A techno-economic study of energy efficiency and renewable energy technologies for supermarkets in South Africa.

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A dissertation submitted to the Faculty of Engineering and the Built Environment, University of Cape Town, in partial fulfillment of the requirements for the degree of Master of Science in Engineering.

Date: August 2011

Declaration

I declare that this thesis, submitted for the degree of Master of Science in Engineering at the University of Cape Town, is my own work and has not been submitted prior to this for any degree at this university or any other institution. I know the meaning of plagiarism and declare that all the work in the document, save for that which is properly acknowledged, is my own.

Acknowledgements

I would like to thank the following people for all their support, encouragement and advice

- both my supervisors, Brett and Stephen for guidance, mentorship and patience in seeing me through this difficult process,
- my colleagues at the ERC, especially David Kitley, who saved me far too many times,
- my friends at Chemical Engineering,
- Prof Burton and Dr Petersen for career support,
- Amanda Bourne for actually enjoying proof reading this thesis.

I would like to thank the following organizations and consultants for all the time given and information supplied:

- Pick n Pay – Andre Nel, Trevor Mc Lachlan, John Bradshaw and the Steenberg PnP store
- Woolworths – Justin Smith
- Energy Partners – Karel Cornellisen and Derik Coetzer
- Robert Zipplies
- Phoenix Racks – Kevin Schlemmer and Dawie Kriel
- Global Carbon Exchange – Kennith Ross
- Carbon Calculated – Nici Palmer
- Metraclark – Jaco Steyl and Philip Theunissen
- Turbovent – Jolandi Dreyer
- Solar tech
- M Tech Industrial
- Sustainable IT
- Setsolar
- Kool Curtains
- The Fridge Factory Warehouse

Most importantly, my family, especially my husband for all the support during the long days, working weekends and sleepless nights, the long discussions on economic theories, and all the other highs and lows, but mostly for allowing me to pursue my dreams. I owe it all to you.

Finally, I would like to thank the United Nations Institute for Training and Research (UNITAR) for financial support in 2009.

I dedicate this thesis to the vermiculture worms whom I forgot to feed.

"You never change things by fighting the existing reality".
Buckminster Fuller, philospher, futurist and global thinker (1895 - 1983)

Abstract

Carbon mitigation in organizations in South Africa is beginning to emerge as an essential business activity for a multitude of reasons including cost savings through reduced energy consumption, investor and customer demands and incentives from government. These strategies are being embedded into all business decisions and mainstreamed into all levels in organizations.

The local food retail sector, although not one of the most energy nor carbon intensive sectors in South Africa, is also participating in voluntary carbon reductions, and some organizations have made bold targets to achieve these reductions. Electricity reduction has also become an area of concern due to the current electricity price hikes, and the threat of further price increases due to the proposed carbon taxes, as well as that of load shedding. Therefore some food retailers are investigating methods of decreasing electricity consumption through energy efficiency technologies and diversifying their electricity source by using renewable energy technologies. This study focuses on reducing carbon emissions that result from electricity usage and concentrates on electricity at the store (supermarkets) level only. There are many opportunities for electricity reduction in supermarkets particularly through energy efficient refrigeration, ventilation, heating and lighting.

The aim of this study was to do a techno-economic analysis for the use of both energy efficient and renewable energy technologies in supermarkets to determine the best options to implement to reduce grid electricity consumption, and its resulting carbon emissions in a cost-effective way.

To achieve this, several large food retail companies were surveyed to determine their views and requirements for electricity and carbon reduction in stores. Due to varying responses to the survey questions, three types of retail categories were formulated such that different technologies could be recommended to meet the needs for different retailers. The first category retailer had the highest targets for electricity and carbon emissions reductions and was willing to experiment with technologies to achieve this. The second category retailer had lower reduction targets and would only use developed technologies. The third category retailer had no target for carbon reduction but would invest in developed energy efficient technologies to reduce electricity consumption if it showed significant long term savings and short payback periods.

The requirements highlighted by the retailers surveyed were also used as criteria for the selection of energy efficient technologies. These included:

a) economic profitability
b) CO_2 reduction,
c) CAPEX,
d) ease of implementation, and
e) awareness and visibility.

Economic profitability was the most important criterion to all retailers surveyed, and the remaining criteria were used as secondary criteria to further aid in the decision making process. A wide variety of technologies were shortlisted. This shortlist was based on technology use in international and local supermarkets, application suitability, its potential for electricity reduction, costs, visibility, availability, and its stage of development. The shortlist included:

a) Electronic ballasts,
b) Compact fluorescent lights (CFLs),
c) Power management systems,
d) Automated fridge curtains,
e) Upright fridges with doors (closed refrigerators),
f) Heat reclamation from refrigeration,
g) Electronic controls for refrigeration,
h) Heat pump geysers,
i) Evaporative coolers,
j) CO_2 fridges.

Closed refrigerators showed the highest electricity/carbon savings and the highest profit (NPV), followed by heat reclamation. Both these technologies were recommended for category 1 retailers who have the largest targets for both electricity and carbon reduction and are willing to trial technologies. A combination of heat reclamation, EE lights, fridge curtains, electronic controls for refrigerators, and power management systems for point of sales (POS) systems were recommended for category 3 retailers. Category 2 retailers have intermediate targets and can adopt a combination of the two recommendations to meet targets.

The feasibility of three renewable energy technologies/mechanisms (onsite hybrid wind/solar generation, solar water heaters, and tradeable renewable energy certificates) were chosen to determine if the rising electricity costs together with the proposed carbon taxes would make these technologies cost competitive with grid electricity. A small amount of renewable energy was modeled to meet the load of energy efficient lights and POS system (17 kWh/day) using a grid connected hybrid wind/solar PV system. The HOMER software package was used to determine the optimum combination of wind and solar energy for an average store size of 1500m^2 located in Cape Town using resources and cost as a basis. The net present cost (NPC) which included all expenses over the life span of the project was compared to the costs of an equivalent amount of tradeable renewable energy certificates (TRECs). At all renewable energy combinations modeled, the cost of TRECs outcompeted on-site renewable energy production. Grid electricity was still cheaper than on-site production, even at the highest electricity tariffs and carbon tax of R750/ton CO_2 modeled. The continuously increasing price of electricity could not be included in the model, however, it is expected that the cost differential between on-site production and grid would further decrease. The costs of the amount of TRECs and on-site RE to reduce the emissions of the store (less than 0.5%) were also judged against the cost of solar water heaters which was able to reduce carbon emissions by 8%. Solar water heaters were orders of magnitude cheaper than the former two technologies, and thus offered a lucrative alternative to reducing the carbon footprint through renewable energy. Therefore solar water heaters are the only renewable energy technology that is recommended currently for all retailers.

This research forms a preliminary investigation into the techno-economic feasibility of electricity and carbon reduction in supermarkets in South Africa. Further research is needed to determine the feasibility of technologies within specific organizations and specific locations. Behavioural changes are also imperative if energy efficient technologies are required to work at optimal levels to reduce the targeted electricity and carbon reductions.

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List of Abbreviations

BAU – business as usual

CAPEX – capital expenditure

CDM – clean development mechanism

CFL – compact fluorescent light

CFR- capital recovery factor

CO_2 - carbon dioxide

EE – energy efficiency

ESCO – electricity saving company

GHG- greenhouse gas

GRI – global reporting index

HOMER – hybrid optimization model for electric renewable

IRR – internal rate of return

KPA – key performance area

kWh – kilo watt hour

LTMS – long term mitigation scenario

MCDA – multi criteria decision analyses

NERSA – National Energy Regulator of South Africa

NPC – net present cost

NPV – net present value

O&M – operation and maintenance

OCGT – open cycle gas fired turbine

PBP – payback period

POS - point of sale

RE – renewable energy

REFIT – renewable energy feed-in tariff

SRI – social responsibility index

SWH – solar water heater

TREC – tradable renewable energy certificate

Chapter 1: Introduction and Literature Review

1.1 Introduction

The food retail sector is energy intensive, consuming large amounts of energy in the form of fuel for transportation, and in the form of electricity for refrigeration, air-conditioning and cooking. Although this sector is not listed as being one of the top 10 energy consumers in the country, it has the potential to make large contributions to energy saving through better planning and efficient use of electricity.

In addition to reducing carbon emissions directly through decreased use of electricity, the food retail sector has the potential to also play an important part in carbon mitigation indirectly through the optimized supply chain of goods; reduced agricultural greenhouse gas emissions through its influence on partner farms; and its connections to other sectors in the economy as well as in society. Therefore the food retail sector has a substantial sphere of influence. Besides the potential for carbon mitigation, the organizations within the sector are also concerned about the current electricity price hikes which will continue until 2013, and which will thus erode their profit margins significantly.

The electricity shortages which SA experienced in 2008 are another concern. These shortages are predicted to extend until 2015 when there will be increased capacity from two more power stations (Medupi and Kusile) (Eskom, 2011a). Therefore, both electricity reduction and electricity security are important priorities for the sector. By combining the three aspects of electricity reduction, electricity security and climate mitigation, all of which are linked but have different drivers, food retailers are starting to tackle this problem by mainstreaming initiatives into their business strategies. There is however, a lack of information and demonstration projects which show how this can be achieved successfully. With no experience to learn from, retailers are largely looking to their international counterparts, who are more advanced in their implementation.

The aim of this thesis is to investigate the opportunities for carbon emissions/electricity reduction in the food retail sector in South Africa, with a focus on the store level. The food retail sector in particular is unique compared to other retail organizations due to the high electricity demand arising from refrigeration, heating, air conditioning and ventilation use in supermarkets. Thus there are many opportunities for reduction, however a strategized approach is necessary to achieve maximum effect without net losses to efficiency and standards. This thesis investigates the needs of the different retailers in the sector, so that different technologies can be recommend for different retailers. After doing a technical assessment of the potential carbon savings, the requirements identified by the different retailers will be used as criteria to select appropriate technologies.

The literature review provides a synopsis of the prevailing electricity situation in SA, the country's greenhouse gas (GHG) emissions, and current and future policies on energy efficiency (EE), renewable energy (RE) and climate change, all of which provide the reader with an idea of what the drivers for carbon and energy reduction are. Initiatives between government, the national regulator (NERSA) and Eskom are also reviewed to identify the available enabling tools for implementation of carbon reduction strategies in the sector. Following from this, international food retailers that have made pioneering strides in carbon and electricity reduction are reviewed to provide the reader with an idea as to how both carbon and electricity reduction can be tackled using a range of technological options. A discussion of these new and retrofit technologies demonstrates their suitability to the local environment. Finally, in order to undertake a techno-economic assessment, methods are reviewed.

