMARY

Energy usage in hotels varies considerably, and it can be based, among other things, on hotel size, class and occupancy levels. Consequently, relying on the available literature to understand hotel electricity consumption in a local context can be misleading. To understand the energy usage patterns of a hotel, it is important to conduct a study at that particular hotel. This is also the case when assessing the contribution of hot water production to total consumption. Furthermore, the economic feasibility of a SWH system in a hotel can also vary considerably based on factors such as electricity prices and component costs as well as local incentive schemes. To accurately evaluate the economic feasibility of a SWH system at a local hotel, it is necessary to take these factors into account.

The review of literature pertaining to SWH systems revealed that the design of the system and of the collector type would be dependent on local conditions and requirements. For a hotel in Cape Town, for instance, a direct system would be more suitable, since there is limited risk of freezing. Additionally, FPCs would be more suitable for a SWH system in Cape Town, due to the low temperatures required for domestic hot water and the lower costs.

3 METHODOLOGY

The objective of this study is to determine:

- how much electricity a large hotel uses
- what proportion of the total use is attributed to hot water production
- how occupancy levels influence hot water use
- the performance of a SWH system under local conditions
- what proportion of electricity attributed to hot water production can be displaced
- the economic feasibility of the SWH system

The method described in this chapter aims to help evaluate whether a SWH system would be a good investment for a local hotel, given the current economic climate, current electricity price structures and recent component costs.

This chapter includes the *Research Design*, where the overall approach to test the thesis statement is explained. This is followed by the *Method*, which describes the instruments used to collect data, the data itself and the analysis of the data.

3.1 RESEARCH DESIGN

The technique used in this dissertation to achieve the objectives is a case study at a 4-star, 220 room hotel in Cape Town. By means of on-site measurements, the initial phase of the case study will establish how much electricity is consumed in the hotel and what proportion of this can be attributed to hot water production. These measurements will necessitate the installation of reliable power metering devices on the hotel's electricity distribution boards. The measurements will be verified by analysing historical consumption. Furthermore, electricity usage data will be requested from additional hotels across South Africa. This will not only verify the accuracy of the measured data but also determine whether the results of this study could be extrapolated over a wider range of hotels. Additionally, a selection of hotels based in Cape Town will be visited and staff will be interviewed. This will serve to determine what is the most common method of producing hot water in hotels is and to ensure the system used at the case study hotel is typical.

The capacity of the SWH system to be installed will be decided on by analysing the existing hot water consumption patterns. Factors affecting such consumption will be identified. This will serve to assess how much of the electricity being used to heat water could be displaced by installing a SWH system.

A design will be proposed for the most suitable SWH system, based on the conditions at the site. Local solar service providers will be contacted for advice on components and system designs. Furthermore, a site visit will be carried out at a hotel at which a large scale SWH system has been installed to gain an understanding of the components and system used.

The thermal performance of the SWH system will be modelled in Microsoft Excel making use of site specific solar radiation and climatic data. The results will be used to determine the required size of the system, based on the assessment of the hot water usage patterns. The calculated thermal performance will be verified by using an alternative software package.

The cost of the system will be estimated by contacting local suppliers of components and solar engineering services companies who have commissioned similar systems locally. The economic feasibility of the proposed system will be established by estimating system costs and calculating the financial indicators, such as Net Present Value (NPV), Internal Rate of Return (IRR) and payback period. The cash flow for the life of the project will be analysed. A model will be generated in Microsoft Excel that has enough flexibility to be able to vary critical parameters to evaluate a range of scenarios. These scenarios will be compared with each other.

3.2 METHOD

This section outlines the actual methodology used to achieve the objectives of the study. It is specifically structured to explain how each part of the research design was met and is thus divided into eight categories. An outline of the structure of the remaining part of this chapter is given on the following page. The *thermal performance* category is relatively broad and is therefore broken down into a further four parts.

- Total electricity use
- Hot Water Cylinder (HWC) electricity use
- Factors affecting HWC electricity use
- System design and components
- Thermal performance
    - Site conditions
    - Efficiency of the collector
    - Orientation of the collector
    - System losses
- Capacity of the system
- Costs of the system
- Economic feasibility

3.2.1 TOTAL ELECTRICITY USE

Electricity is supplied to a site through the main electrical distribution board and is typically a 3-Phase supply for large consumers. Inspection of the main distribution board at the hotel revealed that the supply was in fact 3- phase and an electricity monitoring device had already been installed. The installation of an additional meter was therefore unnecessary. The meter currently installed is a Zaptronix ZAP03BS. To access the data, software package RemIt! Lite was downloaded from the Zaptronics website and a PC was connected to the meter via an infra-red port.

The meter's built-in memory allowed access to data for the period 5 January 2010 - 11 May 2010, which was downloaded and saved to a CSV file for analysis. The meter had previously been programmed to record kWh data at half hour intervals.

The downloaded data was exported to Excel and the hourly total, hourly average and daily total kWh consumption were all calculated. The *daily* total consumption for the hotel was used in this study. This daily total was summed up for each complete month and compared to historical data extracted from the hotel's utility bills for the whole of 2009 for verification.

Additionally, one of South Africa large hotel groups (which asked to remain anonymous) was willing to participate in this research and access was granted to its hotel electricity consumption data. This data was accessed via an online database, through which total electricity consumption for a selection of hotels could be downloaded. This data contained information of electricity consumption in kWh, which could be retrieved in one hour averages. Many of the datasets for the hotels included in the online data base were incomplete, or had extended periods with missing data and were therefore omitted.

Additionally, only hotels within South Africa were considered, and of these, only those hotels with more than 50 rooms. The reason that only hotels with more than 50 rooms was considered was because they are more likely to use a central hot water heating system. Smaller hotels tend to have individual HWCs in each room, which makes retrofitting with a SWH system complicated. The details and data from these hotels can be viewed in Appendix A.

The main limitation of this data was that the consumption could not be recorded for an entire year. Furthermore, the total consumption over the year fluctuates, depending on the time of year, due to factors such as occupancy and outdoor weather. The result is that extrapolating the data over an entire year for analysis purposes does not provide an entirely accurate consumption profile.

With regards to the data from the local hotel group, this data was simply downloaded off of their energy management system, and the manner in which this data is recorded is not clear. Furthermore, the sites for which this data was extracted were not visited.

3.2.2 HWC ELECTRICITY USE

The HWC system at the case study hotel comprises a series of three 10000 litre tanks with electrical heating elements. This is considered a typical system based on telephonic communication with 23 Cape Town hotels with more than 50 rooms, as well as site visits to a selected few to inspect the hot water production systems. The details of these hotels can be seen in Appendix B. The HWC's electricity consumption was measured by connecting an Elster A1700 power meter to the HWC room distribution board. The HWCs received a 3 phase supply and the meters Current Transformers (CT) were connected to each phase. This specifically recorded the power consumed to produce hot water. The meter was programmed to record "time stamped" kWh data, which were exported to a CSV file for analysis. The software package Elster Power Master Unit version 2.3 was used to interface with the unit via an infra-red port.

The electricity usage of the HWCs was recorded over the period 16 March 2010 – 11 May 2010. The meter was initially programmed to record kWh data at 5 minute intervals. After two weeks of recording, the decision was taken to reduce the sample rate to half hourly intervals, since this was believed to be adequate for this investigation.

The raw data was downloaded via the Elster software and exported to Excel. It was then processed to calculate hourly average and daily averages for the period of measurement. This data was compared to the total consumption data to evaluate the contribution of hot water production to total consumption. This was done by using daily averages of each to determine whether the HWC load made up a consistent proportion of the total load. This data was then compared with HWC consumption data from the same additional hotels described in 3.2.1 above.

3.2.3 FACTORS AFFECTING HWC USE

A major factor influencing hot water consumption in a hotel is occupancy level, since the main use for hot water in a hotel applies to the rooms. Occupancy data was supplied by the hotel for the entire year of 2009 as well as for 2010 up to the time the measurement of electricity usage was completed.

The analysis of the occupancy data comprised two parts. Firstly, the historical occupancy data was analysed to evaluate if any trends existed over a year, as well as to determine the arithmetic mean and standard deviation, maximums and minimums. As seasonality often affects hotel occupancy, this in particular was analysed. Secondly, the recent occupancy data was compared to HWC consumption data to determine whether there were any obvious relationships. This was done by using Excel in various ways. The occupancy data and HWC consumption were plotted on a chart for a visual inspection to evaluate whether any relationships were evident. Occupancy and HWC usage were then compared by using an x-y scatter graph to determine if particular daily occupancy levels resulted in similar HWC loads. The linearity of this relationship was assessed visually by introducing a trend line. Furthermore, the HWC data was studied more closely on a daily basis, for days of highest, average and lowest occupancy, to assess the HWC consumption pattern for those particular days.

There are various limitations to the methods used here. Comparisons were made purely visually and with limited statistical analysis. Furthermore, it has been assumed that the majority of hot water is used in the guest rooms. Consultation with hotel staff confirmed that hot water produced in the HWC systems is also used in the kitchen, albeit to a much lesser extent than in the rooms. The actual extent of this use in the kitchen is unclear.

3.2.4 SYSTEM DESIGN AND COMPONENTS

Three methods were used to determine the most suitable design for the system. Firstly, the published literature relating to existing large-scale SWH systems and case studies of existing systems overseas were reviewed. Secondly, local solar engineering companies, which design and install large-scale SWH systems, were asked to make recommendations. Thirdly, a site visit was carried out at a local hotel where a large-scale SWH system, similar to the one being proposed in this case study, was in place.

The methods described above revealed that the system design, which refers to the specific type of system used as well as the type of solar collector chosen, were typically a function of the location and the local climatic conditions. The site conditions at the case study hotel were assessed and a decision was made regarding the most appropriate system and collector.

3.2.5 THERMAL PERFORMANCE

The thermal performance of a SWH system is primarily governed by the conditions at the site, the efficiency of the collector, the orientation of the collector and the losses in the system. These are all discussed individually below.

3.2.5.1 Site conditions

The conditions at the site considered include solar radiation, ambient temperature and inlet water temperature. This data was extracted from the climate database of RETScreen Analysis Software. Details of this software package can be viewed in Appendix C. This database includes historical data from NASA's Surface Meteorology and Solar Energy database. This data is made up of ground measurements taken at Cape Town International Airport, roughly 20 km from the site of the hotel. A screen shot of the climatic data can be viewed in Appendix D. The reasons for using this data were, firstly, because the software package was free, and, secondly, because it provides monthly solar radiation data based on extensive historical measurements.

Although inlet water temperature is calculated in RETScreen by means of an undisclosed formula, the maximum and minimum temperatures for a year are provided in the database.

The monthly solar radiation data, monthly ambient temperatures and the maximum and minimum water inlet temperatures were thus extracted from RETScreen and exported to Excel for analysis. This data was used in the thermal output calculations. Monthly solar radiation data was checked against locally available data and was found to be consistent.

The main limitation of this data is that only maximum and minimum inlet water temperatures are available. Although RETScreen calculates the daily values, the formula used is not shown. Therefore, the performance of the system has been calculated for the minimum and maximum temperature individually for the entire year.

3.2.5.2 Efficiency of the collector

The performances of solar thermal collectors differ according to the type, the materials used and the size of the collector area. Based on the findings of the literature review, contact with local solar engineering companies and site visits to existing installations, it was decided to use a FPC for this study. South Africa has a relatively warm and sunny climate and thus it is not necessary to use highly efficient ETCs for this application. Also, they are more expensive, which would negatively affect the economic feasibility of the system.

The performance of FPCs can also vary considerably between manufacturers and materials used and thus the data for a *typical* FPC has been used in this study. The relevant specifications for a typical FPC were taken from Table 2 in Kalogirou's study on solar thermal collectors (Kalogirou 2004). This table can be viewed in Appendix E. The design of the "typical" collector described in the table was verified by contacting local suppliers of FPC's to determine whether it was, in fact, typical. Furthermore, a sensitivity analysis was carried out to determine the impact on performance by using data from specific collectors on the market. This analysis revealed that there are very small differences among the different panels, and consequently, for the purposes of this analysis, the specifications for a typical collector were used.

Under steady-state conditions, the useful heat delivered by a solar collector is equal to the energy absorbed by the HTF minus the direct or indirect heat losses from the surface to the surroundings (Kalogirou 2004). The useful energy collected from the collector was calculated by using the following formula:

$Q_U = A_c F_R[G_T(\tau\alpha) - U_L(t_i - t_a)]$ (Duffie and Beckman 2006)

Where:

Q_U = Useful heat delivered by the panel per day

A_C = Panel Aperture area (m^2)

F_R = Heat removal factor

G_T = Solar radiation (W/m^2)

$\tau\alpha$ = Transmission absorption coefficient

U_L = Heat loss coefficient (W/m^2)

t_i = Inlet water temperature (°C)

t_a = Ambient temperature (°C)

The data in Kalogirou's table of typical FPC specifications did not include Heat removal factor F_R or Heat loss coefficient U_L. It did however include the collector intercept efficiency ($C_{0)}$ and the negative of the first-order coefficient of the efficiency (C_1). These were used to calculate F_R and U_L by using the following formulae:

$F_R = \frac{C_0}{\tau\alpha}$ (Duffie and Beckman 2006)

$U_L = \frac{C_1}{F_R}$ (Duffie and Beckman 2006)

The transmission absorption coefficient ($\tau\alpha$) is also not specifically given in Kalogirou's study. It is however specified that the glazing is low iron glass and that the absorber coating is black paint. The transmission absorption coefficient is a product of the light transmission factor for the glazing and the absorption factor for the absorber coating. Typical light transmission factors for low iron glass range between 91.7% and 90.3%, depending on the thickness. FPCs typically use 4mm glass, which has a transmission factor of 91.6% (Stegbar 2010). Black paint has typical absorption factors of approximately 0.96 (Aranovitch 1981). Consequently, the transmission absorption coefficient is the product of the glass transmission factor and the black paint absorption factor, i.e. 0.879.

The inputs used in Equation 1 to calculate the output of the panel in question can be seen in Table 1.

TABLE 1: FIXED INPUTS USED TO MODEL COLLECTOR OUTPUT

Input	Value	Source
A_C	$2m^2$	Kalogiou 2004
U_L	7.09	Calculated
F_R	0.94	Calculated
$\tau\alpha$	0.879	Calculated

The remaining variables required, namely G_T, t_i and t_a, vary on a monthly basis and were extracted from the RETScreen database and can be viewed in Table 2.

TABLE 2: VARIABLE INPOUT USED TO MODELCOLLECTOR OUTPUT

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
G_T	7.2	7.1	6.5	5.2	4.1	3.6	3.8	4.4	5.4	6.3	7.1	7.2
t_a	20.4	20.4	19.2	16.9	14.4	12.5	11.9	12.4	13.7	15.6	17.9	19.5
$t_{i\ (min)}$	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
$t_{i\ (max)}$	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7

The data in Table 1 and Table 2 were used to calculate the useful heat output of the collector on a monthly basis.