1.2 Review of SA's energy, GHG emissions and climate change policy

1.2.1 Energy in South Africa

South Africa is an energy intensive country, i.e. relative to other countries, SA consumes high amounts of energy but has a comparatively low economic output (Winkler and Marquand, 2009a). The latest statistics produced in 2008, show that South Africa ranks the 7th largest emitter of greenhouse gas emissions per capita in the world (World Bank, 2008). The high energy intensity is due to historical reasons including the country's dependence on cheap coal for electricity generation, which accounts for 47% of carbon emissions (Winkler *et al.,* 2009b). More than 90% of Eskom's generation is from coal, the remainder from two large hydro (~1%), one nuclear power plant (~4%), two pumped-storage dams (~4%) and two open cycle gas fired turbines (OCGT) (~1%) (Eskom, 2009). The reason for this dependence is due to the abundance of low grade coal resources which has allowed electricity generation at low costs.

The source of fuel for electricity has lead to SA being one of the highest GHG emitting countries in the world. The most recent calculations of GHG emissions where that done in 2007 were 446 Mtons CO_2equiv (Department of Environmental Affairs and Tourism, 2007) which was 1.2% of the world's total GHG emissions (Mwakasonda, 2007). With an emissions ratio of 10.1 tons of CO_2 per capita (including LULUCF)[1] this is about 40% higher than the global average and higher than other developing countries that are coal-based including China (3.8 tons/capita) and India (1.5 tons/capita) (Winkler *et al*., 2009b).

Due to the cheap price of coal in the past, the implementation of alternative energy technologies including those from renewable sources were hampered. Renewable energy was mostly considered for rural areas that did not have access to grid electricity. In 2003, RE in South Africa accounted for 8% of the total energy sector but this was mainly in the form of fuel wood (which was harvested in an unsustainable manner) and animal dung (DME, 2003). At present, Eskom's electricity from RE sources is only about 0.5% of total electricity generated (Eskom, 2010a). It has been estimated that if energy efficiency (EE) measures are implemented through Demand Side Management, more than 3500MW can be saved by 2020 (Eskom, 2009). Therefore there is huge scope for carbon emissions and electricity reductions, and SA lends itself well to these efforts by diversifying using alternative energy sources, and using electricity produced in a more efficient way.

There are several national policies in existence and that are being developed to enable carbon mitigation in SA. As early as 1996, the DME launched the "Energy Efficiency Business Plan" which identified the rationale for promoting EE in terms of its potential contribution to economic growth, environmental sustainability and reduced energy bills. In 2005, the Department of Minerals and Energy published the first Energy Efficiency Strategy for South Africa which took its mandate from the White Paper on Energy Efficiency in 1998 and allowed for the immediate implementation of no cost[2] and low cost[3] interventions, as well as high cost measures with short payback periods[4]. An analysis by the DME in 2008 revealed that through low-cost and medium-cost technical interventions more than 25% of energy costs can be saved (DME, 2008a). Under the Energy Efficiency Strategy of 2008, the government set a national target of EE of 12% by 2015 relative to the Business As Usual (BAU) scenario modeled as part of the National Integrated Energy Plan of 2003. Thus far, only 3% has been achieved (Malburg, 2010).

[1] LULUCF: Land Use and Land Use Change plus Forestry
[2] No cost- those measures that do not cost anything like behavioural changes e.g. switching off appliances when not in use.
[3] Low cost – using energy efficient appliances
[4] Those appliances/equipment that have a payback period of less than 3 years are generally accepted as financially acceptable (Ross, 2010)

The commercial sector (where food retail exists) has a target of 20% electricity reduction by 2015 against BAU. To support this target, in 2005 the DME set up the Energy Efficiency Accord, which is a voluntary agreement between government and companies to increase their EE in order to deal with the looming electricity capacity shortages, environmental concerns, the increasing price of electricity and in addition to create an enabling environment for attracting investment in Clean Development Mechanism (CDM) projects (DME, 2005). Eskom has also provided financial incentives for EE until 2013. Eskom's Standard Offer Pilot Programme has budgeted R30 million for EE lighting. The funding is available to incentivize industrial and commercial electricity users, municipalities and Energy Services Companies (ESCOs) to replace inefficient fixtures, re-lamp inefficient lamps, retro-fit inefficient fixtures and control of lighting. A 34c/kWh rebate, capped at a predetermined electricity saving is available to commercial users. This rebate is only allowed to users who consume between 50 and 1000 kWh/day and is applied to savings gained between Monday to Friday between 6am and 10pm. Eskom intends achieving a demand saving of 7 MW, resulting in an estimated total energy saving of 88.2 GWh by 2013 (Eskom, 2010b).

It has been argued that in countries where there is a negligible amount of EE, market forces are the only tool for driving EE (Laponche *et al*., 1997), and South Africa could prove to be a textbook example as EE is increasingly rapidly with the increase in electricity price (Thorby, 2008). As of April 2010, Eskom was allowed to implement a tariff increase of 24.8% and subsequent increases of 25.8% and 25.9% for 2011/12 and 2012/13 respectively (NERSA, 2009). The increase in tariffs poses a risk to most sectors within the economy, especially those heavily dependent on electricity such as mining, industry and agriculture (Erero, 2010; Kohler, 2010). Thus the increasing electricity tariffs have led to both the domestic and business sectors engaging in EE (van der Merwe, 2010).

Further to policies supporting EE, in 2003, the Department of Minerals and Energy produced the White Paper on Renewable Energy which followed from the White Paper on Energy of 1998. The purpose of the 2003 White Paper was to diversify energy supply in order to help curb environmental problems, specifically GHG emissions. The DME also recognised that South Africa has large RE resources including solar radiation and wind, which are largely untapped. These untapped resources prompted the government to announce a target of 10 000 GWh from renewable energies by 2013 to supply grid electricity and off-grid energies like biofuels and solar water heating, at the World Summit on Sustainable Development in Johannesburg (DME, 2003). Since then, progress of RE implementation has been slow and is still hovering around 1% of the total energy production (REEP, 2009). To promote RE uptake in 2009, NERSA announced the REFIT (Renewable Energy Feed-In Tariff) which promotes the uptake of RE in South Africa by allowing it to be fed into the national electricity grid at a profit to the generator. International experience has shown that regulation and policy, together with the willingness of stakeholders usually have more impact on the uptake of RE than economic and technical feasibility (REN21, 2007). The government plans for Independent Power Producers (IPPs) to produce 30% of the total electricity generation (DME, 2008b). The selection of IPPs to meet the 10 000GWh quota of renewable energy by 2013 is ongoing with the final appointment planned for late 2011 and the procurement process over the next 3-4 years (Eskom, 2011b).

South Africa through the National Climate Change Response Green Paper is also developing a very strong policy on climate change and RE (which is to be gazetted in 2011 ahead of COP 17 and implemented by 2012) (Department of Environmental Affairs, 2010) in which the electricity sector plays a key role for climate change mitigation. The policy includes targets for carbon reductions of 34% by 2020 and 42% by 2025 and is based on the recommendations of the Long Term Mitigation Scenario (LTMS) process on climate change developed by the SA government in 2006. Based on this process, South Africa's emissions trajectory is to follow a growth, plateau and decline curve. Emissions are to stop growing at the latest by 2020-25 and then stabilize for up to ten years before declining. In order to implement this target, clean energy, EE and demand side measures will play an important role. The targets set for EE, RE and GHG reductions thus help facilitate the transition to a low carbon economy.

The Industrial Policy Action Plan (IPAP) 2 promotes the manufacture and use of green and energy efficient industrial goods and services and thus signifies that the government is taking EE and RE more seriously than before. IPAP2 describes government's intention of accessing funding for industries to finance IPAP priorities such as the installation of 1 million solar water heaters by 2014; the implementation of RE systems especially wind, solar (concentrated solar thermal demonstration plants) and biomass; as well as those for industrial efficiency such as motors and fuel efficient vehicles.

All of these government interventions work synergistically with the rising electricity prices and carbon taxes. The carbon taxes which are under discussion include a R75/ton CO_2 tax, rising up to R200/ton (National Treasury, 2010), and it is likely that these costs will be passed down to the consumer (Eskom, 2011c). Thus, through market interventions; various government policies promoting EE and RE; incentives such as the REFIT programme and rebates for DSM measures, SA is theoretically creating an enabling environment for all the sectors within society to use electricity more efficiently and diversify energy supply, thereby allowing SA to meet its targets for EE, RE, and GHG reductions and follow a low carbon pathway.

1.3. The Food Retail Sector in the South African energy and climate change context

In the face of rising electricity costs, the food retail sector has, alongside other sectors, initiated carbon reduction strategies within their organizations. These strategies have been particularly prominent in the bigger supermarkets chain stores such as Pick n Pay, Spar and Woolworths. At the store level, electricity consumption is one of the biggest operational expenses and the biggest carbon emitter (Ross, 2010). Therefore increasing electricity tariffs and the proposed carbon taxes have substantial implications for their profit margins (Zipplies, 2010). Increasing costs coupled with government incentives to reduce their electricity consumptions and mitigate GHG emissions, have led to the food retail sector including carbon mitigation into their sustainability reporting such that carbon reduction is beginning to mainstream into all levels of operation.

Although there are no published data on the electricity consumption of the South African food retail sector in particular, the industry does contribute to GHG emissions directly through its high electricity consumption and refrigerant gas leakages, and indirectly through its supply chain as mentioned. Some food retailers such as Woolworths and Pick n Pay have started to implement strategic interventions to reduce carbon emissions and energy consumption and have included it as part of their sustainability reporting (Zipplies, 2010).

Apart from their environmental reasons for doing so, it is used as a marketing strategy to attract environmentally conscious consumers. In a study by Innovest Strategic Value Advisors in 2002, it was found that globally, those food retail companies that engaged in energy management issues significantly outperformed those that didn't. The difference in performance was due to both savings from EE but also to increased sales and better community relations as a result of an enhanced corporate image and reputation as consumers became increasing environmentally aware (Innovest Strategic Value Advisors, 2002). In the same light, those companies that were environmentally friendly also received better returns on the stock exchange than their competitors as the Socially-Responsible Investor funds tend to attract market premiums. Many corporations such as Walmart, Dow, Philips, Unilever, and 3M have voluntarily undertaken substantial internal EE campaigns simply because these projects represented a good return on their investment (United Nations Foundation, 2007).

1. 3.1 Food Retail Company Case Studies

In SA, the only local food retail companies that have been engaging with carbon reduction strategies as reported in their Carbon Disclosure Project submissions are Woolworths and Pick n Pay. These companies have been looking to their international counterparts, who have been the pioneers in carbon reduction within the sector and have made significant reductions in their footprints, for direction (Nel, 2010; Smith, 2010). The achievements of these international food retailers are discussed below to provide direction towards possible technologies to apply in SA.

1.3.1.1. Sainsbury's

Sainsbury's was the first UK food retailer to publish an environment report in 1996 (Sainsbury's, 2010). The company has been implementing sustained energy savings since 1983 when the first formal Energy management programme for stores was implemented. Their commitment to the environment, in particular energy and climate change goes beyond short-term financial gains (Ecotricity, 2008).

For the past five years, the company has been purchasing 10% of their electricity from RE sources. In 2008 they contracted to a wind turbine generator to supply them for 10 years with 16000 MWh annually which is 1% of their needs and enough to power four stores (Renewable Energy World, 2008).

Sainsbury's has an overall target to reduce CO_2 emissions per square metre by 25% by 2012 against its 2005 levels in its stores. It recently opened its new flagship green store in Dartmouth Devon, taking energy, water, waste, timber and land into consideration. Compared to other stores, the Dartmouth store has had a 50% lower footprint. This was achieved by:

- the extensive use of 'sun pipes' for natural light,
- wind turbines to power checkouts,
- a biomass boiler which utilizes locally sourced waste wood to heat water and the building,
- air conditioners which use water from chillers,
- lower lighting levels and dimming lights,
- non-essential lights are switched off at night

(Sainsbury's, 2010).

The store achieved an "Excellent" rating under the independent BREEAM 2006 Retail Building Assessment Scheme. More than 80% of the energy saving features from Dartmouth are now being replicated in their new stores where appropriate. Their plan is to open a minimum of two green supermarket-sized stores every year (IGD, 2008a).

In addition to that, Sainsbury's have achieved a 28% reduction in energy consumption for existing stores with an average of 15% cost savings. In 2009, Sainsbury's was able to save 10,786 tonnes of CO_2 through their EE programme. The saving was achieved even with significant growth in sales and retail space, allowing for a reduction of over 9% in kg CO_2/m^2 sales area against the 2005/06 baseline (Sainsbury's, 2010).

1.3.1.2. Tesco

Tesco has a target to reduce its current footprint by 50% against 2000 levels by 2020 and be a carbon neutral organization by 2050 using a combination of EE and RE technologies (Tesco, 2010). In 2009, Tesco opened up its first low carbon environmentally friendly store in Cheetham Hill, Manchester, UK. This store has a carbon footprint 70% smaller than stores built in 2006. It also cost 10% more than traditional stores but has an energy saving of almost 50%. Of the 70% carbon savings, 31% has been achieved through EE measures, 20% by using natural refrigerant and 19% by using wood from a sustainable source in a combined heat and power plant (CHP) (Tesco, 2009b). Like Sainsbury's, this flagship store is used as a blueprint to build new stores as well as retrofit existing stores. Tesco is now sharing the design with property teams in the other 12 markets in which it operates.

The Cheetham store generates its own RE on-site through solar panels, a ground source heat pump, biomass and wind turbines, and sells the excess back to the grid. The wind turbines are mainly used for visual impact (Tesco- Amesbury Renewable Energy Statement, 2007) as it only saves about 1% of the stores emissions (63 tonnes CO_2/year) (IGD, 2008b) as compared to CHP which saves 11%. The store also incorporates a number of environmentally friendly design features and technologies, including:

- Sustainably sourced timber frame,
- Roof lights and sun pipes that allow natural daylight into the sales floor and staff areas,
- Energy-efficient heating and air conditioning systems,
- Rainwater collection to flush the toilets and run the carwash,
- CHP plant to generate electricity using renewable fuel,

- No harmful refrigerants in the refrigerators, heating, ventilation and air conditioning systems,
- The first LED-lit car park in the UK,
- Solar-powered streetlights, and
- Energy-efficient equipment, such as low-energy bakery ovens

(Tesco, 2010)

These measures were financed by Tesco's Sustainable Technology Fund which has set aside an initial £100 million to support large-scale carbon reduction technologies in its stores, distribution centres and supply chains worldwide. £60 million was invested in energy-saving and low-carbon technologies in 2008 which has led to energy use in stores per square foot decreasing by 50% of 2000 levels. Energy consumption in existing stores and distribution centres (those built before 2006) has decreased by 12.6% since 2007. Tesco's carbon footprint increased only 3.7% while net sales area grew by 16.4% (Tesco, 2009a). For these efforts, the company achieved the highest score among retailers in the Global Carbon Disclosure Leadership Index in 2008 (Alden, 2009).

<ins>1.3.1.3. Walmart</ins>

Walmart is the world's biggest retailer and has recognised its role in influencing society from the supply chain through to its customers. It has an ambitious aim of attaining of 100% of its electricity from RE (Walmart, 2009a). Thus far, Walmart has secured deals with Duke Energy to provide wind energy for the next four years which is expected to supply up to 15 % of Walmart's total energy load in approximately 350 Texas stores and other facilities. The wind farm has a 90.4 MW capacity, generating roughly 226 million kWh of renewable power each year which will avoid producing more than 139,000 metric tonnes of CO_2 emissions per year (Walmart, 2009b).

It has also been purchasing solar power from BP Solar, SunEdison LLC, and PowerLight since 2007 and in 2010 consumed 18 GWh of solar energy, reducing GHG emissions by an estimated 8,000 tons per year. In April 2009, Walmart announced it had entered a joint solar development agreement with BP Solar to install solar panels on an additional 10 to 20 Walmart facilities in California by 2011. The expansion is expected to generate 8 - 16 GWh of renewable power each year and reduce more than 10,000 tons of CO_2 emission annually. These two solar ventures are expected to provide 20 - 30 % of each location's total electric energy needs (Walmart, 2009c). Walmart is currently also installing solar PV to its stores in South America which will produce almost 1MW or 25-35% of the electricity needs of all the stores and has plans to expand solar PV to 23 other stores over 5 years (Walmart, 2009d).

In terms of EE, Walmart reduced its electricity consumption of new stores by 30% in 2010 and aims to reduce the footprint of existing stores by 20% by 2012. Walmart is continually testing and trialing new EE stores. In 2009, it opened up its 6th generation EE store in Sacremento which has a reduced energy consumption of 30% compared to the 2005 baseline store. The new store has the following features:

- Evaporative cooling and radiant flooring technologies - the water temperature for this cooling is reduced by pumping it through roof-mounted cooling towers, then running the cold water underneath the retail floor to cool the shopping area,
- The refrigeration system includes a low temperature CO_2 secondary loop which reduces the refrigerant in the store by 90%,
- Skylights have reduced the amount of energy required to light the store by up to 75%,
- LED lights have saved 70% more energy than the traditional fluorescent lighting (Walmart, 2009e).

Due to these initiatives, Walmart received an award from Aspen Environmental Forum for Corporate Energy Efficiency in 2009 (Walmart, 2009f).

These case studies demonstrate the successful implementation of carbon reduction strategies in the international food retail space. Although some of these technologies are site specific, local food retailers have adopted appropriate technologies to implement in their organizations. The achievements of the local retailers, Pick n Pay,, Woolworths and Shoprite Checkers are discussed in the sections which follow.

1.3.1.4. Pick n Pay

Pick n Pay has more than 500 stores throughout the country and SADC region. Energy issues have become an important focus area in their sustainability reporting as a result of their carbon footprint and rising electricity tariffs. In an effort to reduce their carbon footprint, Pick n Pay has many strategies in place that include decreasing its energy consumption through EE and diversifying into RE production; relocating distribution centres; limiting air travel of staff, and offsetting the carbon of new stores by planting trees in conjunction with Food and Trees for Africa. In 2007, Pick n Pay made a target of reducing its grid electricity consumption by 20% by

2012 against their 2007 level (Pick n Pay, 2009a). Pick n Pay was the first retail company in South Africa to participate in the Carbon Disclosure Project. It is also the first food retailer in South Africa to install wind turbines. These wind turbines are small (e300i -1kW) and are used to generate electricity to its Eastern Cape regional office in Port Elizabeth, although for now it only fulfills 3% of the office's demand (Pick n Pay, 2009a).

The current demand profile of a typical store is given in Fig. 1.1. Most of the electricity is used for refrigeration and air conditioning.

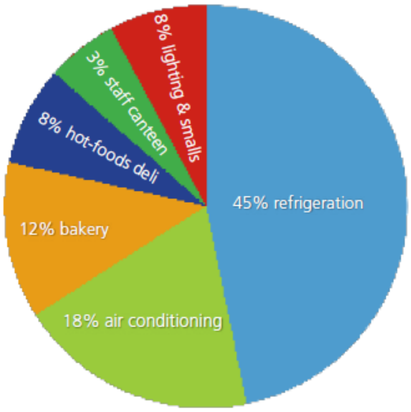

Fig. 1.1: Demand profile of a typical Pick n Pay store (Pick n Pay, 2010).

Pick n Pay have installed several energy efficient systems in their stores including:

- The replacement of magnetic ballasts with electronic ballasts in 2005, resulting in a saving of almost 20% on trading floor lighting,
- Replacement of fluorescent lights with LED lights which are 85% more efficient,
- Metering and sub-metering has been installed in all stores allowing monitoring,
- Power Management software has been installed on all PCs,
- Lighting has been isolated to necessary spots only,
- Geysers have been set at optimal temperatures and have been fitted with geyser blankets,
- Equipment has been set with timers so they switch off at non-essential times,
- Cold rooms have been installed with alarms to detect changes in temperature,
- Fridge covers have been installed for open-top refrigerators which are used at night,
- Upright refrigerators with closed doors are used,
- Evaporative air-conditioners have been used as pilot demonstrations,
- Heat reclaim systems have been used in the new stores to harnesses heat dispelled from refrigeration systems to provide hot water.

(Pick n Pay, 2010).