Various limitations to this methodology have been identified. This analysis uses the efficiency of a typical collector, whereas any actual feasibility studies carried out for large-scale SWH systems should perform calculations based on the *actual* collector being installed. Furthermore, inlet water temperatures have only been found as minimum and maximum temperatures and not as monthly averages. Additionally, since only monthly solar radiation data is available, the output is only calculated on a monthly as opposed to a daily basis. Using daily data would provide a more comprehensive analysis. It is believed, though, that monthly data is sufficient for this study.

3.2.5.3 Orientation of the Collector

To determine the most appropriate orientation of the collector field, the slope and the azimuth of the collector need to be optimised. The *slope* of the collector refers to the angle between the absorbing surface of the collector and the horizontal. The *azimuth* in this case is the orientation with respect to the poles and should always be 180° to optimise solar energy collection. In most cases, the slope will be set equal to the absolute value of the latitude of the site, to maximize the annual solar radiation in the plane of the solar collector. However, the evaluation the most suitable slope for the collectors was carried out by assessing the output of the chosen collector when adjusting the slope. This was carried out in RETScreen, by adjusting the slope input and recording the corresponding output. The results can be viewed in Figure 1**Error! Reference source not found.**. The slope that would result in the highest annual solar radiation, namely 27°, was selected for this study.

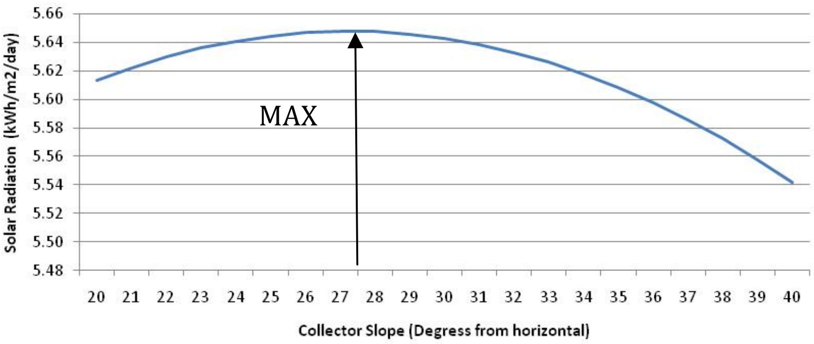

FIGURE 1: SOLAR RADIATION VS. COLLECTOR SLOPE HIGHLIGHTING MAXIMUM

3.2.5.4 Losses in the system

The system losses for the case study system are difficult to estimate since it would require a very detailed design. As such, the method and recommendations outlined in RETScreen has been followed. losses considered are divided into *miscellaneous* and *balance of system* losses.

Miscellaneous losses, according to RETScreen help files, refer to, for example, losses due to the obstruction of the solar collector by snow and/or dirt. The value of this parameter will also depend on local climatic conditions, the tilt angle of the collector and on the presence of personnel on-site to clean the collector. The recommendation is that for well maintained collectors, this value should range between 2% - 5%. It was decided to reduce the output of the system by the average of these values, namely 3.5%.

There are also losses associated with the balance of the system, i.e. heat losses from the pipes and/or the tank to the surrounding environment. According to RETScreen's recommendations, found in the help files, systems without storage only experience losses from the piping, which are typically between 1% and 2% if there is a relatively short distance from the collectors to the HWC room. This will also be affected by insulation of the piping. Based on this information, an estimate of 2% has been used. The output of the panels has therefore been decreased by 2% to account for these losses.

3.2.6 SYSTEM CAPACITY

To decide on the capacity of the SWH system, the HWC consumption data referred to in Chapter 3.2.2 was analysed. This was carried out with the aim of minimising surplus output from the system. This is important for the following reason. To evaluate the economic feasibility of a SWH project, it is important to ensure that the predicted electricity saving – due to the system supplementing hot water production – is achieved. The economic indicators to be evaluated by decision makers when deciding whether it is worthwhile to implement such as system are directly linked to how much the system is predicted to save. Furthermore, oversupply in times of high system output, i.e. summer, cannot be stored until times of low output, i.e. winter. The size of the system must therefore be optimised to prevent any surplus production during the year, which would essentially be wasted. This will ensure that the financial analysis is based on savings that can be achieved in reality. This will be done by closely analysing the HWC electricity consumption data over a typical year. However, since the measurements of the HWC were only taken for a period of a few months, the HWC consumption data has been carefully extrapolated to create an "expected" year of consumption.

The output of the collector described in Chapter 3.2.5.2 – Thermal Performance – was then built into an Excel model, which allowed for adjustment of the number of collectors, and thus total system output. The output of the system was then adjusted, by altering the number of collectors, and compared to the HWC load forecast described above to determine the most optimal number of collectors.

3.2.7 System Cost

Very little information is available regarding the cost breakdown of large-scale SWH systems in South Africa. It is believed to be inappropriate to make use of international cases since i) few are recent and the rate of change of solar thermal collectors prices is high, ii) costs for certain components can be different to locally sourced components and iii) the cost of a system is very specific to the components being used, as well as the system type. Consequently, local service providers were contacted to obtain cost estimates for the relevant components. One company contacted had recently installed a large SWH system at a local hotel and it is therefore in a good position to provide estimates. Additionally, a Bill of Quantities was provided for the costing of a current design on which they are working, which can be viewed in Table 3. This provided a detailed breakdown of components and costs. The costs outlined in Table 3 were assessed to determine which components would be similar in the case study system design. The costs were broken down into fixed and marginal costs, which were included in the cost analysis. Marginal costs were adjusted according to the number of collectors used in the case study. The fixed costs are representative, since they will not vary based on the number of collectors. Furthermore, local suppliers of certain off-the-shelf components were contacted to verify the costs supplied by the local service provider.

TABLE 3: BILL OF QUANTITIES FOR SOLAR WATER HEATING SYSTEM

ITEM	DESCRIPTION	QTY	RATE	TOTAL
Design & Development	Professional Fees	1	120 000	120 000.00
Project Management	Incl. Commissioning	6	20 000	120 000.00
Transport		1		–
Lodging		1		–
COLLECTOR FIELD				
Panels	R4 S – 500 Bulk Pricing	150	4 499	674 850.00
installation		0		–
Stands	Multi Panel Triangle Stands	150	2 000	300 000.00
installation	Clear & Free, no special req's	0		–
PLANT ROOM				
HWCs	12,000L each	3	50 000	150 000.00
installation	included	0		–
Heat Exchanger	Alfa Laval	1	50 000	50 000.00
installation	included	0		–
Pumps	Salmson/Wilo	2	5 000	10 000.00
Expansion Tank	Salmson/Wilo	1	2 000	2 000.00
Control System		1	5 000	5 000.00
installation	included	0		–
M & V (incl software)		1	150 000	150 000.00
PIPING/RETICULATION				
Piping – Collector Field	incl. Installation & Lagging	150	3 250	487 500.00
Piping – Plant Room	incl. Installation & Lagging	20	2 000	40 000.00
Piping – Transfer	incl. Installation & Lagging	150	700	118 830.00
Ball Valves	included	0		–
Air Release Valves	included	0		–
Elbow Joints	included	0		–
Tee's	included	0		–
Records	To Connect Panels in Series	100	67	6 700.00
		TOTAL		**2 234 880.00**

Since a specific collector has not been used in the output analysis, a typical cost for a FPC that would be suitable for this particular case study has been determined by researching the local industry. It was found that a suitable FPC is a unit with the typical characteristics for a top end FPC. This includes a low iron toughened glass glazing, a selective coating on the absorber plate and corrosion resistant materials for the pipes, frame and backing plate. Another important characteristic is the ability to connect many of the panels in series to create a collector “bank”. The cost was determined from averaging the price of ten locally available FPCs that meet the requirements for this application.

The limitations of using cost estimates are that they might vary slightly for a different case, although they are believed to be the best estimates for this study. A more thorough costing would require a much more detailed design, including plumbing fixtures, pipe lengths and thickness, as well as details of the mounting structure.

3.2.8 ECONOMIC FEASIBILITY

Large-scale solar installations are generally characterised by a high initial investment and low operating costs. In the case of a SWH system there will be a large upfront investment, which will result in a reduction of the operating costs. Operating costs in this case are the electricity costs for the production of hot water. The installation of a SWH system will reduce the hotel's expenditure associated with the production of hot water. It is important for the hotel owner to be able to evaluate whether these savings are worth the initial investment and this requires an economic analysis. The feasibility indicators used in the financial analysis, as well as the details of the economic parameters chosen, are discussed below. Furthermore, the proposed Standard Offer Incentive Scheme (SOIS) is also considered. The details of this scheme can be found below.

3.2.8.1 Feasibility Indicators

The economic feasibility of RE projects have been evaluated in a variety of ways. These include Life Cycle Costs (Colle *et al.* 2001), Life Cycle Savings (Kalogirou 2004), Net Present Value (NPV) (Tsoutsos *et al.* 2003; Bakos & Soursos 2002), payback period (Tsoutsos *et al.* 2003; Bakos & Soursos 2002; Dalton *et al.* 2008; Dalton *et al.* 2009) and Internal Rate of Return (IRR) – also known as Return On Investment (ROI) (Bakos & Soursos 2002). These economic indicators evaluate the economic feasibility of a project to enable investors to make prudent decisions. For the purpose of this study, the feasibility analysis is limited to calculating the IRR, NPV and payback period.

IRR can be described as the *annualized effective compounded return rate* (or discount rate) that makes the net present value of all cash flows from the investment equal to zero. If the IRR of the project is greater than the required rate of return of the investor, then the project will most likely be acceptable. The required rate of return of the investor would have to be higher than an alternative investment into which he could invest his money instead of in a SWH system.

The NPV of a time series of cash flows can be defined as the *sum of the present values of the individual cash flows*. One could take the savings afforded by the system and work out the NPV, but this does not take into account the financing of the project. If the project were to be paid for in cash up front, then this could apply. However, this is unlikely for a project of this size. In order to calculate the feasibility of a SWH system, two cash flows need to be considered, namely, cash flow with the SWH system in place and cash flow without the SWH system. Cash flows without the system comprise the cash flows associated with the current production of hot water, i.e. electricity costs. Cash flows with the system are calculated by subtracting the savings afforded by the system, as well as the debt repayments if it is financed, from the cash flows without the system. The NPV is calculated for each and the difference between the two is assessed. If the difference is positive, it indicates that the present value of cash flows with the system installed would be greater than without the system, thereby indicating a feasible investment.

The IRR and NPV are closely related in that the rate of return calculated by the IRR is the interest rate corresponding to a zero NPV value.

The payback period is the length of time required by the project to recover the initial investment through the positive cash flows it generates. In other words, it is the length of time for the cumulative savings due to the SWH system being in place to equal the initial capital investment, without taking the “time-value” of money in to account.

3.2.8.2 Economic Parameters

To make use of the indicators described above, certain financial parameters need to be defined. These include project life, interest rate, discount rate, inflation rate and debt-equity ratio. Electricity prices are also discussed. These parameters will be used in the financial analysis to calculate NPV, IRR and payback period for the project for a variety of scenarios.

3.2.8.2.1 Project life

The project life of 10 years has been based on the typical guarantee periods for the equipment being used. The main components, the collectors, normally have a lifespan of 20 years, although the guarantees are typically limited to five to ten years.

3.2.8.2.2 Discount rate

The discount rate is used to discount future cash flows to the present day, in order to calculate the present worth of these cash flows. There are various sources of information available to make a choice with regard to an appropriate discount rate to use. However, it was decided instead to contact a specialist in the field for recommendations. Andre Cillie, a certified financial analyst at Fountainhead Partnership, was consulted on 4 July 2010 regarding the choice of an appropriate discount rate. He states that the discount rate is typically estimated by adding an *equity risk premium* to the "risk free" long term government bond yields. Current bond rates in South Africa are nominally 8% (Johannesburg Stock Exchange 2010). Risk premiums in South Africa are nominally 6% (Dimson *et al.* 2003). Consequently, a discount rate of 14% has been used in this analysis.

3.2.8.2.3 Interest rate

The interest rate affects the amount of money the borrower would have to repay, which therefore influences the economic outcome. Cees Bruggemans, chief economist at First National Bank forecasts that for the next five years the prime interest rate will increase from 10% in 2010 to 13% in 2014 (Bruggemans 2010). Long term interest rate forecasts are beyond the scope of this analysis and the average of the FNB five year forecast, namely 11.5%, is therefore used.

3.2.8.2.4 Debt equity ratio

The Debt equity ratio is an indication of what proportion the initial investment is paid for with borrowed money. This would depend on the cash flow status of the organisation making the investment as well as on the credit history of the organisation. This can therefore not be assumed. This is an important factor, since the analysis needs to include interest charged on borrowed money, which means that the outcome will be slightly different. Consequently, the economic analysis considers two alternatives for comparison, namely 0% and 100% of debt.

3.2.8.2.5 Electricity price

The current electricity price for the case study hotel, based on past utility bills, stands at R0.38 per kWh. However, this will increase by 25.8% in 2011 and by another 25.9% in 2012, based on the recently accepted tariff adjustments (NERSA 2010a). Electricity prices after 2012 are uncertain, but for the purposes of this analysis, the price is increased by 8% a year after 2012 in line with local inflation forecasts.

3.2.8.3 Standard Offer Incentive Scheme

In May 2010, the DoE constructed a framework to develop rules in respect of incentives for the Energy Efficiency and Demand Side Management program. This framework is outlined in the DoE policy document entitled "Policy to support the Energy Efficiency and Demand Side Management Program for Electricity Sector through the Standard Offer Incentive Scheme" (DoE 2010). According to this document, the Standard Offer Rebate holds :

> "...a mechanism to acquire demand-side resources (energy efficiency/load reduction) under which a utility purchases resources based on predetermined rates (e.g., R/kWh or R/kW)."

The rules were revised and the proposed rebates have been published in a NERSA consultation paper released in June 2010 (NERSA 2010b). The rebates stipulated for the next three years, 2010, 2011 and 2012, are 0.5404 R/kWh, 0.5168 R/kWh and 0.5795 R/kWh respectively. Although SWH systems qualify for this rebate, no clarity is given regarding large-scale systems. Approval of the rebate is expected to take place in September 2010. This proposed rebate has also been included as a scenario in the financial analysis.

4 RESULTS

This chapter comprises the results and the analysis of the i) on-site electricity usage measurements, ii) occupancy data and effects, iii) performance of the proposed systems, iv) capacity of the system, v) system costs and finally vi) economic feasibility.