The flagship Hurlingham store built in 2010 also has the following:

- Sensors to detect refrigerant leakage,
- Separate suction pumps on the compressors for air-conditioning and the refrigeration system to optimize for efficiency using different temperatures,
- Heat exchangers reclaim heat from the refrigeration systems and use the heat for water heating (1600L) for the supermarket and all the other stores in the building,
- Rainwater tanks provides water for the gardens,
- Solar PV (100 kW) is used to provide power for the outside signage lights at night for the entire complex.

  (Pick n Pay, 2009b)

In 2009, two of the stores (Strand and Randpark) were fitted with eco friendly and energy efficient refrigerators. These were also installed in the new flagship store in Hurlingham in 2010. These fridges work with an ammonia/CO_2 cascade. It is expected that each store will save 200 tons of CO_2/year through using the refrigerant (Nel, 2010). It is also 10% more energy efficient than conventional refrigeration systems. Pick n Pay has signed an agreement with the German Federal Government (Deutsche Gesellschaft für Technische Zusammennarbeit (GTZ)) as well as the South African Department of Environmental Affairs and will launch the South African National Refrigerant Project with the aim of demonstrating the technical feasibility and superiority of the new refrigeration system, as well as develop an attractive model for investment (Pick n Pay, 2009b).

1.3.1.5 Woolworths

Woolworths has a target to reduce its emissions by 30% (benchmark of 273 010 tons in April 2007) by 2012 through EE (reducing electricity usage by 30% and reducing product transportation by 20%). Their programme is strongly influenced by the sustainability agenda of the international retailers such as Marks & Spencer and Walmart, as well as by the Global Reporting Initiative (GRI) guidelines and JSE Socially Responsible Investment (SRI) index criteria (Smith, 2010). Woolworths signed the Energy Efficiency Accord with the Minister of Minerals and Energy in 2006 and is working towards achieving the National Energy Efficiency Strategy targets (Incite Sustainability, 2010). The company received the National Business Initiative special award for top performance in 2008 (Incite Sustainability, 2010) and in 2009, Woolworths was rated second in the JSE Top 100 Carbon Disclosure Leadership index.

Woolworths strategies include:

- Savings from EE and transportation will be reinvested into exploring additional sustainable business alternatives,
- Woolworths is aiming to work more closely with suppliers and customers, creating awareness around climate change. As a large retailer with more than 20,000 employees, 300 stores, 6 million customers and a network of over 1,000 suppliers, the company acknowledges its ability to influence the environmental and social issues in the supply chain and the way their suppliers do business. In this way, it also makes it easier for customers to adopt more sustainable practices in their daily lives. Surveys and customer tracking show that their “Good Food Journey” is supported by staff and customers,
- Is one of the first retailers worldwide to only sell energy-saving light bulbs.

(Woolworths, 2010)

Woolworths achievements in electricity reduction include:

- On-line metering devices have been installed in over 50 facilities to facilitate electricity consumption reduction,
- Energy-saving light fixtures and electronic ballasts were retrofitted in most Western and Eastern Cape stores,
- Woolworths only uses electronic ballasts, in place of magnetic chokes in stores, depots and offices, resulting in a 15% saving in lighting cost,
- The electrical profiles of selected stores, depots and offices are monitored remotely to ensure that lighting and air-conditioning units are managed in the most efficient way,
- Automated lighting switching equipment has been installed in 20 stores to ensure that lights do not remain on after hours,
- Woolworths has conducted awareness programme and campaigns at stores for the last 25 years to educate staff about efficient use of energy,
- None of Woolworths stand alone food stores have air-conditioning, except in KwaZulu-Natal where the air-conditioning is required to control humidity,
- Energy efficient refrigeration plants installed in stores and depots have reduced the power consumed by refrigeration by up to 40%,
- Frozen foods are displayed in closed refrigeration cabinets - this has been the practice for over a decade, reducing energy usage in the freezers,
- Waste heat, recycled from the refrigeration system, is pumped back in to the food market, helping to maintain comfortable trading conditions,

- CO_2 refrigeration is being piloted in stores and has reduced electricity consumption by 30% (Woolworths, 2010).

In October 2010, Woolworths opened their greenest store in Cape Town. The store continues to use automated doors and natural ventilation and features CO_2 refrigerants. The heat reclaim system using heat from the refrigeration process is used for under floor heating. Energy efficient LED's and skylights are also used together with rainwater harvesting for the toilets. On-line metering allows electricity consumption to be visible to the customers and facilities are also available for recycling drop off (Smith, 2010).

1.3.1.6 Shoprite Checkers

The company operates on a very lean business model and as such implements measures and mature technologies that are well demonstrated to have short pay-back periods of less than two years (Shoprite, 2010). Shoprite Checkers does not participate in the Carbon Disclosure Project and does not have publically announced targets for carbon emission reductions nor energy (Incite Sustainability, 2010). Cost savings are their only driver to the uptake of EE (Shoprite, 2010). Shoprite Checkers have installed more than 30 energy-efficient technologies in their stores. These technologies focus predominantly on improving the EE of refrigeration, lighting, heating, ventilation and air-conditioning systems. Over the last three years EE improved by 5.8% as a result of the company energy management programme and brought about a saving of R31 million (Shoprite Checkers Group , 2010).

The above review highlights the numerous technologies available that are suitable for use in supermarkets. The technologies that have been adopted in the various supermarkets in SA using international retailer examples are summarized in Table 1.1.

Table 1.1: Comparison of interventions implemented abroad and adopted in SA.

	International	**Local**
Natural light	√	√
EE lights	√	√
Lower lighting levels	√	
Natural refrigerants	√	√
EE A/C	√	√
EE ovens	√	
Secondary loop refrigeration	√	√
Wind turbines	√	√
Biomass boiler	√	
Solar PV	√	√
Ground source heat pump	√	
CHP	√	
Metering	√	√
Power management software	√	√
Closed refrigeration cabinets	√	
Heat reclamation from refrigeration for store and water heating	√	√
Fridge covers	√	√
Sensors and alarms e.g. refrigerant leaks, freezer temperatures	√	√
Timers for equipment e.g. lights	√	√
Using geyser blankets	√	√
Adjusting geyser temperatures	√	√

International retailers have used several technologies and measures to reduce their carbon emissions and electricity consumption, and have thus provided important cases for the success of the various technologies. Most of these technologies have been installed on a trial basis by some of local retail companies and in only a few of the stores. Furthermore, there are other technologies that have not been used by the retailers e.g. heat pumps and solar water heaters. The technical suitability of all these technologies in the SA context needs to be determined and the information available in the public domain so that the information is available for all companies to further investigate within their specific environments.

1.4. Implementing carbon reduction/EE technologies in the SA food retail sector

Section 1.2 of this chapter showed some EE technologies which have been applied in supermarkets to achieve large reductions in electricity and carbon emissions. Some of the technologies highlighted above in Table 1.1 have been selected for further discussion (see below) due to their popularity, as well as their ability to reduce high amounts of electricity consumption. This discussion provides a brief overview of these technologies and how they can be utilized in supermarkets to achieve large scale electricity savings. In addition to EE, RE technologies are also explored due to the incentives that government has provided e.g. rebates for SWHs and feed-in tariffs for renewable energy fed into the national grid.

1.4.1 EE options for supermarkets

1.4.1.1 Electronic ballasts and T8 lights

Magnetic ballasts are still widely used in SA. In other countries, the manufacture of magnetic ballasts have been discontinued however, its use still prevails due to the long life span (Maister, 2009). Electronic ballasts which are 20% more efficient than magnetic ballasts, can be used to replace them (Fassbinder, 2008). Electronic ballasts also have a number of other advantages over magnetic ballasts. Electronic ballasts are readily available that operate three or four lamps, allowing the use of a single ballast in 3-lamp and 4-lamp luminaires (in contrast to 2 lamps for magnetic ballasts), which reduces both installation and wiring labor costs (Maister, 2009). Electronic ballasts are also designed to operate lamps in either series or parallel mode which means that in parallel mode a single lamp failure will not affect the operation of the remaining lamps controlled by the same ballast. Other advantages of the electronic ballast include reduced weight, quieter operation, and reduced lamp flicker with dimmers (Maister, 2009). Both low and high light outputs are available for either reduced electricity or reduced number of lamps depending on the illumination required.

1.4.1.2 Compact Fluorescent Lights (CFLs)

The retrofit saves 85% electricity compared to an incandescent light and furthermore, the average life time of a CFL is about 10 times longer (Energy Star, 2011). Most of the saving is through decreasing the heat load.

1.4.1.3 Natural Refrigerants

Due to leakages in the refrigeration system and the release of synthetic refrigerants which have global warming potentials that range from hundred to tens of thousands, times that of CO_2, natural refrigerants are starting to become more popular (Australian Institute of Refrigeration, 2007). Carbon dioxide (CO_2) has been used in the refrigeration industry since the 1860s. The use of carbon dioxide as a refrigerant declined between the 1890s and 1930s for a number of reasons, including changes in technology and the introduction of fluorocarbon refrigerants, which were billed as 'safety refrigerants' at the time. Interest in the use of carbon dioxide resurfaced in the 1990s, with discussion of the phase out of ozone depleting refrigerants (Australian Institute of Refrigeration, 2007) and carbon dioxide refrigeration systems are now beginning to gain popularity (Australian Institute of Refrigeration, 2007).

When used as a refrigerant, carbon dioxide typically operates at a higher pressure than fluorocarbons and other refrigerants (Australian Institute of Refrigeration, 2007). While some design challenges are presented, they can usually be overcome in systems designed specifically to use carbon dioxide – more issues may be encountered if carbon dioxide is to be retrofitted to a system designed for a different, lower-pressure refrigerant.

Besides preventing the leakage of synthetic refrigeration gases with high global warming potentials (GWP) thousands of times higher than CO_2, refrigeration units using natural refrigerants such as CO_2 have a 30% lower energy consumption than their counterparts (Kriel, 2010).

1.4.1.4 Evaporative air-conditioners

Work on the principle of cooling by evaporation. A pump circulates water through a set of cooling pads through which air is forced by a motor driven fan. The hot outside air passing through the pads evaporates the water in the wetted pads at a very high rate, thus cooling the air that is then pumped into the building. Using this natural process, between 50-80% less electricity is used (Dreyer, 2010). Other advantages include:

- Drawing fresh air from outdoors, evaporative coolers offer a great health advantage over refrigerated air conditioning, which re-circulates the same stale dry air,
- Evaporative coolers do not dry out the air like refrigerated air conditioning,
- Doors and windows can be kept open,
- As temperatures outside increase, humidity usually deceases, resulting in more efficient cooling,
- Can use grey water which can be recycled a few times depending on the amount of dissolved solids in the water or impurities in the air. (Dreyer, 2010).