4.1 IN SITU MEASUREMENTS

This section discusses the findings and analysis of the hotel's total and HWC consumption measurements taken from the installed power meters. This is done to determine how much power the hotel normally consumes on a daily, monthly and yearly basis. This also makes it possible to compare hotels with other buildings in order to highlight the importance of the contribution of energy saving methods. This section also shows how much the production of hot water contributes to the total consumption. Furthermore, data from other hotels in South Africa are analysed to verify the findings and to determine whether the results for the case study are typical in terms of other hotels.

4.1.1 TOTAL ELECTRICITY CONSUMPTION

Data was analysed for the period 5 January 2010 to 11 May 2010. A chart of the processed data can be viewed in Appendix F. The average daily consumption for the period was 9869 kWh/day, with a maximum of 11608 kWh/day, a minimum of 5140 kWh/day and a standard deviation of 813 kWh/day.

The Energy Intensity (EI) for the hotel was 215 kWh/m^2/year, when the average consumption during the measured period is extended over the entire year and divided by gross floor area. To put this into perspective, the South African National Standards (SANS) 204-1 stipulates that the EI for a hotel in Cape Town should be no more than 600 kWh/m^2/year at full capacity, i.e. with occupancy levels of 100% (SANS 204-1:2008).. The same standard recommends levels no higher than 190 kWh/m^2/year in respect of office blocks, and no higher than 245 kWh/m^2/year in respect of large shopping centres. The effect of occupancy on the case study hotel's EI described above is covered in Chapter 4.2

This data was compared to the hotel's 2009 utility bills. It was found that, although slightly lower, the measurements taken over the same time of year are similar.

4.1.2 HWC ELECTRICITY USE

Data was recorded over the period 16 March 2010 – 11 May 2010. This data was collated into hourly and daily averages for analysis. The average daily electricity consumption for the period was 1373 kWh/day for the HWC system, with a standard deviation of 216.7 kWh/day. The maximum daily average for the period was 1913 kWh/day, whereas the minimum was 1099 kWh/day. It was found that the HWC use varies considerably, which is to be expected, since the use of hot water should be related to the functioning of the hotel. It is important to note that the HWC usage rarely falls below 1099 kWh/day, regardless of the operation of the hotel. This indicates that there is a base load being maintained by the system, as highlighted in Figure 2.

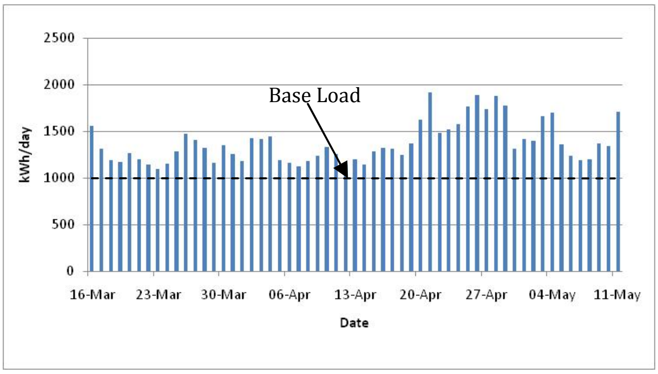

FIGURE 2: MEASURED HWC CONSUMPTION HIGHLIGHTING BASE LOAD

When analyzing *hourly* consumption data, the average consumption rarely fell below 48 kWh. The three HWCs each have three 24 kW heating elements. It follows that at least two elements were powered the vast majority of the time, regardless of hotel operation.

The HWC contribution to the hotel's total usage over this measurement period was, on average, 13.9% a day. The maximum was 17% and the minimum was 11%, with a standard deviation of 1.5%. It must be noted that, according to the hotel maintenance staff, the HWC only supplies hot water to the rooms and kitchen. However, the kitchen only absorbs a very small portion of this demand.

4.1.3 VERIFICATION

Both total and HWC consumption data for a variety of additional hotels were assessed by downloading data from a local hotel chains online database. The 16 additional hotels for which suitable data could be extracted comprise three 5-star, seven 4-star, five 3-star and one 2-star hotel, all situated in South Africa. All data sets contained at least ten months of data, from June 2009 to March 2010.

What the analysis of this data highlighted was the fact that the contribution of the HWC to total consumption was highly variable. No similarities were found amongst hotels of similar classes or similar sizes. However, it was found that the 13.9% for the case study hotel was average. This is highlighted in Table 4.

TABLE 4: CONTRIBUTION OF HWC CONSUMPTION FOR SELECTED SA HOTELS

Hotel	Class	Rooms	% of Total
1	5	546	**7.4**
2	5	334	**9.5**
3	5	89	**9.6**
4	4	410	**5.1**
5	4	368	**4.5**
6	4	366	**7.7**
7	4	346	**11.5**
8	4	242	**17.5**
Case Study	**4**	**220**	**13.9**
9	4	147	**13.2**
10	4	122	**23.8**
11	3	158	**10.5**
12	3	157	**11.0**
13	3	157	**15.8**
14	3	150	**38.0**
15	3	135	**11.8**
16	2	115	**14.9**
Average			**13.2**

Gross Floor Area Data could only be obtained from 11 of the 16 additional hotels. The average EI for the 11 hotels with floor area data is 187.6 kWh/m^2/year, which is summarised in Table 5. To determine the case study hotel EI, measured data has been extrapolated for the entire year. Since hotel occupancy has a direct effect on electricity consumption, the effects of this needs to be evaluated before drawing any conclusions based on the EI described here. This is covered in Chapter 4.2 below.

TABLE 5: ENERGY INTENSITY FOR SELECTED SA HOTELS

Hotel	Class	Rooms	EI (kWh/m²/year)
3	5	89	**331**
4	4	410	**167**
5	4	368	**139**
6	4	366	**187**
8	4	242	**156**
9	4	147	**191**
10	4	122	**126**
Case Study	**4**	**220**	**215**
13	3	157	**210**
14	3	150	**119**
15	3	135	**108**
16	2	115	**330**
Average			**190**

4.2 HOTEL OCCUPANCY

This section aims to show the effects of occupancy levels on hot water use in the hotel. This relationship will be assessed to decide whether the measurements taken on the HWC can be extrapolated over the coming year to assist in designing the most appropriate system for this particular case. Furthermore, it aims to verify whether the same effects are evident in other hotels around South Africa.

4.2.1 INFLUENCE OF OCCUPANCY ON HOT WATER CONSUMPTION

Hotel occupancy data for 2009 was analysed. The average occupancy over the 2009 was 42%, with a minimum of 7% and a maximum of 96%. When averaging the occupancy data on a monthly basis, a seasonal trend is evident (see Figure 3). This was compared with 2010 data, which is also included in Figure 3.

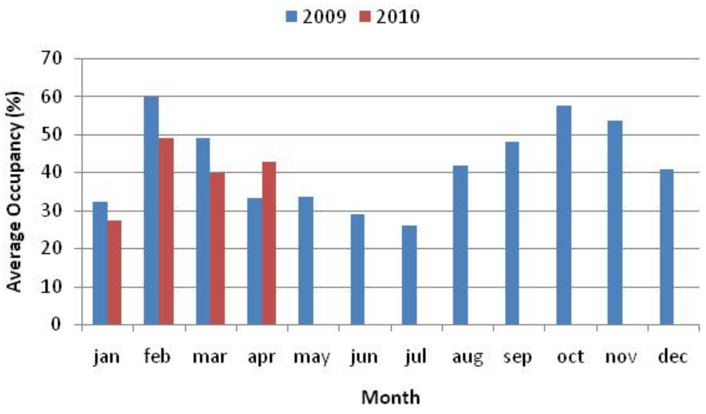

FIGURE 3: 2009 AND 2010 OCCUPANCY MONTHLY AVERAGE

Plotting daily average HWC consumption against daily occupancy rates exposed an apparent correlation (Figure 4) . The HWC consumption ranges from a minimum of 1099 kWh per day to a maximum of 1913 kWh per day, with occupancy ranging from 7% to 99%.

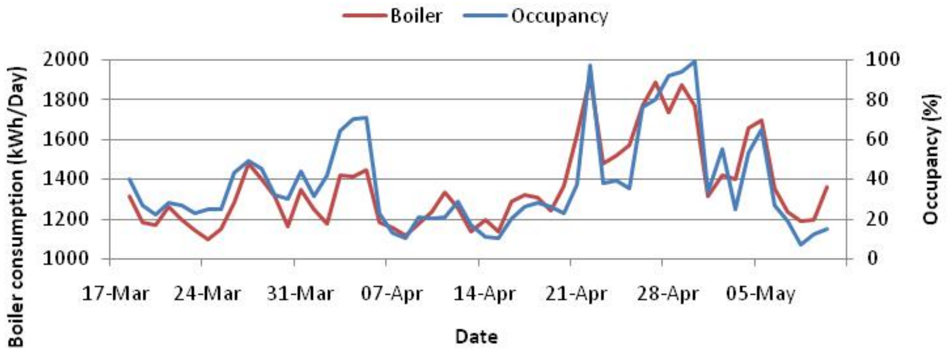

FIGURE 4: HWC CONSUMPTION VS. OCCUPANCY

Furthermore, the HWC consumption data was analysed on the days of highest, average and lowest occupancy levels. It was seen that, even on the day of lowest occupancy, the consumption rarely fell below 48 kWh (Figure 5).

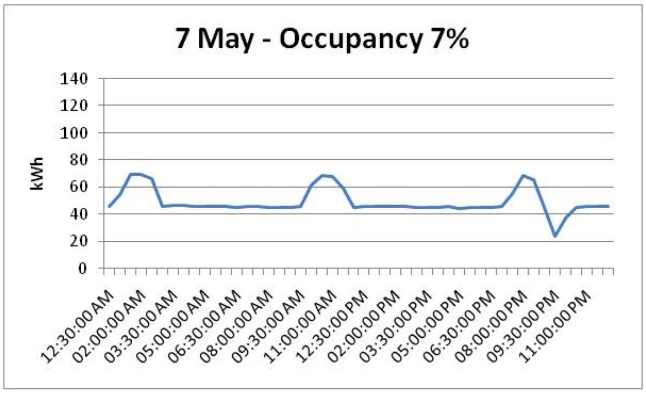

FIGURE 5: CHART OF HWC CONSUMPTION VS OCCUPANCY ON DAY OF LOWEST OCCUPANCY

The link between occupancy and hot water use was investigated further to determine whether the measured data could be extrapolated over the entire year to predict HWC consumption for the remainder of 2010. This would assist in designing the capacity for the proposed system. A trend could be seen when analysing the linearity of the HWC data for each occurrence of occupancy, which is highlighted in Figure 6. It appears that the HWC consumption increases fairly linearly with an increase of occupancy. When a trend line is fitted to the data, the resulting equation is:

$$y = 7.7442x + 1079.2$$

where **y** is the HWC usage and **x** is the occupancy level. What this equation shows is that the HWC consumption appears to be at least 1079.2 kWh/day regardless of occupancy. Furthermore, the Coefficient of Determination (R^2) was calculated to be 0.723, which indicates a relatively close match between the actual values and predicted values. A R^2 value of 1 represents an exact correlation and a R^2 of 0 represents no correlation in the data.

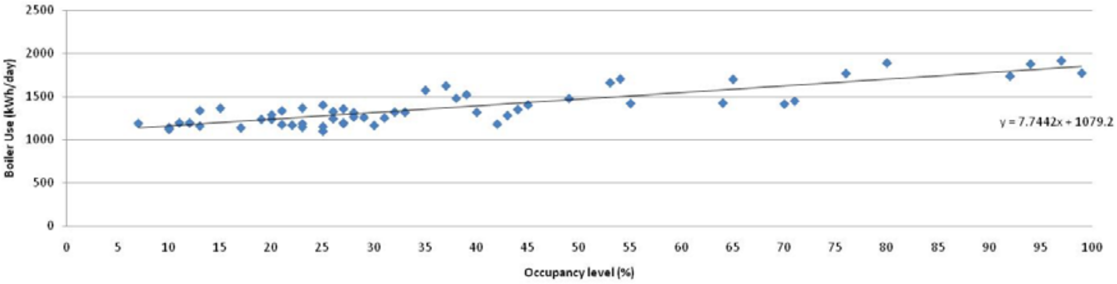

FIGURE 6: HWC USE VS. OCCUPANCY SCATTER CHART

4.2.2 VERIFICATION

Occupancy data was requested from the hotels that had supplied electricity data to compare these results with those of other hotels. This is summarised in Table 6. What this data shows is that, for all the hotels, the average occupancy – for the same period for which the consumption data had been supplied – was similar around 50%.

When this data was analysed more closely to establish whether the HWC use was linear with respect to occupancy, as was the measured data at the case study hotel, no similar trends were found. In other words, the apparent relationship between HWC consumption and occupancy, seen at the case study hotel, was not evident for any of the additional hotels. The reasons for this are not clear. Furthermore, no evidence of similar HWC base loads became evident. The HWC vs. Occupancy Scatter charts for these hotels can be viewed in Appendix G.

TABLE 6: OCCUPANCY FOR 2009 AT SELECTED HOTELS

Hotel	Class	% occupancy
1	5	**56.8**
2	5	**49.3**
3	5	**51.7**
4	4	**58.6**
5	4	**52.8**
6	4	**57.2**
7	4	**50.0**
8	4	**54.2**
9	4	**54.9**
10	4	**49.3**
11	3	**49.7**
12	3	**55.0**
13	3	**53.2**
14	3	**57.3**
15	3	**52.8**
16	2	**52.1**
Average		**53.4**

4.3 SYSTEM PERFORMANCE

This section discusses the results of the system design and components, as well as the results of the output analysis for the system. The section is divided into the System Design and the Thermal Performance Results.

4.3.1 *SYSTEM DESIGN*

It was decided to implement a *direct* circulation system in the case study hotel, for reasons discussed in the literature review. Cape Town rarely experiences temperatures below freezing and thus it is not necessary to implement a more expensive *indirect* system. Also, a direct system does not need a heat exchanger, which would add further costs and induce more thermal losses into the system. Furthermore, local solar service providers were contacted for their opinion in this regard. A service provider in Johannesburg insists that, although Cape Town rarely experiences outdoor temperatures low enough to damage the system, indirect systems should be used, since he believes that for an investment of this nature it is important to reduce risks. However, a service provider in Cape Town believes that an indirect system is not necessary for this city.

A site visit was conducted at the Da Vinci Hotel in Johannesburg where a large scale SWH has been installed. This hotel is similar in size and class to the case study hotel. Due to the climatic conditions, the designers chose an indirect system. The collector array is made up of 120 FPC's and is predicted to supplement the hot water production by 60%. Photographs of the system can be seen in Appendix H.