Disadvantages include:

- Evaporative air-conditioners are not suitable in humid areas, and unfortunately in SA, the areas of the country that allow the process to function to optimal efficiency are also the areas with the least water resources,'
- Between 5 -7 Litres/hr per 1000 m^3v/h of air flow is the norm. This is an important consideration for use in a water stressed country like SA. One way of getting over high water usage is to use evaporative pre-cooling where the air is cooled over the condensers before it gets into contact with the water. If used in this way, 35% of electricity costs can still be saved. This method is called indirect evaporative air-conditioning and is not yet available in SA, however, can easily be retrofitted into direct evaporative air-conditioners.
  (Dreyer, 2010).

1.4.1.5 Fridges with doors

These types of fridges save 35% electricity as it prevents mixing of cold air in the fridge and warm air in the store, when the door is closed (Schlemmer, 2010). Although this technology shows significant savings in electricity and increases shelf life of products, retailers have been very hesitant to install these types of fridges, as the shelf products become less accessible to the customer (Smith, 2010; Nel, 2010). Although research shows that the doors to do hamper sales and influences some consumers, other consumers welcome it as it makes the food section thermally comfortable and attracts customers to food aisles (Schlemmer, 2010).

1.4.1.6 Heat Reclamation Systems

Heat reclamation units use a heat exchanger which transfers heat between two mediums. There are several types of heat exchangers depending on their application. A typical exchanger has a large surface area to increase absorption of heat and transfer it to the recipient medium. In supermarkets, the biggest source of heat is from the refrigeration units. The heat can be reclaimed using a heat exchanger and transferred to water for the deli and bakeries and staff areas; and to the air for thermal comfort in the stores. Heat reclamation is used overseas extensively (Schlemmer, 2010), however, in SA, supermarkets are only starting to use them for thermal heating of stores and for supplying all the hot water needs (Schlemmer, 2010). Depending on its use, heat reclamation from refrigeration compressors can be used to supply all the hot water needs of the store and completely replace electrical geysers (Schlemmer, 2010).

1.4.1.7 Fridge curtains/Automated night blinds

Fridge curtains or night blinds are made of perforated PET fabric that allow breathing and prevent condensation. These can be pulled over the fridge after hours to minimize mixing of the air and thus helping to keep the cold air in and the warm air out. This simple retrofit is able to save 20% electricity demands of the unit if used at night (Schlemmer, 2010). The night blinds can be manual or automated and remotely controlled.

1.4.1.8 Heat pumps

A heat pump geyser works like a refrigerator in reverse where heat is extracted from the air which is then compressed causing the air to heat further. The heat is then transferred to water. The cool air in return works like an air-conditioner. Therefore heat pumps are an extremely efficient way of heating water, with a saving of 70-90 % to that of electrical geysers depending on temperatures (Theunissen, 2010). Other benefits of heat pump geysers:

- Provide free air cooling and thus saves on air-conditioning energy requirements,
- Are more efficient than a solar water heater and works uncompromised in cloudy weather,
- Use an environmentally friendly refrigerant (R134a),
- Can be installed or retrofitted with pipes for an electrical geyser easily,
- Require minimum maintenance.

(Theunissen, 2010)

The SA government has introduced subsidies for heat pumps which thus allow them to be more cost effective. These rebates apply only if a heat pump is used to replace an existing electrical geyser. Heat pumps sold by registered suppliers have already been discounted so customers don't have to apply for the rebate as with SWH rebates. Depending on the size of the heat pump tank, the rebates are between R3600 and R4300. Their use in SA is very limited and currently only Woolworths utilizes them in a few stores.

These EE technologies have been used successfully to reduce electricity and carbon emissions in international supermarkets, and have been adopted at various levels in the different supermarkets in SA. However, depending on the location of the supermarket, some may be suitable than others and therefore a site specific analysis is required. EE technologies are usually installed before RE technologies due to their ease of implementation, and their costs relative to RE.

1.4.2 RE Options for Supermarkets

Carbon emissions can also be decreased through the use of RE technologies. South Africa has high amounts of RE resources. It has one of the highest solar radiation levels in the world (Fluri, 2009) and has good wind energy resources (van Niekerk, 2008). The biggest disadvantage of RE resources is their unpredictability due to these natural sources being intermittent. To overcome this problem, the energy generated can be stored e.g. as heat in solar water heaters (SWHs) or as electricity in batteries or it can be fed into the national grid. Another way of addressing variability in natural resources is to diversify the resource utilization and use a combination of different RE technologies such as wind and solar. These are referred to as hybrid systems and are becoming popular (Dalton *et al*., 2009).

The main impediment to RE is the high cost of it when compared to conventional fossil fuel energy, especially in SA due to low electricity tariffs. However, with the energy sector being transformed by increased electricity tariffs and government policy, whereby both technical and economic aspects of EE and RE will be supported, the business case for these technologies becomes more feasible. Furthermore, when economies of scale are applied and uptake of technologies increase, learning curves show that costs for RE technologies are projected to decrease significantly (Fig. 1.2) (Greenpeace International, 2007).

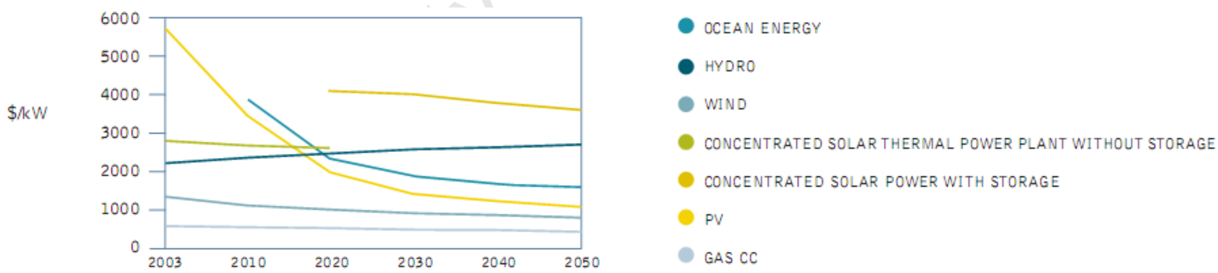

Fig. 2.2: Future development of investment costs for RE technologies (Greenpeace International, 2007).

Relative to their initial unit capital costs which tend to be much higher than fossil generation systems, electricity from RE tends to have little or no fuel, operation and maintenance (O&M) costs.

The most common RE generation technologies in SA for on-site generation are through SWHs for hot water, or through various technologies which generate electricity e.g. wind turbines, solar PV.

RE can also be purchased via the national electricity grid in the form of Tradeable Renewable Energy Certificates (TRECs) (Agama Energy, 2009).

1.4.2.1 Solar Water Heaters (SWHs)

SWHs work by trapping sunlight and converting it into heat. The heat is then transferred to water directly. There are various configurations to suit climatic conditions, mostly they differ in their tanks and collector loop heat exchange systems. Solar collectors use pipes attached to the collecting plate and a heat transfer fluid, such as water, to transfer (active or passively) the heat captured by the solar collector to a storage tank. Due to the high solar resources and warm climate in SA, a thermosyphon is common with flat plate (Webber, 2010). Thermosyphon works on natural circulation reducing the need electricity to drive a pump. Studies have shown that SWHs can save as much as 70% energy compared to an electrical geyser (Winkler *et al*., 2002).

1.4.2.2 On-site RE electricity generation

The cost of generating electricity from RE technologies is high. RE is typically used in conjunction with grid electricity as a backup. Currently hybrid systems composed of solar PV and wind turbines are used to generate electricity in SA (Ross, 2010). A hybrid system is better able to cope with unreliability of solar and wind resources and therefore these systems decrease their dependency on the grid. However, due to the uncertainties of both supply and demand, the optimum sizing of the grid-tied hybrid system, both in terms of costs and technicalities, is essential. An optimization model that includes economic objectives needs to assess the system's long-term performance in order to reach the best compromise for both reliability and cost (Zhou *et al*., 2010).

1.4.2.3 Purchasing RE as an alternative to generation

With all these economic hurdles, as well as technological and legal barriers associated with on-site RE production, purchasing RE through TRECs is a simpler alternative that organizations may choose to consider. TRECs represent units of certified green electricity and are a financial instrument that is used to offset carbon emissions. A consumer purchases the certificate and when electricity is consumed together with the purchase of the green certificate, effectively RE electricity has been consumed (DME, 2007). Due to the electricity linked to TRECs being sourced from RE sources, TRECs can thus be used to meet RE targets.

Currently, only a limited number of TRECs are available as government only has a small target of 4% RE by 2013 (DME, 2008b). TRECs are available through a few companies in South Africa as well as the City of Cape Town, which is the first municipality to offer them (City of Cape Town, 2010). These TRECs are generated from the Darling Wind Farm but are currently limited to only 10 GWh worth of TRECs (City of Cape Town, 2010).

1.5. Approaches to technology selection

Depending on what the retailer puts value on, the method used to select technologies may vary. For instance, some organizations may put a larger emphasis on CAPEX than others, and may thus choose to install a technology that is cheaper but which is difficult to install and may not have as high an electricity savings potential as an alternative technology. Therefore it is important to decide on the selection criteria and methods early on in an assessment.

Even for organizations that have environmental sustainability goals and carbon reduction targets, cost and economic profitability are still the biggest factor that hampers the implementation of EE and RE (Zipplies, 2010). Most organizations still favour limiting the low cost of present day over reduced future costs (Ross, 2010). Historically, programmes with payback periods of longer than one and a half years were seldom implemented (DME, 2002). In many other countries where markets for both EE and RE have been created, these technologies have progressed without the need for strict government policy but have rather been driven by market based mechanisms such as taxes, subsidies (REFITs) and high electricity prices. In South Africa, this change is beginning to emerge but will not happen on a large scale without strong market mechanisms and a major cultural shift and awareness of not only energy but sustainability issues as well (Zipplies, 2010).

Financial considerations are crucial in the selection of technologies, and therefore the use of an appropriate method of analysis is important. There are three common methods to determine economic profitability:

1. Net Present Value (NPV),
2. Internal Rate of Return (IRR), and
3. Pay Back Period (PBP).

These methods incorporate the time value of money which is the value of money, which takes into account a given amount of interest over a given period, i.e. R1 today is worth more than R1 in the future due to interest that can be earned over the period. If the interest rate over a period is known, then the present value of future cash flows can be determined. The method of determining these present values is known as discounted cash flow analysis. The concept is essential for determining the economic feasibility of a project or technology.

Typically, a retailer will use money gained from operational profits, and is less likely to raise money through stocks or from the bank (Nel, 2010). The retailer has an expectation that this capital outlay will be used to make profits in the future. However, by assigning a value to the cost of capital, the cash flow in the early years of a project has greater value at the present time than the same amount in the later years of a project (Colin, 2008). Therefore the discount rate (the interest rate used in determining the present value of future cash flows) allocated is very important. The selection of a discount rate can depend on many factors. Usually the rate depends on the opportunity cost of capital, which is defined as the foregone production or potential return when capital is invested in one project rather than another (Colin, 2008). The discount rate is used to determine present values by means of the discount factor shown below:

Discount factor =

Where R = interest rate or cost of capital

n = time

The time value of money is known to increase with greater risk and uncertainty. If the project being evaluated does not have an internal rate of return equal to or better than this discount rate, then the project should not be undertaken (Colin, 2008). The three methods discussed below use this discount rate to evaluate projects.

1.5.1 Net Present Value (NPV)

Under the NPV method, the present value of all cash inflows is compared against the present value of all cash outflows associated with the investment project. The difference between the present values of these cash flows determines whether or not the project is generally an acceptable investment. Positive NPV values are an indicator of a potentially feasible project (Colin, 2008).

C_t = discounted cash flow

R = discount rate

t = time

NPV method is suitable for projects with long time frames as multiple discount rates can be included. The analyses can become time consuming if different discount rates and multiple cash inflows are included, which is often necessary for long term projects, however, it gives a good measure of profitability of a project (Colin, 2008).

1.5.2 Internal Rate of Return (IRR)

The IRR represents the true interest yield provided by the project over its life. It is calculated by finding the discount rate that causes the NPV of the project to be equal to zero.

The formula for IRR is:

C_t = discounted cash flow

(savings per year);

R = discount rate;

and where the discount rate = interest rate or cost

of capital = R;

n = number of periods;

t = time

Ideally the required rate of return should be greater than the cost of capital. If the IRR of the project is equal to or greater than the required rate-of-return of the investor, then the project will likely be considered acceptable. If it is less, then the project is typically rejected. The IRR method can also be quick and simple however, without modification, does not account for changing discount rates, so it's just not adequate for longer-term projects with discount rates that are expected to vary (Colin, 2008).

1.5.3 Pay-back Period (PBP)

The simple PBP represents the length of time that it takes for an investment project to recoup its own initial cost, out of the cash receipts it generates. The PBP index is of great importance to private owners or smaller firms that may be cash poor (Bakos and Saursos, 2002). The PBP is calculated by deducting the cash flows in each successive year from the original investment amount until the total cash flow is equal to the original investment. The PBP method is simple yet crude and does not take into account cash inflows or risk beyond the payback period. It also ignores the time value of money (Colin, 2008). To overcome the time value of money, the discounted PBP was developed which uses the discounted value of the cash flows in each successive year. In addition, the discounted PBP considers the risk of the project by incorporating cost of capital, however, it still ignores the cash flows that are generated beyond the payback period analyses (Colin, 2008).

These three methods have different benefits and limitations, and thus it is up to the assessor to determine which method is the most suitable for the intended analysis. It is also not uncommon for more than one method to be used to indicate financial viability.

While costs and economic profitability are still limiting barriers, environmental and social aspects are also of concern, especially in those companies which have sustainability targets for energy and carbon reduction. For these companies, limiting the assessment to a financial evaluation only is not sufficient for determining which of the EE and RE options are preferred (Diakoulaki and Karangelis, 2007) and a multi-criteria decision making analysis (MCDA) approach may be more suitable (Loken, 2007).

The literature reveals that MCDA is being used more frequently for energy projects (Hobbs, 2000; Jones, 1990; Diakoulaki *et al*., 2005). MCDA allows for comparative assessment of projects that may have conflicting evaluation aspects e.g. least cost technologies versus high energy reduction targets. MCDA criteria for the energy sector might incorporate, amongst others, the estimation of energy use, life-cycle costs, environmental burdens and functionality and/or operability (Loken, 2007). Energy planning is an area that is quite suitable for MCDA methods because it is subject to sometimes conflicting objectives, many sources of uncertainty, long time frames and capital-intensive investments, along with featuring multiple stakeholders with different needs. Although food retailers in SA still base their decisions on financial feasibility of projects, MCDA may be considered when criteria other than the economic criterion become important.

1.6. Objectives of this study

The literature review presented above shows that carbon and electricity reduction is important to the food retail sector. Organizations within this sector have been engaged in electricity reduction due to a variety of reasons, but primarily due to the increasing cost of it. For those organizations who have engaged in electricity reduction before the onset of the price hikes, these hikes have now lead to an acceleration of their efforts.

With costs being the main driver to all sectors alike in SA, there is an enabling environment for the uptake of EE technologies and carbon reduction measures (including RE technologies), which has been provided by government and Eskom through market interventions such as subsidies, rebates and preferential tariffs. The food retail sector now has the opportunity for investment in these technologies by adopting and improving on technologies that the international food retailers have been able to successfully demonstrate and implement on a large scale.

Although there have been several studies published in scientific journals on the techno-economic evaluation of EE and diversifying the energy mix for various sectors, there is very little information on the food retail sector, especially on the supermarket (store) level in SA. Feasibility studies that have been done are usually by consultancies, with the information not freely available in the public domain.

The aim of this thesis is to conduct a techno-economic analysis of carbon and electricity reduction technologies for the sector by also including a study of how different retailers in SA feel towards these reductions and their specific needs in terms of this. For example, some retailers have voluntarily agreed to reduce their carbon footprints and have made targets to achieve this, while other retailers have not engaged with carbon or electricity mitigation on any level. An in depth analyses of retailers' views of on the subject and their drivers and outputs for mitigation are identified. These are used to formulate criteria to incorporate into the decision making process. Using a range of suitable technologies which have already been identified in the literature review, both a technical and financial (NPV) analyses is done to investigate the potential for electricity and carbon reduction, and the financial savings from using these interventions. It is envisaged that these results will provide the sector with an analysis that is specific to the SA context, and that it will be used as a guideline to further explore the reductions in each organization.

Chapter 2: Choosing Energy Efficiency options to implement in supermarkets

2.1 Introduction

In the previous chapter, a literature review provided details of different carbon/electricity reduction technologies available to food retailers in SA, the progress of the retailers in implementing some of these technologies, as well as government initiatives to stimulate the market uptake of these technologies, through energy efficiency (EE) and renewable energy (RE).

This study evaluates the appropriateness of EE technologies to SA supermarkets first, as it is the simplest and most cost effective way to save on energy costs, increase sustainability and productivity in an organization (The Centre for Energy and Climate Solutions, 2002). The United Nations also recommends that "governments exploit energy efficiency as the energy resource of first choice because it is the most readily scalable energy resource option that fuels sustainable global economic growth" (United Nations Foundation, 2010). Within every sector in SA, there is huge scope for EE (DME, 2005), and when implemented and maintained correctly, EE can be successfully used to decrease electricity and the resulting carbon emissions. As a result of the market conditions and awareness about climate change, businesses are now using EE as a cost effective means to approach all aspects of sustainability (Supermarket and Retailer, 2009).

In the food retail sector, EE can be applied to various electricity uses including refrigeration, heating and ventilation, cooking, water heating and lights. There have been numerous case studies on the success of these measures internationally (Innovest Strategic Value Advisors, 2002; The Centre for Energy and Climate Solutions, 2002; Ligthart, 2007) and locally (Ethekwini Municipality, 2009; Maister, 2009; Supermarket & Retailer, 2009), but it has yet to be mainstreamed and extended into all stores. Reasons for the lack of uptake vary between food retail companies, but cost is the ultimate factor. This chapter investigates drivers and obstacles for implementing carbon/electricity reduction, particularly EE technologies in supermarkets, and using this information, a shortlist of EE technologies are selected. These technologies then undergo a techno-economic evaluation to determine the best technologies to implement.

The analysis takes the following approach-

1. Determines the motivations and needs of popular SA food retailers, and categorises them accordingly,
2. Determines a suitable range of EE options to consider for each retailer category based on their needs
3. Makes recommendations on which EE options to install to best suit retailer requirements

2.2 Determining motivations of SA food retailers for reducing their carbon footprints

2.2.1. Methods

To determine the motivations of retailers in the local context, a survey was undertaken for large supermarket retailers, which dominate 90% of the market in SA (Weatherspoon, 2003). The survey evaluated the priority given to carbon (and electricity) reduction and the reasons for this; the needs of the retailer in terms of costs and implementation and benefits such as profitability and other outputs; the measures and achievements thus far; and their future plans. Several corporate sustainability consulting firms and large supermarkets were approached to attain this information. The heads of sustainability divisions and store management from a range of supermarkets that were perceived to have different responses to climate change and carbon reduction, as well as different drivers for carbon and electricity reductions were contacted. For those retailers who declined to respond, sustainability consultants such as Carbon Calculated and Global Carbon Exchange who do carbon audits in the corporate sector, and who have worked extensively in the food retail sector were also consulted to provide their opinions. All communications were done in person or telephonically. The following questionnaire posed to participating retailers was used as a guideline:

a) How does your company (the sector) view climate change?
b) What role do you think your company has to play in mitigating climate change, e.g. our carbon footprint is high and we need to reduce it; it is important to raise awareness of climate change and energy reduction to our customers through demonstrations; we need to only supply energy efficient products; climate change mitigation is the role of the government and the energy provider to tackle, etc?
c) Please rate the level of priority given to carbon reduction in your organization: 0-10 (0 – not important; 10 – top priority).
d) Where did the decision to make these changes come from? Internally, from within the company; or externally from customers; JSE/NBI; investors, etc?

e) Why is carbon reduction important/ not important? (External requirements (investors, JSE); to outcompete other retailers and attract customers; to save costs on energy etc)?

f) What are the long term energy reduction and renewable energy goals for the company?

g) How have the electricity prices affected your decision to implement energy efficiency? Did you implement these measures before the price hikes? If so, what were the reasons for this? OR Is cost the only reason for implementing energy efficiency and renewable energy technologies? Rate on scale 0-10 of how financial rewards affect your decision to implement measures/technologies. (0 – decision not based on economic rewards; 10- will only implement if there are direct and significant financial rewards with short payback period).

h) What carbon reduction measures have you incorporated? Provide details of energy savings and other secondary benefits if any.

i) Do you have any carbon/electricity reductions measures/technologies in the pipeline and what are they?

j) Is your organization experiencing any barriers to implementation of the above? What are they and how do you think these can be overcome?

k) Does the ease of implementation affect your decision of what to implement/retrofit? Rate how important this is. (0 = will implement technologies which will have large carbon/electricity reductions but are extremely difficult to install; 10 = will not implement if there is significant down time and loss of sales).

l) How important is climate change/energy issues, and education/awareness raising to customer and employees of your organization? Please rate on scale 0 -10 (0 = not important; 10 = important)

m) Do you think it makes a difference to the image of your company for customers/ investors?