The proposed system for the hotel will comprise a collector array connected in series, a control system and a pump. The hotel's HWC system will be used as the storage tank. The collector array will be directly connected to the hotel's HWC through a series of insulated copper pipes, as shown in Figure 7. The controller will monitor the temperature of the water in the collector array. When the water temperature in the array is higher than the water temperature in the HWC, the pump will be activated to transfer the hot water to the HWC.

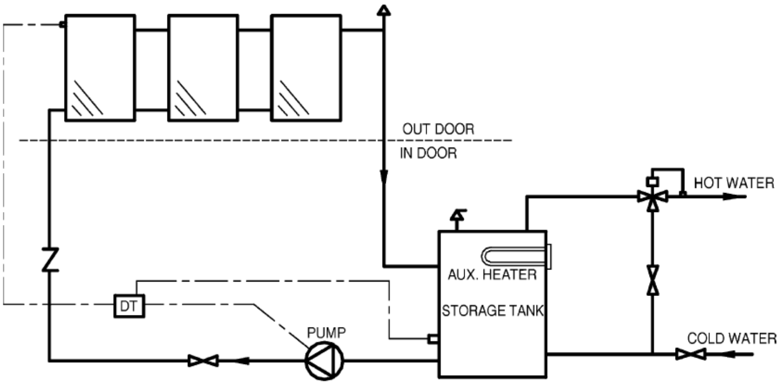

FIGURE 7: SCEMATIC OF A DIRECT CIRCULATION SYSTEM

(Source: Kalogirou 2004)

4.3.2 THERMAL PERFORMANCE

The thermal performance of a solar system is a function of the site conditions, the efficiency of the collector, the orientation of the collector and the losses in the system.

Table 7 shows the solar radiation for the site (i.e. Cape Town) at the chosen slope (27° from the horizontal), the ambient temperature and the average inlet temperature based on data extracted from RETScreen. The output for a single panel per month based on these values is also shown. This output includes 2% losses to accommodate thermal losses. The resulting output for the panel is thus 3.12 MWh/year. Inputting the same values into RETScreen for verification revealed a total annual thermal yield of 3.016 MWh/year, which is similar to the output from the model and is therefore believed to be a reliable figure.

Figure 8 is a graphical interpretation of the monthly thermal output for this system.

TABLE 7: MONTHLY INPUT AND TERMAL OUTPUT FOR THE SYSTEM

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Solar Radiation (kWh/m^2/day)	7.22	7.09	6.47	5.17	4.13	3.61	3.79	4.35	5.38	6.26	7.11	7.24
Ambient temperature (°C)	20.4	20.4	19.2	16.9	14.4	12.5	11.9	12.4	13.7	15.6	17.9	19.5
Average inlet temperature (°C)	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2
System thermal output (kWh/month)	**334**	**328**	**299**	**237**	**188**	**164**	**172**	**199**	**247**	**289**	**329**	**335**

Source: RETScreen (thermal output calculated)

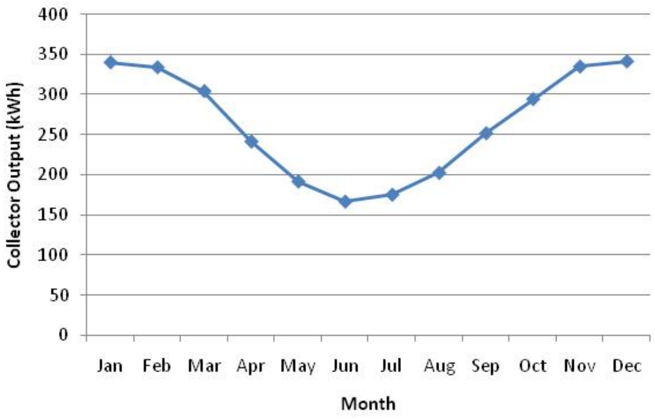

FIGURE 8: PREDICTED COLLECTOR OUTPUT

4.4 SYSTEM CAPACITY

This section shows how the optimal size for the case study system was determined and it discusses the three scenarios, which were considered to optimise this sizing.

4.4.1 SIZING THE SYSTEM

The linear relationship between HWC use and occupancy levels, discussed in Chapter 4.2.1, was taken advantage of to predict the HWC consumption for a period of one year. The linear relationship allowed for the input of historical occupancy data (2009) to get as an output the estimated HWC consumption for an entire year. This is shown in Figure 9. A slight seasonal pattern can also be seen, with the hotel being busier during the warmer summer months. This is useful for a SWH system, since the majority of the output would be in the summer months due to the higher radiation levels. The predicted HWC consumption will be used to optimise the size of the SWH system, i.e. to reduce surplus thermal output and therefore reduce system costs.

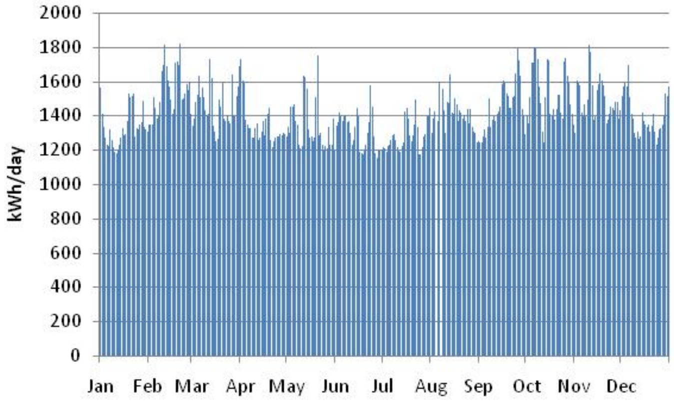

FIGURE 9: PREDICTED HWC CONSUMPTION

Three very important facts became apparent when analysing this data, which may be unique to this hotel. Firstly, there is a base load (approximately 1100 kWh/day) which is consistent throughout the year. Secondly, it has been shown that HWC consumption is very closely linked to occupancy. Occupancy can vary significantly on a daily basis, and it cannot be predicted over the long term. This is important when sizing the system because one cannot predict what the requirements will be over the lifetime of the system, and therefore one also cannot predict the shortage or surplus output of such a system. Thirdly, the seasonal pattern of the historical occupancy data seems to match the pattern of the output of the collectors, being higher in summer and lower in winter.

Considering these factors, three scenarios were considered.

4.4.1.1 Scenario 1

The first scenario was to size the system to meet the base load requirement of 1100 kWh/day all year round, i.e. to size the system to produce this amount in the period of lowest solar radiation (see Collector A in Figure 10). This would ensure that at least 1100 kWh/day of output was being used throughout the year; however, there will be surplus heating in the months with higher solar radiation. Although the HWC use is shown to increase over these months, it does not increase sufficiently to make use of the surplus, thus it is wasted. This scenario would require a total collector area of 386 m^2.

4.4.1.2 Scenario 2

The second scenario was to size the system to contribute towards the base load requirement throughout the year without any surplus heating being generated. This means that the system was sized to supply an output of 1100 kWh/day, during the period of highest solar radiation, and that the output would then decrease to around 549 kWh/day in winter (see Collector B in Figure 10). This ensures there is no surplus output, but it does not take full advantage of the seasonal pattern of HWC consumption. This scenario would require a total collector area of 200 m^2.

4.4.1.3 Scenario 3

The third scenario was considered to take advantage of the seasonal pattern in the HWC use and the collector output, thus to increase the contribution of the system while limiting the amount of surplus being generated (see Collector C in Figure 10). Various collector areas were considered to fit the collector output to the requirements, but ultimately this hot water requirement will be based on predicted occupancy rates for the hotel. If this were a situation where the quantity of the surplus could be predicted with any degree of certainty, one would be tempted to optimize the system based on a cost/benefit analysis. It has been decided, however, that this is not a sensible approach in this situation, since the levels of occupancy in hotels are very unpredictable. Even the use of historical occupancy data is not believed to be sufficient to predict future occupancy.

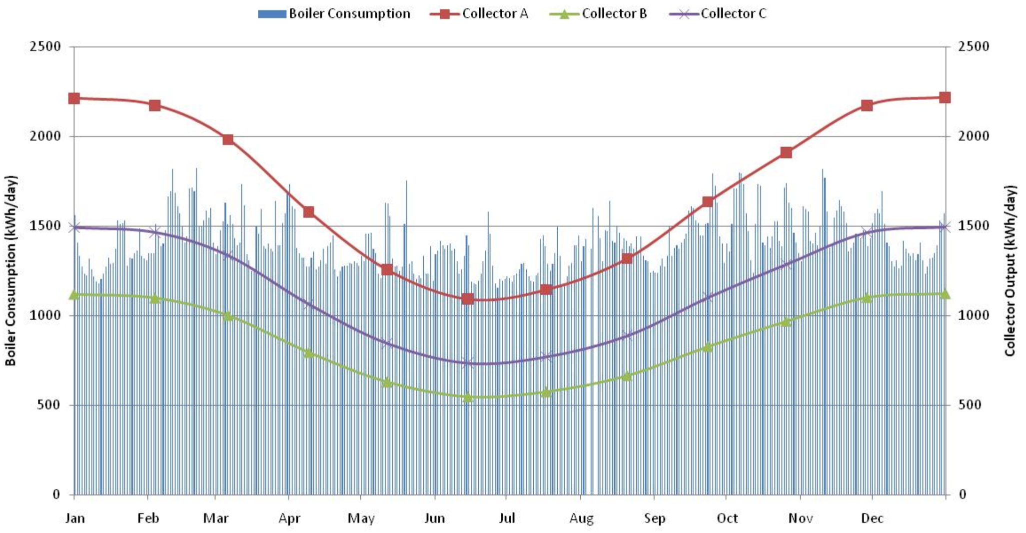

FIGURE 10: PREDICTED HWC CONSUMPTION VS. COLLECTOR ARRAY OUTPUT

4.5 SYSTEM COST

This section outlines the component costs used in the economic model. These are divided into fixed costs and marginal costs. A summary of the costs used in this study is provided below.

4.5.1 FIXED COSTS

4.5.1.1 Development, management and commissioning

It can be calculated from Table 3 that the costs of design and development, project management, transport and commissioning make up 10% of the hardware costs, which is a typical mark-up for a large industrial project. This percentage has therefore been used for this case study.

4.5.1.2 Pumps

The cost of a pump will vary due to its power rating, and this in turn will depend on the actual design of the system. Since the detailed design of flow rates and pipe friction losses is beyond the scope of this study, estimates have been used. Local suppliers of circulation pumps were consulted to make recommendations for the proposed system. One local supplier recommended a DAB circulation pump, which was quoted to cost R3 900. This figure is similar to the pump price in Table 3 and therefore the average of the two prices, R4 450, has been used in the analysis. Since the system is a direct system, only one pump is required.

4.5.1.3 Control system

A control system for a SWH is a standard component and is not likely to differ in price due to the size of the system. The controller should however be able to control more than one pump at a time, if required. Suppliers of SWH control systems were consulted and the recommended control system, manufactured by leading brand Steca, was quoted to cost R4 200. This price quoted is also similar to that in Table 3 and again the average of the two prices has been used in this analysis, namely R4 600.

4.5.2 MARGINAL COSTS

4.5.2.1 Collectors

Since a specific collector was not used in the output analysis, the cost of a typical FPC suitable for the application has been used. It was decided that a suitable FPC would be a unit with typical characteristics for a top end FPC, namely low iron toughened glass glazing, a selective coating on the absorber plate and corrosion resistant materials for the pipes, frame and backing plate. Another important characteristic is the ability to connect many of the panels in series to create a collector bank. Research into the local FPC suppliers revealed that such a unit would cost approximately R1 800 per gross square meter. This value was determined from averaging the price of 10 locally available FPCs, which meet the requirements for this application. Consequently, a price of R4 140 per collector, at 2.3 m^2 gross area, was used. This is consistent with the collector price in Table 3.

4.5.2.2 Collector mounting

Since the collector mount’s are not a standard component, they are typically designed based on the conditions at the site. Factors, which could affect this design, include the local wind conditions, the structure of the roof, the material used for waterproofing the roof, the required height, and the number of collectors per frame etc., and therefore it is not trivial to estimate a price. This was confirmed by James Shirley, general manager at Kayema Energy Solutions, during a site visit to their most recent installation at the Da Vinci hotel. The mounting for this installation posed a problem, since they needed to be a certain height off the ground due to fire escape restrictions. This added significantly to the costs of the mountings. This highlights the fact that the cost of these mountings will depend on the site conditions and thus only an estimate can be included in this cost analysis. The estimate for such mountings has been taken from the data in Table 3, namely R2 000. This estimate was based on the experiences of many large-scale solar installations and it is believed to be suitable.

4.5.2.3 Piping and insulation

The cost of providing plumbing for the SWH system is very much dependent on the site. This cost will differ considerably depending on the distance and height difference from the collector field to the storage, as well as the manner in which the collectors are connected to each other. Since a detailed design of the plumbing for the proposed system was not possible, an estimate was necessary. The estimate used in this cost analysis was also based on the data provided in Table 3. This was R3 250 per collector for field piping and R700 per collector for transfer piping. The piping in the plant room should be similar, regardless of the number of collectors, and thus a total of R40 000 was used. All these costs include insulation, valves and joints. The “records” to connect the collectors in series would add up to two thirds of the number of collectors, namely 70 at R67 each.

4.6 ECONOMIC FEASIBILITY

This section discusses the results of the economic feasibility analysis carried out in respect of the case study. The indicators used to assess feasibility are NPV, IRR and payback period. The analysis comprises the evaluation of four different scenarios. For each scenario, a cash flow analysis was carried out alongside the economic indicators. This comprised analysing the Net Cash Flow *without* a SWH system and *with* a SWH system, as well as analysing the cumulative cash flow differences between the two.

“Net Cash Flow without SWH” refers to the payments the hotel will make to produce hot water over the next ten years *without* a SWH system in place. “Net Cash Flow with SWH” refers to the payments the hotel will make to produce hot water over the next ten years *with* the proposed SWH system in place. The “Cumulative Cash Flow difference” is the cumulative sum of all the differences between the payments with and without the SWH over the same period.

Scenario 1 and Scenario 2 are evaluated to compare the economic feasibility of paying for the system completely upfront with cash, with the feasibility of using borrowed money from a bank. Scenarios 3 and 4 are similar to Scenarios 1 and 2, except that the rebates proposed in the SOIC, discussed in Section 3.2.8.3, are included.

A discount rate of 14% and an interest rate of 11% have been used. The electricity price has been increased for the first three years according to the approved tariff increases. Thereafter, the price has been increased by 8% per annum in line with inflation forecasts. The life of the project has been limited to 10 years.

4.6.1 *Scenario 1 – Equity Investment*

The capital investment of R1 124 488 for the SWH is paid for in full with cash. The NPV of project is negative R62 528 and the IRR is 16%.

The series "Net Cash Flow with SWH" in Figure 11 shows the large initial investment, but also the reduced annual payments when compared to the series "Net Cash Flow without SWH". It can also be seen that the "Cumulative Cash Flow difference" becomes positive in year 7, i.e. over a payback period of 7 years.

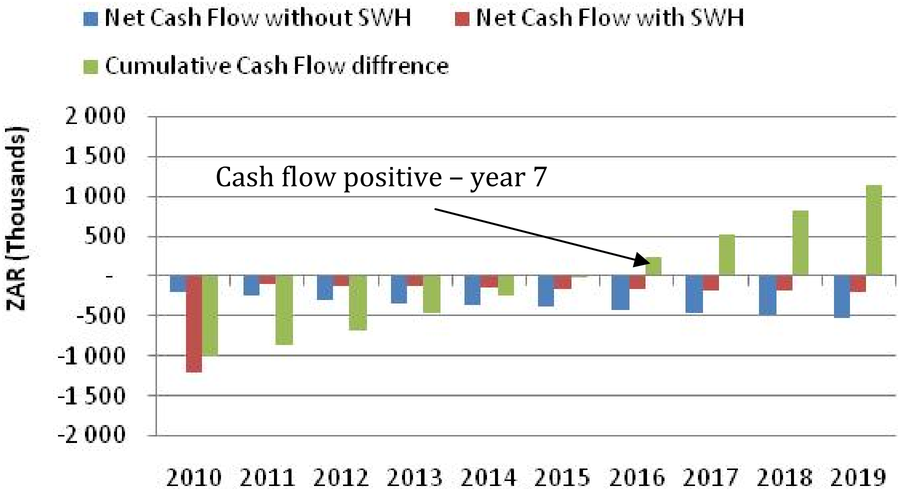

FIGURE 11: CASH FLOWS FOR PROJECT PAID FOR IN CASH

4.6.2 *Scenario 2 – Debt Investment*

In this scenario, the capital investment is financed with debt at 11% interest and paid off over a period of 5 years. A 5 year payment period for an asset of this type is typical. The NPV of the project is R17 434 and the IRR is 15%. The cash flows in Figure 12 highlight the initial investment paid off over 5 years, which results in the time until cumulative cash flow becoming positive and increasing to year 8 when compared to Scenario 1.

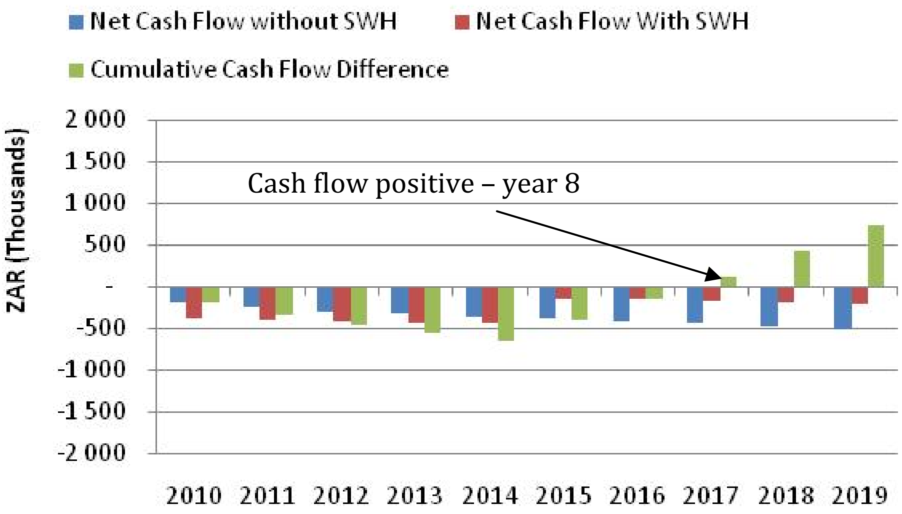

FIGURE 12: CASH FLOWS FOR PROJECT FINANCED WITH DEBT

4.6.3 SCENARIO 3 – EQUITY INVESTMENT WITH STANDARD OFFER REBATE

Scenario 3 is similar to Scenario 1, except that the proposed SOIC is included in the analysis. The NPV of the project in this case is R331 267 and the IRR is 31%.

Figure 13 highlights the Net Cash Flow with SWH and Rebate becomes positive for year 2 and year 3 due to the rebate funds being included. The rebate is only proposed for three years and the Net Cash Flow then drops to negative for the remainder of the period. The result is that the cumulative cash flow now becomes positive in year 4.

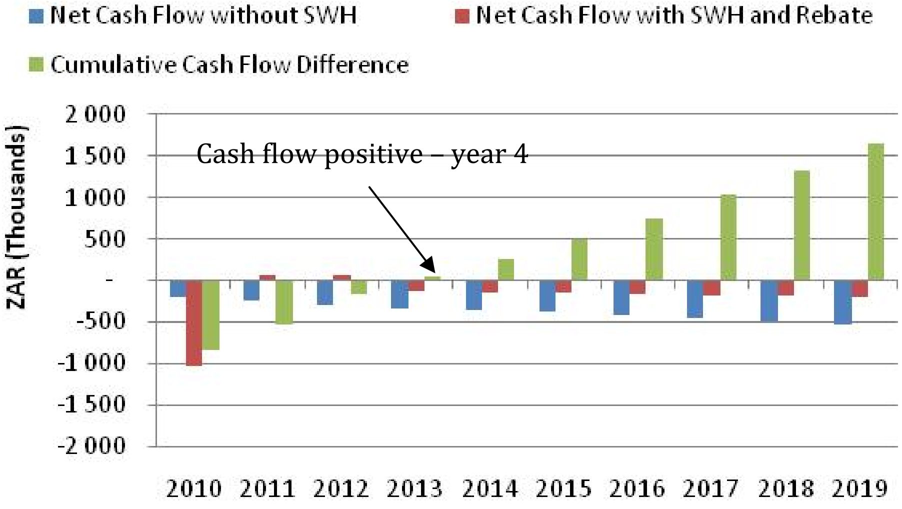

FIGURE 13: CASH FLOWS OF PROJECT PAID IN CASH INCLUDING REBATE

4.6.4 *SCENARIO 4 – DEBT INVESTMENT WITH STANDARD OFFER REBATE*

Scenario 4 is similar to Scenario 2, except that the SOIC is included. The NPV for the project is R411 230 and the IRR is 96%. Figure 14 shows clearly that the cumulative cash flow becomes positive in year 3 as a result of the rebate, but it then drops to negative in year 4 and 5 before recovering in year 6.

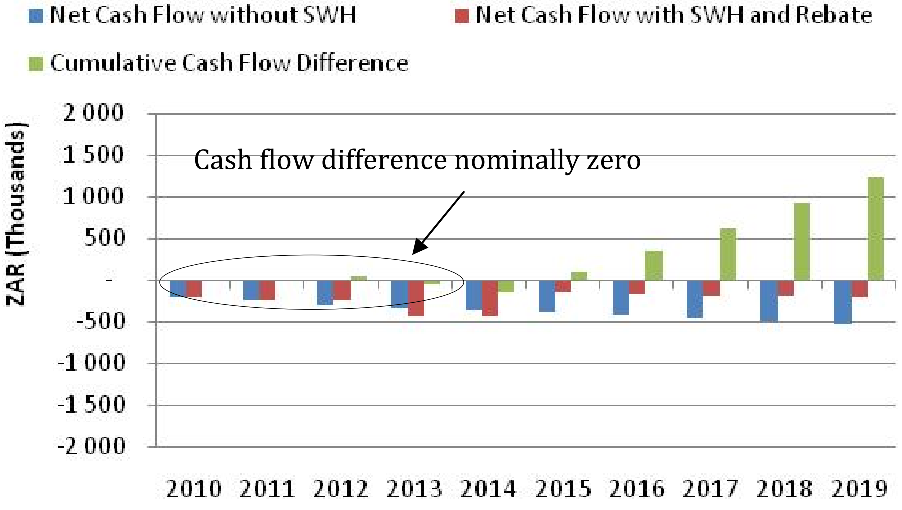

FIGURE 14: CASH FLOW OF PROJECT FINANCED WITH DEBT AND INCLUDING REBATE

5 DISCUSSION OF RESULTS

This chapter presents the discussion of the results for each of the sections covered in Chapter 4 and is concluded with a summary.

5.1 IN SITU MEASUREMENTS

The source of the base load identified on the HWC system is not clear. It could perhaps be due to the hotel's hot water circulation system. Pumps circulate hot water around the hotel to ensure that it is available in each room almost immediately after the tap is opened. There are therefore thermal losses associated with the water in the pipes which means that the return water needs to be reheated regardless of it being used or not.

The EI of the case study hotel, namely 215 kWh/m^2/year, is slightly above the average of 190 kWh/m^2/year for the South African hotels analysed. The contribution of the HWC load is also fairly average. This analysis simply highlights the fact that the measurements taken for the case study are reliable and that they are consistent with other South Africa hotels. However, all the analysed hotels fall far below the recommended EI for hotels in Cape Town stipulated in the SANS 204-1 standard. These standards assume 100% occupancy, which means that occupancy needs to be considered when making such comparisons.

5.2 HOTEL OCCUPANCY

An analysis of the case study hotel's occupancy levels has shown that a seasonal trend was apparent for 2009. The busy times correspond with local summer, although January and December had relatively low occupancy levels. Since this is the holiday season, the reasons for this are not clear. The average occupancy for the year of 2009 was 42%.

The analysis also shows that the HWC consumption is related to occupancy levels, and that the HWC consumption rarely falls below the base load, even on days of lowest occupancy. What the analysis also revealed was that the relationship between HWC consumption and occupancy is linear.

It is important to note, however, that no similar trend emerged when analysing occupancy and HWC consumption data for 16 additional hotels in South Africa. The relationship between HWC consumption and occupancy was not linear in nature and no HWC base load was evident in any of the other hotels. The reasons for this are not clear and only investigation of the individual sites would provide answers. This again highlights the vast differences in energy use between different hotels.

Another interesting outcome of this analysis was that that the occupancy rates for the year of 2009 for the other 16 hotels were all similar. This is important because the energy intensity values are now comparable since the EI was calculated without taking the occupancy levels into account. Furthermore, taking this average occupancy of approximately 50% into account, it now becomes more appropriate to make a comparison with the SANS 204-1 standard. If the expected EI of a full capacity hotel was 600 kWh/m^2/year, then one could expect it to be close to half of this value for a hotel at half capacity. In other words, the EI of the hotels could be expected to be around 300 kWh/m^2/year, which is indeed similar to what was found.

5.3 SYSTEM PERFORMANCE

The proposed collector for the case study will produce 3.12 MWh/year of thermal energy under the specified conditions. This output was compared to the output of RETScreen software package for verification of the model. The difference in annual outputs from this study's analysis and that of RETScreen is 4%. The reason for this difference may be because RETScreen uses monthly water inlet temperatures, whereas this study's model uses one average inlet temperature for the year. Monthly inlet temperature values were not available. Furthermore, there is a strong seasonal trend to the output of the panel. This is to be expected due to the fluctuating solar radiation levels.

5.4 SYSTEM CAPACITY

In view of the results outlined in Chapter 4.4.1, the most appropriate solution would be to design the system as described in Scenario 2, where the system is sized to supplement the base load all year round and to meet the base load demand in the high output periods. This option is also more suitable for a robust economic analysis, since all the electricity savings will actually be realized over the lifetime of the system and not be based on predicted savings, as would be the case in the other scenarios. This scenario would also, to a certain extent, take advantage of the seasonal pattern, in terms of which the output of the collectors drops in the colder months as does the HWC requirement, thus resulting in a more consistent contribution towards the requirements. This scenario, although only designed to meet base load need, will supply approximately 60% of the hotel's hot water needs.

Even though the system could perhaps be scaled up slightly to cover more of the demand during the year and thus perhaps produce a wasted surplus in summer, it is believed that this is not a good option. It is important that potential users of such systems have a guarantee regarding the savings on a large investment. It has been shown that the hotel industry is particularly averse to uncertainty, especially when it comes to service delivery. Furthermore, although the pattern of occupancy this year appears to be seasonal, there is no guarantee that this pattern will be repeated. This uncertainly is compounded by the fact that the time of year at which one would expect a seasonal tourist hotel to be most busy is in fact also the slowest, namely December and January. This adds to the uncertainty and it is therefore emphasized that a system sized to supply a fixed base load, with guaranteed savings is the most suitable in the circumstances. Consequently, it was decided to implement a collector area of 200 m^2 (100 FPCs) for this particular SWH system.

There are various limitations to this method. Firstly, it needs to be noted that average annual inlet water temperature has been used in place of monthly or daily values. The commercial software programs, which were not accessible for this study, would take these into account. However, the results are believed to be indicative. Additionally, the predicted HWC use for the year is based on previous years' occupancy data and on the apparent linear relationship.

5.5 SYSTEM COSTS

The final costs for the system and its components are summarised in Table 8. It should be noted that these costs are based on estimates and that they could vary. It is believed, however, that these are accurate estimates and that they will thus suffice for a feasibility analysis of this system. The system variable costs are R1 013 462, whereas the fixed costs are R111 026. The total cost for the system is R1 124 488. This total was based on i) numbers used by an experienced SWH system installation company and ii) cost estimates from hardware suppliers. It should be noted that Operating and Maintenance (O & M) costs have not been included. For a direct system in a coastal area, however, the are minimal since there is not HTF which needs replacing. For this reason O&M costs have not been included.

TABLE 8: FIXED AND VARIABLE SYSTEM COSTS

Variable Costs	Unit	Rate	Total
Collector	100	R4 140	R414 000
Mount	100	R2 000	R200 000
Field pipe	100	R3 250	R325 000
Transfer pipe	100	R700	R70 000
Raccords	66	R67	R4 462
Total			**R1 013 462**
Fixed costs	**Unit**	**Rate**	**Total**
D & D, PM and installation	-	102 226	R102 226
Pump	-	4200	R4 200
Controller	-	4600	R4 600
Total			**R111 026**
GRAND TOTAL			**R1 124 488**

5.6 ECONOMIC FEASIBILITY

If the system were to be paid for in full with cash, the NPV, IRR and payback amount to negative R62 528, 16% and 7 years respectively. If the system were to be fully financed, the NPV, IRR and payback would amount to R17 434, 15% and 8 years respectively. However, if the proposed SOIC were to be adopted, the feasibility of the system would increase significantly. In this case, if the system was paid for upfront, the NPV, IRR and payback amount to R331 267, 31% and 4 years respectively. Should the system be financed by means of a loan, the NPV would be R411 230 and the IRR would be relatively high at 96%. This last result is significant. If the system were financed and the Standard Offer rebate was in place, the system would be paid off in 5 years but with very little variation to what the hotel would pay if the system were not in place. In other words, the yearly costs *with* and *without* the system would be similar for 5 years, after which the system would be paid off and all the cost savings would be realised. Moreover, the electricity price increase of 8% post 2012 used in this analysis is regarded as very conservative.