Do you think that customers will see the value in it? Have you done any surveys to determine whether energy matters and carbon footprints are important to your customers?

The answers from these questions were used to classify different categories of retailers. The categories were hypothetical but were based on the needs, motivations and targets of the retailers as well as opinions from expert consultants. Using this approach, different sets of criteria were used to evaluate which technologies to implement and at what degree of penetration for each category. The questionnaire was also used to determine the best method for analysis i.e. whether a financial analysis or MCDA would be most suitable.

2.2.2. Results

The answers from the questionnaire, from both the retailers and consultants revealed that there were various motivations for retailers in SA to reduce their carbon and electricity footprints. The answers from the individual retailers to these questionnaires have not been shared due to confidentiality reasons. These motivations included financial reasons due to the electricity price hikes over the next few years. All the retailers stressed costs as the most important deciding factor as it was directly linked to their bottom line. However, some retailers were able to take on more risk, and thus also include less developed and/or more costly technologies that may have longer payback periods, but which may show significant electricity/carbon reductions, and in the long term show significant cost savings. Similarly, some retailers were more willing to absorb costs related to downtime during the installation process, as long as the technologies showed high long term financial rewards. Although the ultimate deciding factors were cost and short term savings, especially for those companies operating on a lean business model, other factors such as meeting consumer demands to capture niche markets and ethical corporate sustainability reporting were also highlighted. The latter reasons varied substantially between the retailers, with some being able to take on more risk and experiment and demonstrate technologies, while others only adopted technologies that were mature. The results from the survey also suggested that the reasons for some retailers only adopting technologies with short pay-back period (with less than 2 years) and high financial rewards was due to climate change not being viewed as a priority and it was not felt that climate change mitigation was an area to engage with, i.e. they were not concerned about their footprint. Using this as a basis, three hypothetical categories of retailers were formulated (see below). Although there were several reasons for adopting a carbon and/or electricity reduction programme, costs and economic profitability were the most important deciding factors for all retailers interviewed. Although it is acknowledged using an MCDA would be the best approach to take, a financial analysis was pursued due to time limitations. However, the other criteria were also incorporated by using them as secondary criteria to further decide on EE technologies, such that these technologies would be suitable to the different categories of retailers. In future, these criteria can be used in a MCDA to provide a more rigorous analysis.

The retailer requirements were categorized into the following:

- Category 1 – retailer puts a large emphasis on carbon and electricity reduction. Their targets are higher than other retailers and carbon/electricity reduction has a higher priority than for other retailers. Cost savings and profitability are still very important, however experimentation and demonstration products and technologies are considered for uptake.

- Category 2 – intermediate retailer between those in categories 1 and 3. The retailer wants to reduce the footprint, however, targets for reduction are more conservative than retailer 1, and only mature technologies are adopted.

- Category 3 – Technologies that aid in carbon/electricity reduction are only considered if they allow the business to save on costs significantly and/or where payback is less than 2 years. There are no targets for carbon reduction, but carbon reduction does occur due to the retailers needs to save on electricity bills. Costs and savings are the main or only factor used for decision making process, with environmental and social concerns being of low/no priority. Only mature technologies are considered.

A summary of the retailer requirements are below in Table 2.1.

Table 2.1: Targets and requirements for carbon and electricity reduction of each category at store level.

	Category 1	**Category 2**	**Category 3**
Carbon reduction targets	30% of current levels by 2013	20% of current levels by 2013	No target
Electricity savings	30%	30%	30%
Cost factor, initial costs vs long term savings (economic profitability)	Important but willing to trial/ demonstrate technologies	Important – use only developed technologies with short pay back periods etc.	Very important – only factor considered, mature technologies only
Staff and customer awareness	Very important	Very important	Neutral

Although carbon emission reductions and electricity savings are directly linked and dependent on each other, in table 2.1, carbon reduction and electricity savings were separated. This is because carbon reduction can result from electricity savings (energy efficiency measures) and through renewable energy production, as well as through refrigerant GHG leakages and carbon offsetting. Additionally, the category 3 retailer did have a target for carbon reduction, but had targets to save 30% of costs that are associated with electricity consumption from stores.

2.3 Selecting and calculating criteria for determination of EE technologies

2.3.1 Methods

Although economic profitability was used as a deciding factor to select technologies for implementation, other secondary criteria were included, so that suitable technologies could be identified for the different retailers with a set of technologies that would be more suitable to their business model. These criteria were chosen according to a combination of retailer needs (acquired from the questionnaire), and data availability and accessibility for the technology options chosen. Only criteria that had a significant difference between technology options were included e.g. serviceability of options was not included as most technologies required servicing at the same intervals. These electricity savings were encapsulated into the carbon reduction category, i.e. it was not a criterion on its own. This is because, at the supermarket level, most carbon emissions originate through the use of electricity, and thus electricity reductions are directly linked to carbon reduction, so the two factors are not mutually exclusive. The emissions that result from refrigerant gas leakages were not included as it was not within the scope of this study. The effect of market capture, although important, was not included due to lack of data/ data accessibility.

The final criteria adopted were:

a) CO_2 reduction,
b) Economic profitability,
c) Initial costs (CAPEX),
d) Ease of implementation, and
e) Awareness and visibility.

EE options that were chosen for consideration in this study depended on their current level of use in international and local supermarkets, government support through subsidies, availability in SA, potential to decrease electricity and their degree of maturity (refer to Chapter 1). A wide variety of technologies was chosen to illustrate their differences and to meet different retailer needs i.e. some retailers would only consider developed technologies while others were willing to experiment and demonstrate. Details of these technologies have been discussed in Chapter 1. The technologies selected for evaluation included:

a) Electronic ballasts,
b) Compact fluorescent lights (CFLs),
c) Power management systems,
d) Automated fridge curtains,
e) Upright fridges with doors (closed refrigeration),
f) Heat reclamation from refrigeration,
g) Electronic controls for refrigeration,
h) Heat pump geysers,
i) Evaporative coolers,
j) CO_2 fridges.

Each of these technologies was evaluated using the criteria above. Technologies were shortlisted based on use in supermarkets both locally and internationally. Those technologies which have the potential for high electricity savings/CO_2 reduction, were further selected. The CAPEX and economic profitability were calculated for these technologies and using ease of implementation and awareness and visibility as secondary selection criteria, the best fitting technologies were identified.

The evaluation of the performance of criteria for different options was conducted as follows:

a. <u>CO_2 reduction</u>

The average electricity consumption of a store was calculated using data made available from the large supermarket retailer companies that are located in the Western Cape. The study limited itself to the province for several reasons. Head offices of all the major food retailers are located in Cape Town, most trials are done in the province (Nel, 2010; Smith, 2010), the province is known to have the highest number of environmentally conscious consumers (Ross, 2010); the City of Cape Town has introduced TRECs from the Darling wind farm (City of Cape Town, 2010); and the province has good resources of both solar and wind energy for RE consideration (Fluri, 2009; van Niekerk, 2008) (refer to Chapter 3). Similarly, the average electricity end use consumed was based on electricity usage of stores in the Western Cape.

Calculations for CO_2 reduction are as follows:

Electricity (kWh) savings per year = average store consumption per month x estimated % use of electricity by the technology[5] x estimated energy savings x 12 months.

e.g. Electricity (kWh) savings per year = 150 000 x 12% x 50% x 12 months

total electricity = 150 000

water heating consumes 12% of total electricity

heat pumps save 70% of electricity for lighting

CO_2 (tons) savings per year = Electricity (kWh) savings/year x 0.001 ton CO_2eq[6]

(Eskom, 2010a; Letete *et al*., 2010).

To measure the performance of EE, several different metrics are available including, absolute terms (kWh or CO_2 reduced/year); or normalizing the data against occupational density (kWh or CO_2 /employee), or floor space (kWh or CO_2/m^2). Measuring performance relative to floor area is the simplest indicator and EE is usually expressed as kWh/m^2 as a way of normalizing data to compare or benchmark it to other buildings and other building types (Better Buildings Partnership, 2010). The data has not been represented here using these metric, as the purpose was not to compare against other buildings, but to meet reduction targets expressed as percentage.

b. Initial costs

The costs were obtained from suppliers and included installation (Table 2.3). These are the current costs and will vary depending on supplier/ contractor and the volumes purchased. Initial investment was stressed as an important consideration. All retailers valued the no/low cost measure approach and were more willing to install technologies that had a smaller initial cost.

c. Economic profitability

The long-term profitability of technologies was described by all retailers to be very important, although some retailers placed lesser priority to it relative to other criteria and other retailers. To determine the economic profitability of each technology option, the Net Present Value (NPV) was the method of choice due to its advantages of using multiple discount rates and its applicability to long term projects (Refer to Literature Review, Part 3). The following formula was used for NPV:

[5] The number of units per end use was included in calculations

[6] The emissions factor varies between years. This factor includes losses in transmission (5.58%) and distribution (1.74%) specific for the Western Cape (Letete *et al*., 2010).

C_t = discounted cash flow (savings per year)

R = discount rate

savings per year = kWh savings per year x unit cost of electricity

and where the discount rate = interest rate or cost of capital = R

n = no. of periods

t = time

The initial investment included CAPEX, and installation costs. To evaluate all options equally, the lifespan for all options was set at 15 years as this time frame was common for most technology options. For those options with shorter life spans, replacements were included e.g. CFLs have a lifetime of 7 years, so on the 8th year, a new CFL would have to be purchased and installed, the replacement CFL then being used until the 15th year project time frame. Thus two CFL's would be used in that time.