5.7 SUMMARY

It was found that electricity use in a hotel is highly variable and that it is based on external factors including hotel class, size, location and occupancy. Although the measurements carried out for the case study revealed an EI of 215 kWh/m^2/year, the analysis of data from an additional 16 hotels revealed that EI in the hotel sector was highly variable. No obvious similarities could be found between hotels of similar classes or sizes. What this study also revealed was that the EI of the hotels analysed was in line with, if not slightly lower, than the recommendations outlined in the SANS 204-1 energy efficiency standards.

Furthermore, it was found that the contribution of hot water to the total consumption of the case study hotel was approximately 13%. The analysis of data from an additional 16 hotels revealed, however, that this contribution is also highly variable. It ranged from approximately 5% to as much as 38%. Nonetheless, the average was 13%, which is consistent with the case study hotel. What this highlights is that the contribution of hot water load is highly variable between different hotels, and that no trends and similarities could be found between hotels of similar characteristics.

Analysis of the HWC consumption data for the case study hotel highlighted the fact that there is a consistent base load throughout the year. This base load makes up a large portion of the total load. The variation of the load above the base load is linearly related to the hotel's occupancy levels. However, analysis of occupancy and HWC consumption data from a further 16 hotels did not reveal similar trends.

The thermal output of the proposed system has been designed to meet 60% of the hotel's total hot water needs over an entire year. The total amount of approximately 312 MWh/year of thermal energy is supplied by 100 FPC's. This system is estimated to cost approximately R1 125 000, the vast majority of which is made up by the collector and mounting costs.

It was found that, without any financial assistance through rebates or incentives, the system in its current form is not a very attractive investment, regardless of whether the system is paid for upfront with cash or whether it is financed with debt. However, if the proposed Standard Offer Rebate model is adopted, the feasibility of the system is significantly more attractive. The most economically attractive case is the one where the system is entirely financed and the SOIC is applied. The resulting NPV would be R411 230 and the IRR is 96%. The most important finding in the case study is that the system would be paid off in 5 years with little variation to what the hotel would pay for hot water production if the system were not in place.

6 CONCLUSIONS

Hotels are very energy intensive, more so than offices or shops and are therefore important targets for reducing demand on our strained electricity supply infrastructure and to reduce greenhouse gas emissions related to the burning of fossil fuels.

A SWH system has been shown to be capable of reducing a hotel's electricity demand in regard to producing hot water by approximately 60%. This equates to approximately 312 MWh per year of reduced demand, or 8% of the hotel's total demand. However, this design was based on a very specific analysis of the hotel's actual hot water load and local conditions. It was shown that not all hotels have similar hot water loads, or similar relationships with occupancy levels. The results can therefore not be extrapolated over the entire South African hotel industry and it is recommended that, for feasibility studies of SWH system, the system design be based on an analysis of measured data.

It was found that the SWH system designed for the particular case study hotel was, on its own, not economically attractive. The feasibility of the system increases substantially with the introduction of the SOIC which is scheduled for implementation in September 2010. If this program were adopted, the hotel could install the SWH at little extra cost for the first 5 years, after which the system would be paid off.

Investigation of HWC use and occupancy data from a further 16 hotels did not reveal similar correlations to the findings in regard to the case study hotel. The reasons for this are not clear, since the analysis was carried out in a similar manner. The data for the case study was carefully measured in a controlled environment and the specific linear correlation seen between occupancy and HWC use was intuitively expected. This leads one to believe that this analysis is in fact accurate and that the reliability of the data from the other hotels needs to be questioned.

Nevertheless, the aim of this dissertation was to determine whether a SWH would be a good investment for a hotel and to show that a significant amount of electricity use could be displaced. The conclusion is that it is currently not a very attractive investment and that some form of subsidy would be required to improve this, even with the high tariff increases over the next three years. It was also found that a SWH system can reduce electricity consumption for heating water by 60%. However, the results cannot be viewed as representative for all South African hotels, since it has been shown that electricity use in a hotel environment is very dynamic and that detailed measurement and analysis of usage patterns should thus be undertaken for each specific SWH feasibility study. The results of one hotel’s SWH feasibility study do not necessarily apply to any other hotels, even if they are very similar, and this too is an important finding.

7 FURTHER RESEARCH

This dissertation revealed several areas in which further research is necessary to understand more clearly the feasibility of a SWH system in a hotel. These are listed briefly below:

I. It has been shown that hot water consumption in hotels varies considerably and no obvious relationship exists with occupancy. A comprehensive study regarding what affects hot water consumption in a hotel is recommended.
II. The feasibility of a SWH system in South Africa will depend very strongly on the available subsidies and incentives. It is therefore recommended that an extensive study be carried out to investigate what options, besides the Standard Offer, currently exist. These might include CDM, carbon taxes, loans from the Development Bank of South Africa etc.
III. The extent of the base load on the HWC system discovered in this case study was unexpected. Furthermore none of the other hotels investigated for verification experienced similar base loads. The existence of the base load in the case study hotel affected the system design and it is therefore recommended that HWC/hot water use in hotels is studied more closely. This would assist in understanding what is the most suitably sized system required for a hotel environment.
IV. This study did not consider alternative technologies currently being employed in hot water production in the hotel industry, such as heat pumps. A comparative study looking at all the available technologies and options for reducing electricity consumption related to hot water production would be valuable.
V. It was found that the mounting costs for the solar collectors made up a very large part of the total system costs, which was unexpected. This highlights that there might be potential to design a low cost mounting system, or to investigate why mounting costs are typically so high.
VI. No consistency in regard to energy use in similar class or size hotels was found, which was unexpected. An investigation of the factors which affect EI in hotels would be valuable to be able to extrapolate case studies over the entire hotel industry.
VII. A comprehensive survey into the local hotel industry to evaluate the core barriers to SWH would be valuable

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9 APPENDIX A – HOTEL ELECTRICITY USE DATA

Details and processed data for the additional 16 hotels

Details				Occupancy		Total electricity use				HWC Electricity Use						Total per occupied room		
Hotel	Class	Rooms	Location	Ave occupancy per day	Std dev	ave Hourly kWh	Std dev	kWh/day	per room per day	Per hour	Std Dev	kWh/day	per room per day	HWC % of Total	Std Dev	Per hour	Std Dev	kWh/day
1	5	546	CT	56.8	9.2	615.6	47.7	14774.4	**27.06**	45.3	16.2	1087.2	1.99	**7.4**	2.5	2.6	0.3	62.4
2	5	334	JHB	49.3	8.5	901.8	94.3	21643.2	**64.80**	89.7	32.4	2152.8	6.45	**9.5**	3.3	5.7	1	136.8
3	5	89	DBN	51.7	10	350.2	36	8404.8	**94.44**	36.3	14	871.2	9.79	**9.6**	4.2	7.6	1.6	182.4
4	4	410	CT	58.6	7.3	604.8	47.5	14515.2	**35.40**	31.2	11.7	748.8	1.83	**5.1**	1.5	2.6	0.3	62.4
5	4	368	CT	52.8	8.6	714	63.9	17136	**46.57**	31.7	15.9	760.8	2.07	**4.5**	1.6	3.78	0.8	90.72
6	4	366	JHB	57.2	7.1	453	157.4	10872	**29.70**	38.6	16.2	926.4	2.53	**7.7**	2.7	2.2	0.4	52.8
7	4	346	JHB	50	7.1	476	52.5	11424	**33.02**	54.9	19.8	1317.6	3.81	**11.5**	3.6	2.7	0.5	64.8
8	4	242	PTA	54.2	15.2	380	46.9	9120	**37.69**	67.2	40	1612.8	6.66	**17.5**	9.8	3	0.8	72
9	4	147	Bloem	54.9	8	230.1	35	5522.4	**37.57**	30.7	11.8	736.8	5.01	**13.2**	4.4	2.9	0.5	69.6
10	4	122	JHB	49.3	6.5	111.6	23.3	2678.4	**21.95**	26.3	9.4	631.2	5.17	**23.8**	8.9	1.8	0.3	43.2
11	3	158	JHB	49.7	6.3	207.6	19.7	4982.4	**31.53**	21.4	8.2	513.6	3.25	**10.5**	3.2	2.6	0.3	62.4
12	3	157	PTA	55	11.5	182.6	24.7	4382.4	**27.91**	20.2	7.4	484.8	3.09	**11.0**	3.9	2.1	0.5	50.4
13	3	157	JHB	53.2	9	172	16.6	4128	**26.29**	27.1	10	650.4	4.14	**15.8**	5.4	2.1	0.4	50.4
14	3	150	JHB	57.3	5.4	104	20.4	2496	**16.64**	39.5	15.2	948	6.32	**38.0**	11.9	1.2	0.2	28.8
15	3	135	KIM	52.8	8.3	167	22.9	4008	**29.69**	19.3	8.2	463.2	3.43	**11.8**	5.1	2.5	0.5	60
16	2	115	NEL	52.13	6.6	144.65	16.23	3471.6	**30.19**	25.4	8.8	609.6	5.30	**14.9**	4.5	2.6	0.3	62.4

10 APPENDIX B – CAPE TOWN HOTEL LIST

Table comprising details of the hotels contacted in Cape Town to determine what the most typical way to heat water is in South Africa.

Hotel	Star	Rooms	Address	Contact	Central HWC	Site Visit
51 on Kloofnek		<50	City Centre	+27 (21) 424 2347		
Adderley Hotel		<50	City Centre	+ 27 21 423 1426		
Ambassador Hotel	5	97	Bantry Bay	021 439 6170		yes
Atlanticview Boutique Hotel			Camps Bay and Clifton	+27 (0)21 438 2254	no	
Bantry Bay Luxury Suites	4	41	Camps Bay and Clifton	+ 27 (0)21 434 8448	yes	
Bay hotel	5	87	Camps Bay and Clifton	021 438 4444	yes	yes
Best Western Cape Suites Hotel	4	123	V&A Waterfront	021 461 0727	no	
Blue Peter Hotel		<50	Blouburg	021 554 1956	yes	
Boutique Manolo		<50	City Centre	+27 21 426 2330		
Breakwater Lodge			V&A Waterfront	021 406 1911	no	yes
Bridge House		<50	City Centre	+27 21 424 0905		
Camps Bay Resort			Camps Bay and Clifton	+27 21 438 5560	no	
Cape Grace hotel	5	121	V&A Waterfront	021 410 7100	yes	
Cape Heritage Hotel		<50	City Centre	+27 21 424 4646		
Cape Town Hollow		<50	City Centre	+27 21 423 1260		
Cape town Lodge Hotel	4	119	City Centre	021 422 0030	yes	
Cellars-Hohenhort		<50	Southern Suburbs	+27 21 794 2137		
City Lodge - Grand West		<50	Cape Town	+27(021) 535 3611		
City Lodge - Pinelands		<50	Cape Town	+27 21 685-7944		
City Lodge - V&A Waterfront		<50	V&A Waterfront	+27 21 419 9450		
Courtyard Hotel - Cape Town		<50	Cape Town	+27 21 448-3929		
Crystal Towers Hotel & Spa		<50	Cape Town	0861 50 50 50		
Cullinun hotel	4	410	City Centre	021 4154000	yes	
Derwent House Boutique Hotel		<50	City Centre	+27 21 422 2763		
Dock House	5	<50	V&A Waterfront	+27 21 419 6677		
Dolphin Beach Protea			Tableview	021 557 8140	no	yes
Ellerman House		<50	Camps Bay and Clifton	+27 21 430 3200		
Ezard House		<50	Camps Bay and Clifton	+27 21 438 6687		
Floréal House		<50	City Centre	+27 21 465 6259		
Garden Court De Waal	3	136	City Centre	021 465 1311	yes	
Greenways Hotel		<50	Southern Suburbs	+27 21 761 1792		
Hippotique		<50	City Centre	021 423 2500		
Icon - Cape Town CBD		<50	Cape Town	+27 21 981-9366		
Ikhaya Lodge		<50	City Centre	+27 21 461 8880		
Lady Hamilton Hotel		78	City Centre	+27 21 423 3888	yes	
Le Vendome	5	142	Camps Bay and Clifton	+27-21-430 1200	yes	
Leisure Bay Luxury Suites		<50	City Centre	+ 27 (0)21 551 7440		
More Cape Cadogan		<50	City Centre	+27 21 480 8080		
New Kings Hotel		<50	Camps Bay and Clifton	27214205580		

Park Inn Greenmarket Square		165	City Centre	+27 21 423 2050	yes	
The Peninsula			Sea Point	021 430 7777	no	yes
Place on the Bay		<50	Camps Bay and Clifton	+27 21 437 8500		
President Protea Hotel		353	Camps Bay and Clifton	+27 21 434 8111		
Protea Hotel Cape Castle		<50	Cape Town	+27 21 4391016		
Protea Hotel Fire & Ice!		<50	Southern Suburbs	+27 21 488 2555		
Protea North Wharf		<50	Cape Town	+27 21 443 4600		
Quayside Hotel		<50	Southern Suburbs	+27 21 786 3838		
Raddison	5	177	V&A Waterfront	021 441 3000	no	
Ritz	3	222	Sea Point	021 439 6010	yes	yes
Rockwell All Suite Hotel		<50	Cape Town	+27(0) 21 421 0015		
Sea Point Protea Hotel		124	Camps Bay and Clifton	+27 21 434 3344		
Southern Right Hotel		<50	Cape Town	+27 21 782 0314		
Southern Sun Waterfront	5	546	V&A Waterfront	+27 21 4094000	yes	
Straightway Head Country Hotel		<50	Southern Suburbs	+27 (0) 21 851 7088		
Sugar Hotel		<50	Cape Town	+27 21 430 3780		
The Capetonian Hotel	4	170	City Centre	+27 21 405 5670		
The Commodore	5	236	V&A Waterfront	+27 21 415 1000	yes	yes
The Glen Boutique Hotel		<50	Cape Town	+27 21 439 0086		
The Portswood	4	103	V&A Waterfront	+27 21 418 3281	yes	yes
The Twelve Apostles Hotel	5	60	Camps Bay and Clifton	+27 21 437 9000	yes	
The Village Lodge		<50	Cape Town	+ 27 (0) 21 421 1106		
The Walden House		<50	City Centre	+27 21424 4256		
Townhouse Hotel	4	106	Cape Town	+27 21 465 7050		
Tudor Hotel		<50	City Centre	+27 21 424 1335		
Twenty Seven on First		<50	Camps Bay and Clifton	+27 21 438 0163		
Urban Chic		<50	Cape Town	+27 21 426 6119		
Van Riebeek Hotel		<50	Cape Town	021-856 1441		
Villa Amari		<50	Cape Town	+27 21 461 0310		
Villa Via Luxury Hotel		<50	Cape Town	+ 27 21 856 8200		
Villa Zest Boutique Hotel		<50	Cape Town	+27 21 433 1246		
Western Grand	5	483	City Centre	021 412 9999	yes	yes

11 APPENDIX C – RETSCREEN INFORMATION

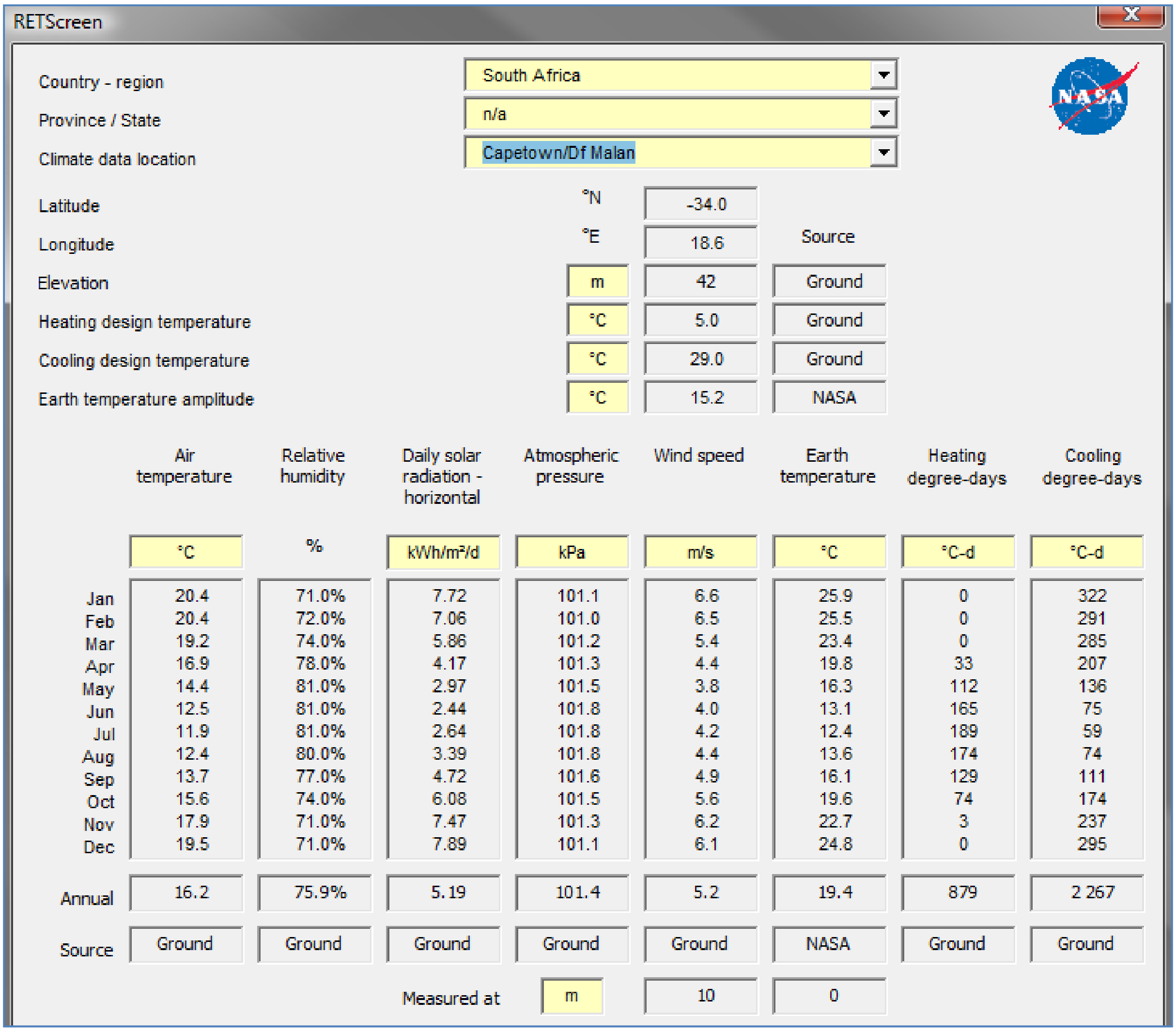
RETScreen details:

The RETScreen Clean Energy Project Analysis Software (usually shortened to RETScreen) is a Microsoft Excel-based free software package used to determine the feasibility of clean energy projects, which includes renewable energy installations and the means to assess a wide range of energy efficiency options. The software provides the user with a broad range of options for assessing the technical, financial and environmental suitability for an investment in a 'clean energy' project, which includes energy efficiency, renewable energy, and cogeneration (combined heat and power). It integrates a number of databases to assist the site assessor, including a global database of climatic conditions obtained from 4,700 ground-based stations and NASA's satellite data.

RETScreen is managed under the leadership and ongoing financial support of the CanmetENERGY research centre of Natural Resources Canada, a department of the Government of Canada. It is developed in collaboration with a number of other government and multilateral organisations, and with technical support from a large network of experts from industry, government and academia.

12 APPENDIX D – RETSCREEN CLIMATE DATA SCREENSHOT

Screen shot of RETScreen climate data



Country - region: South Africa

Province / State: n/a

Climate data location: Capetown/Df Malan

Latitude	°N	-34.0	
Longitude	°E	18.6	Source
Elevation	m	42	Ground
Heating design temperature	°C	5.0	Ground
Cooling design temperature	°C	29.0	Ground
Earth temperature amplitude	°C	15.2	NASA

	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
Jan	20.4	71.0%	7.72	101.1	6.6	25.9	0	322
Feb	20.4	72.0%	7.06	101.0	6.5	25.5	0	291
Mar	19.2	74.0%	5.86	101.2	5.4	23.4	0	285
Apr	16.9	78.0%	4.17	101.3	4.4	19.8	33	207
May	14.4	81.0%	2.97	101.5	3.8	16.3	112	136
Jun	12.5	81.0%	2.44	101.8	4.0	13.1	165	75
Jul	11.9	81.0%	2.64	101.8	4.2	12.4	189	59
Aug	12.4	80.0%	3.39	101.8	4.4	13.6	174	74
Sep	13.7	77.0%	4.72	101.6	4.9	16.1	129	111
Oct	15.6	74.0%	6.08	101.5	5.6	19.6	74	174
Nov	17.9	71.0%	7.47	101.3	6.2	22.7	3	237
Dec	19.5	71.0%	7.89	101.1	6.1	24.8	0	295
Annual	16.2	75.9%	5.19	101.4	5.2	19.4	879	2 267
Source	Ground	Ground	Ground	Ground	Ground	NASA	Ground	Ground
			Measured at	m	10	0		

13 APPENDIX E – TYPICAL FLAT PLATE COLLECTOR DETAILS

Typical characteristics of a FPC, extracted from Kalogirou's paper on solar thermal collector and applications (Kalogirou 2004).

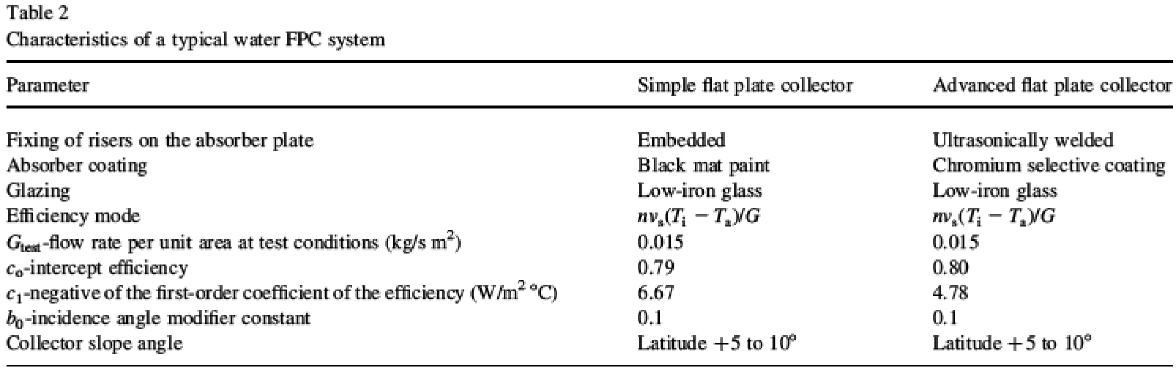
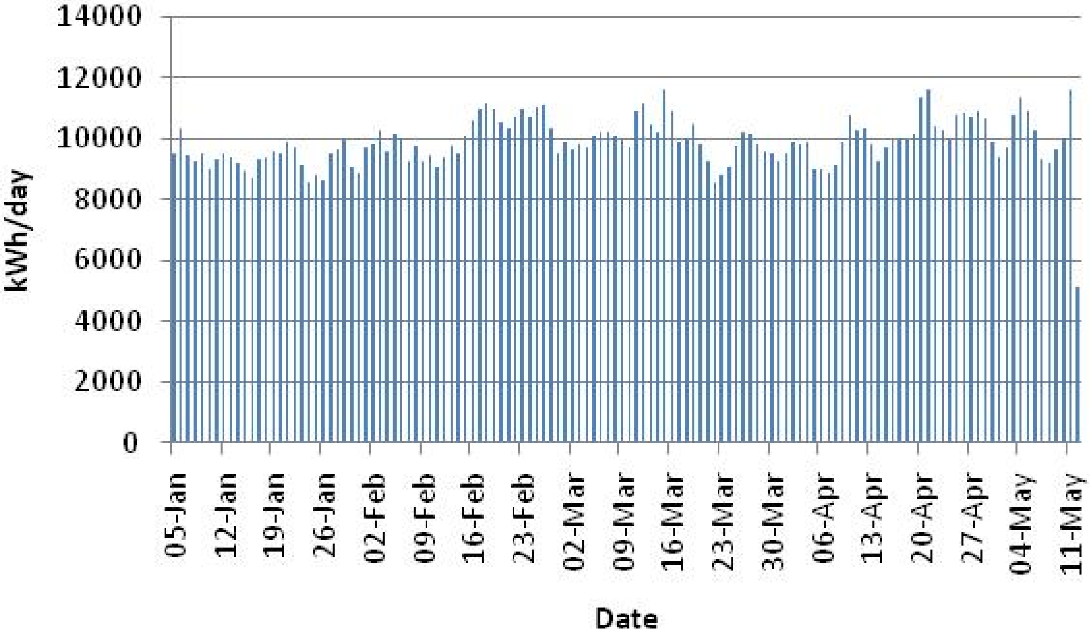


Table 2
Characteristics of a typical water FPC system

Parameter	Simple flat plate collector	Advanced flat plate collector
Fixing of risers on the absorber plate	Embedded	Ultrasonically welded
Absorber coating	Black mat paint	Chromium selective coating
Glazing	Low-iron glass	Low-iron glass
Efficiency mode	$nv_s(T_i - T_a)/G$	$nv_s(T_i - T_a)/G$
G_{test}-flow rate per unit area at test conditions (kg/s m^2)	0.015	0.015
c_o-intercept efficiency	0.79	0.80
c_1-negative of the first-order coefficient of the efficiency (W/m^2 °C)	6.67	4.78
b_0-incidence angle modifier constant	0.1	0.1
Collector slope angle	Latitude +5 to 10°	Latitude +5 to 10°

14 APPENDIX F – CASE STUDY HOTEL CONSUMPTION DATA

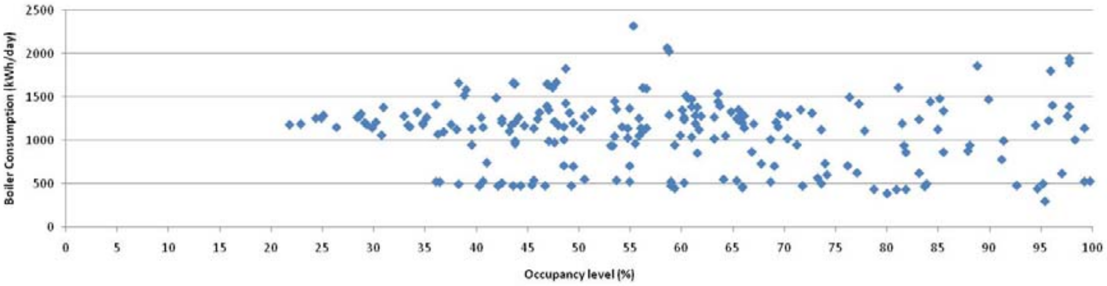
Processed power consumption data extracted from the power meter installed at the main distribution board of the case study hotel.



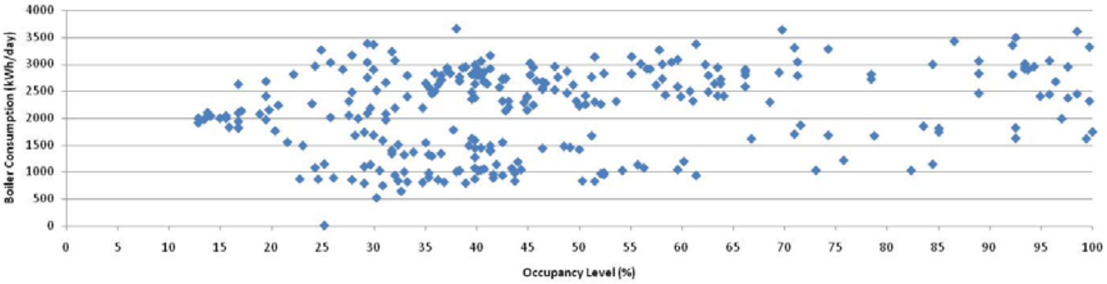
15 APPENDIX G – HWC VS. OCCUPANCY GRAPHS

HWC consumption vs. Occupancy level scatter graphs for the 16 additional hotels analysed.

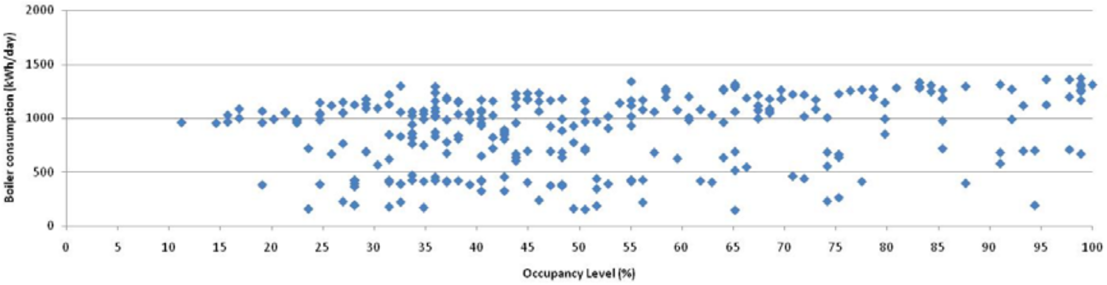
Hotel 1



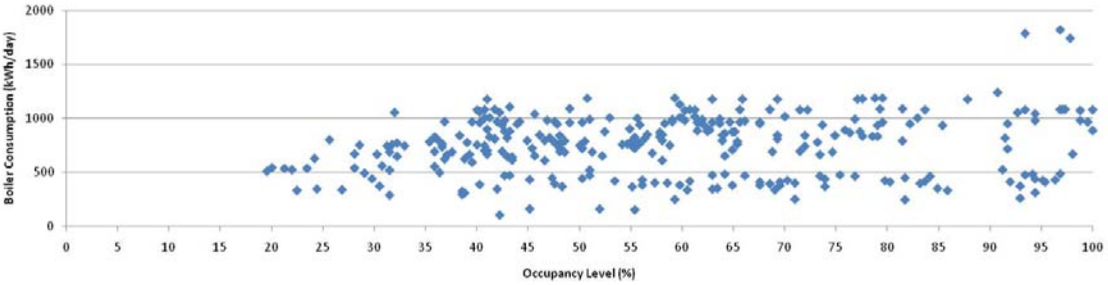
Hotel 2



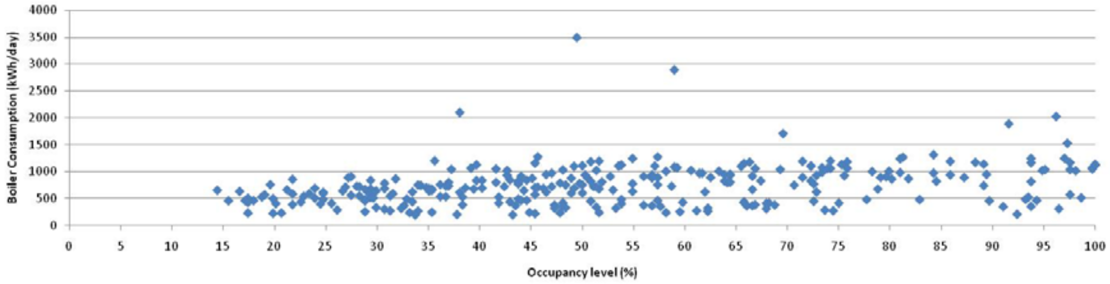
Hotel 3



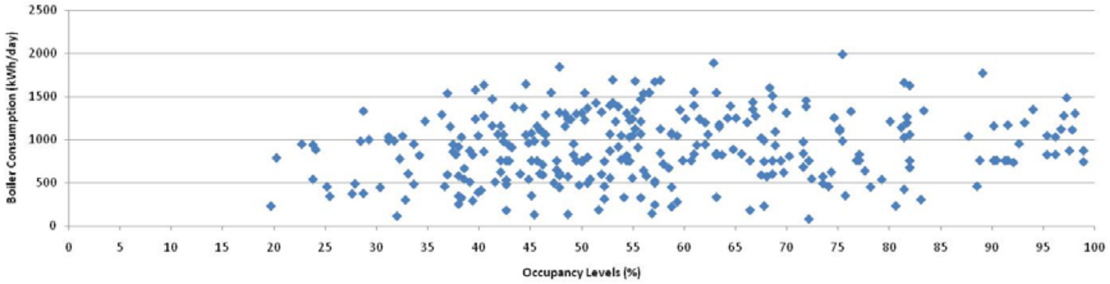
Hotel 4



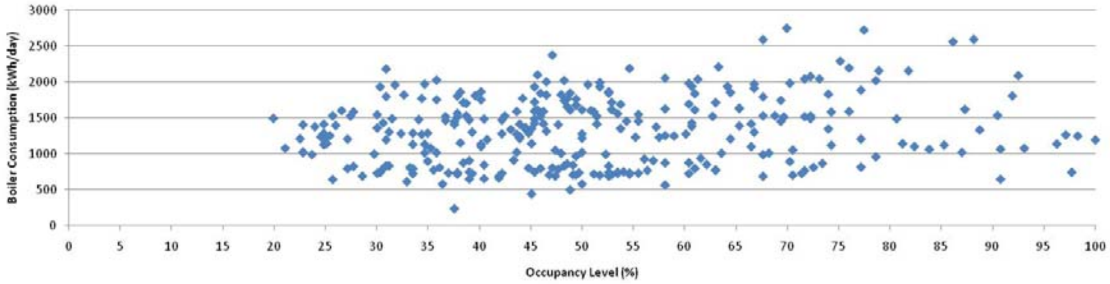
Hotel 5



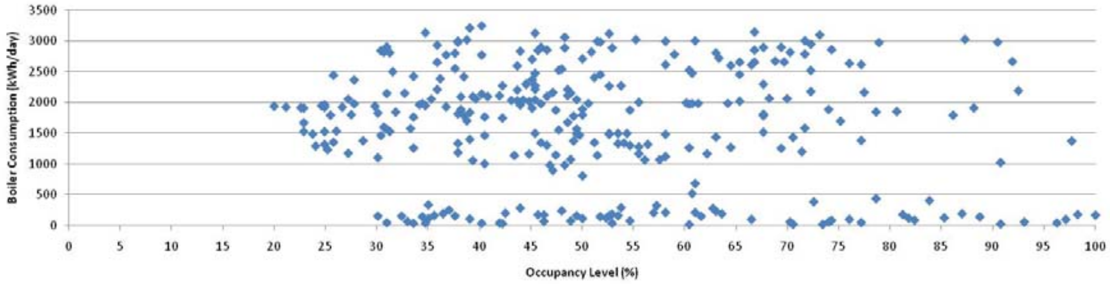
Hotel 6



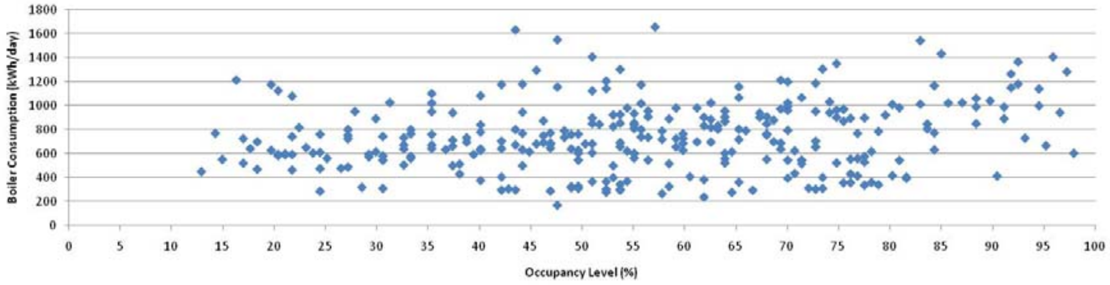
Hotel 7



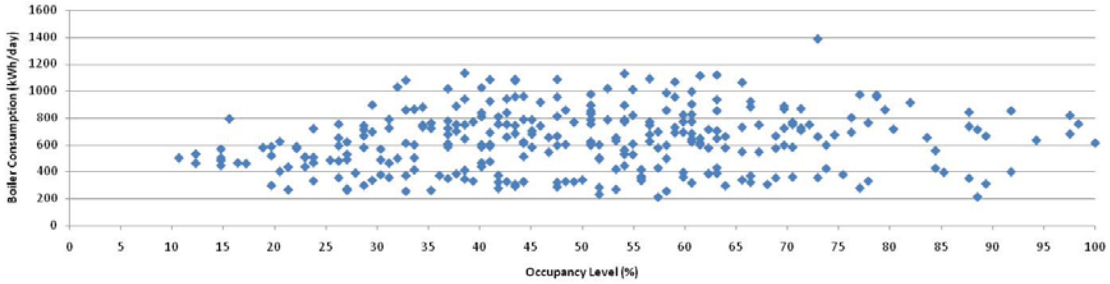
Hotel 8



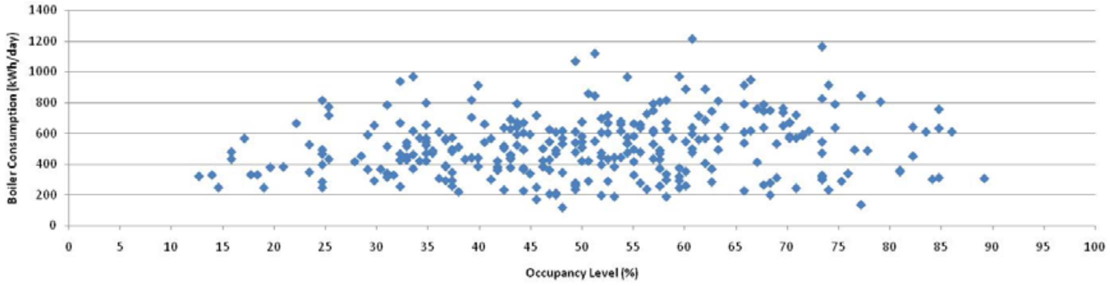
Hotel 9



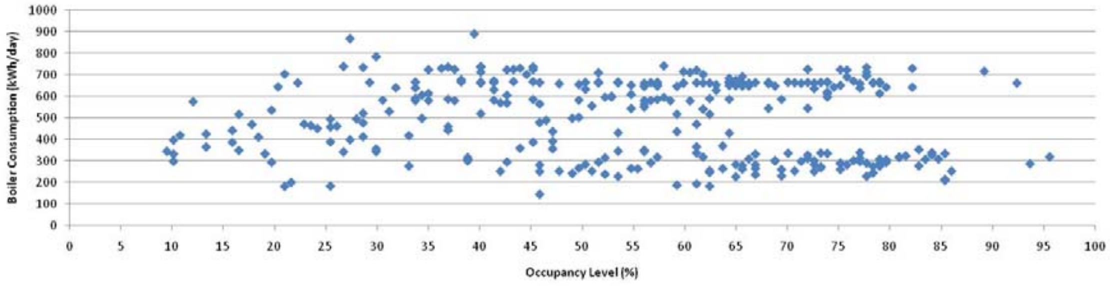
Hotel 10



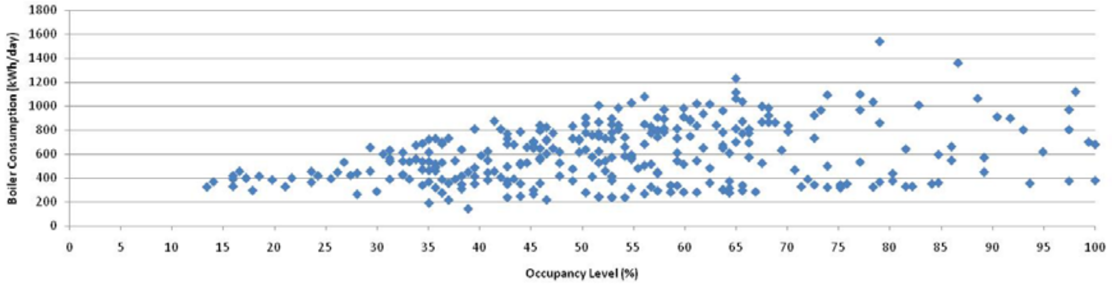
Hotel 11



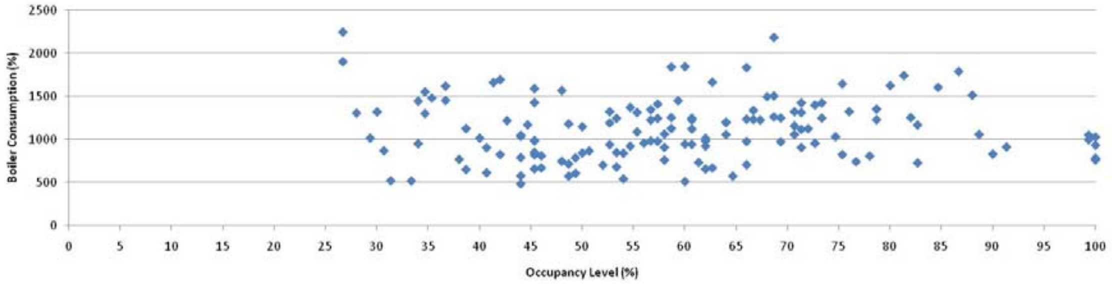
Hotel 12



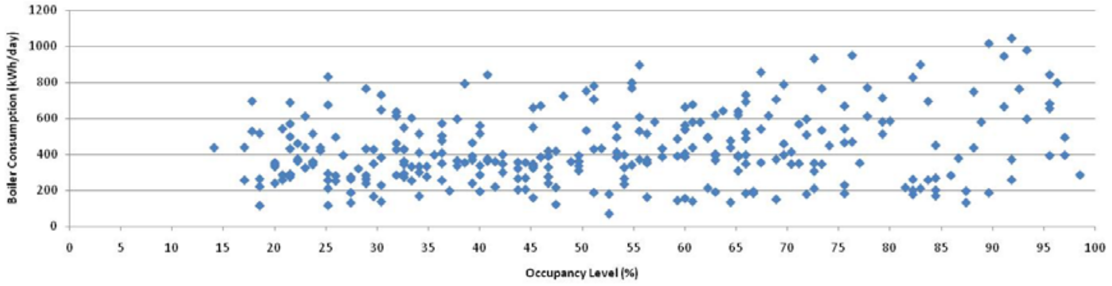
Hotel 13



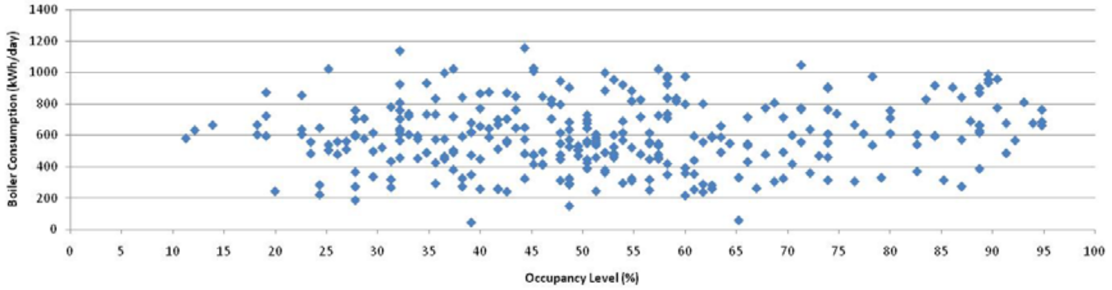
Hotel 14



Hotel 15



Hotel 16



16 APPENDIX H – SITE VISIT PHOTOGRAPHS

A site visit was carried out at the Da Vinci Hotel in Johannesburg, which has recently been fitted with a SWH system similar to what is being proposed for the case study in this dissertation. Selected photographs of the system can be viewed below.