The cash flow was based on electricity savings per year for each technology option, as calculated above under CO_2 reduction. A unit cost of 92c/kWh was used for 2011, R1.15 for 2012 and R1.45 for 2013 in line with the NERSA's electricity pricing (NERSA, 2009). Thereafter, electricity prices increased by 10% every year (based on historical price increases). The detailed NPV calculations can be found in Appendix 1. The discount rate was pegged to interest rate forecasts provided by Standard Corporate Merchant Bank in SA (Darmalingam, 2011). These interest rate forecasts are adjusted for risk premium and inflation and they are commonly used as a discount rate (Darmalingam, 2011). NPV calculations are very sensitive to the discount rate selected.

d. <u>Ease of implementation</u>

All retailers interviewed were cognizant of the ease of implementation of retrofitting to varying degrees. The inconveniences associated with time of installation, downtime, space requirements, and labour could lead to loss of sales in the short term. Thus while all retailers were hesitant to consider installing technologies that jeopardize their turnover, those retailers who fit into categories 1 and 2, would be more willing to install these technologies as long as it showed high economic profitability ultimately.

e. Visibility/Awareness

Consumer (and staff) awareness was an important criterion for some retailers and was thus included. Awareness was rated according to visibility and information accessibility in the store, e.g. CFL lights are very visible to consumers, however, large electricity savers such as efficient refrigeration devices are hidden and therefore not visible.

The technologies were evaluated using the following details for each:

- Electronic ballasts

  Electronic ballasts are directly interchangeable with magnetic ballasts, and they are available to operate most full-size and compact fluorescent lamps. T8 lights of 28W were modeled to replace 40W T12 lights used with magnetic ballasts. Only main store lighting was included. Installation costs were included as an electrician needs to change over the ballasts. The Eskom rebate of 34c/kWh was included for periods between weekdays 6am to 10pm (Eskom, 2010b).

- CFL's

  CFL lights (28W) were included to replace 100W incandescent light in peripheral areas such as the store rooms, offices, some back areas etc. The life span is 3 years as its lasts 15 000 hours (Osram, 2006). The light fittings do not need to be changed and therefore there are no installation costs. The Eskom rebate of 34c/kWh was included for periods between weekdays 6am to 10pm (Eskom, 2010b).

- Power management software for POS

  POS systems are rated at 60W. Power management systems were estimated to save 50% of electricity as the system typically allows POS to go into hibernation when not in use and shut down when the store is closed from 8pm to 8am. Besides the initial cost of the software, a yearly subscription fee was also included as maintenance costs.

- Automated fridge curtains

  Fridge curtains made of perforated PET fabric were only considered for open refrigeration cabinets. Fridge curtains were modeled with a 20% electricity saving if used when the store is closed (12 hours). Although these are meant to last indefinitely, a 5 year life span was modeled due to over packing of fridges which is common scenario and leads to the deterioration of the mechanism and fabric (Schlemmer, 2010).

- Upright fridges with doors

  The number of these types of fridges was assumed to replace all fridges. Fridges with doors were modeled to save 35% electricity (Ligthart, 2007). Maintenance costs were negligible as only cleaning is required, and were not included. Lifespan was modeled at 15 years.

- Heat reclaimed from refrigeration systems

  The waste heat from the refrigeration process was included to provide all the requirements for water heating for the supermarket. Thus 100% electricity saving for water heating was modeled. The envisioned store had two multiplex refrigeration systems, and two heat reclaim systems were included for analysis. Maintenance was not included as they do not require maintenance other than servicing which is included in the normal servicing of the refrigeration system.

- Electronic controls for refrigeration

  These controls allow the user to control the various parameters for refrigeration electronically and remotely. These include parameters for the compressors cycles; temperatures for individual units of fridges and freezers, as well as switching off lights for the units, anti-sweat heater controls and the automated fridge curtains. These controls collectively were modeled to save 15% of total refrigeration consumption (Steyl, 2010). The control requires no/little maintenance so maintenance was not included. These packages can last indefinitely but a 15 year life span was modeled to be able to compare the NPV with those of the other technologies being considered.

- Heat pump geyser

  Heat pumps were chosen as an alternative to electrical geysers. As part of its Demand Side Management Programme, Eskom has introduced subsidies of R3600 per heat pump (150L; 3kW) (Eskom, 2010b) which have been included in calculations. 2 x 150L heat pump geysers were modeled to replace current electric geysers. Maintenance costs were R500 per year for servicing without parts. Heat pumps can last for at least 15 years and was estimated to save 70% electricity.

- Evaporative coolers

  These work by extracting latent heat from water and then using that cooled air to circulate into the building. They are used as a replacement to conventional air conditioners. Up to

80% electricity can be saved, depending on local climatic conditions. For a store in Cape Town, 70% savings was estimated (Dreyer, 2010). Maintenance costs of R500/year were included for servicing. Evaporative coolers last between 10-15 years.

- CO_2 fridges

  CO_2 systems were modeled with a 30% electricity saving and high maintenance costs of R10 000 per store per year (Kriel, 2010). These systems can last 25 years but a 15 year time frame was used so that the economic profitability of CO_2 fridges can be compared to the other technologies in this study. All the supermarkets considered in this study, used direct refrigeration systems, which consists of a rack of compressors operating at the same saturated suction temperature with common suction and discharge refrigeration lines. Direct systems are not compatible with CO_2 and thus retrofitting this system would require a major overhaul.

The number of units for each option was based on an average store size of 1500m^2. This information was provided by different retailers. For each option, the current numbers of fridges, lights, geysers etc. were based on the existing infrastructure and equipment, such that these options would serve as retrofits. The store designs for the different categories of retailers were not significantly different, and thus one generic model was used. Expert consultation with technology suppliers was provided to compensate for the difference in power output between the current equipment and the retrofits. The difference of the power output was also taken into account and the number of units that were selected was provided by expert consultation with technology suppliers as well. Information on costs, installation, maintenance, life span and electricity savings were also provided by suppliers and energy engineers.

2.3.2 Results

2.3.2.1. Evaluating the performance of criteria for each EE option

The average area for the surveyed supermarkets in SA was found to be 1500m^2 with an average electricity consumption of 150 000 kWh/month.

The average electricity end use used for all calculations was:

- Refrigeration – 45%
- Air conditioning -18%
- Water heating – 12%
- Lights – 8%
- Point of Sales (POS) – 1%
- Heating (ovens) – 16%

There were no significant differences in the end use between retailers interviewed who fall into the different categories, although there are significant differences in stores located around the country due to differences in outside temperature and humidity.

The biggest electricity savers shown in table 2.2 are heat reclamation, CFLs, heat pump geysers and evaporative coolers. However, due to the biggest use of electricity being refrigeration (45%), followed by air conditioning (18%), ovens (12%), hot water (12%) and lights (8%), the retrofits that were associated with these end uses produce the highest savings in electricity and thus carbon emissions. The CO_2 refrigeration option is a clear example, which saves 30% in electricity but saves 253 tons of carbon emissions per year per store.

Table 2.2: CO_2 savings per year for each technology option.

Retrofit Option	**Units**	**Life time (years)**	**Electricity savings (%)**	**Electricity savings/year (kWh)**	**CO_2 saving/year (tons)**
Electronic ballast & T8 (28W) light	50	7	22	31 000	31
CFL (28W)	5	3	85	8000	8
Power management software for POS	10	15	50	9000	9
Fridge curtains (1.8m)	20	5	20	84 000	84
Fridges with doors (closed)	10	15	35	295 000	295
Heat reclamation from refrigeration	2	15	100	225 000	225
Electronic controls and monitoring (refrigeration)	1	15	15	126 000	126
Heat pump geyser (150L)	2	15	70	151 000	151
Evaporative cooling A/C	11	15	70	270 000	270
CO_2 fridges	1	25	30	253 000	253[7]

The following table 2.3 shows the CAPEX and economic profitability (NPV) for these EE technologies.

[7] Emissions from leakages not included.

Table 2.3: Costs and NPV for technology options considered.

Retrofit Option	**Units**	**Capex/ unit (R)**	**Total Initial Costs (R)**	**Maint. costs/ unit/ year (R)**	**Total Maint. Costs/year (R)**	**Product life time (years)**	**Savings/Year (R)**	**NPV (15 year) (R)**
Electronic ballast & T8 (28W) light	50	240	10, 200[8]	0	0	7	29 000	495 000
CFL (28W)	5	35	-257[9]	0	0	3	7 000	126 000
Power management software for POS	10	160	1,600	30	300	15	9 000	140 000
Fridge curtains (1.8m)	20	1,500	30,000	0	0	5	78 500	1,3 000 000
Fridges with doors (closed)	10	10,000	100,000	0	0	15	271 000	4,720 000
Heat reclamation from refrigeration	2	20,000	40,000		0	15	207 000	3,600 000
Electronic controls and monitoring (refrigeration)	1	60,000	60,000	0	0	15	116 000	2,000 000
Heat pump geyser (150L)	2	9,000	18,000[10]	500	1,000	15	145 000	2,500 000
Evaporative cooling A/C	11	25,000	275,000	500	5,500	15	248 000	2,520 000
CO_2 fridges	1	5,000,000	5,000,000	8,000	200,000	25	233 000	- 870 000

[8] Includes Eskom rebate for lights at 34c/kWh saved
[9] Includes Eskom rebate for lights at 34c/kWh saved
[10] Includes rebate of R3600 per heat pump

The biggest cost savings were through refrigeration, water heating and air conditioning related technologies as expected due to the proportion of electricity they consume. Fridges that had doors saved the most amount of money in the long term and did not have a significant initial investment amount, compared to energy efficient air conditioning, electronic controls or CO_2 refrigeration. Changing the lighting and installing power management systems which are frequently regarded as low cost measures did not show significant savings. However, the results also revealed that there was no relationship between initial investment costs and the long term financial rewards thus supporting the case for strategic analysis and reviews instead of adopting random technologies, which is what is currently done now.

The CO_2 refrigeration is interesting as at first glance the NPV showed a loss which is contradictory to international case studies that show large savings. However, on inspection, when the project lifetime was increased to 25 years (the expected lifespan)[11], a profit of more than R3.5 million was projected (refer to Appendix 1).

The effect of increasing electricity tariffs in the next three years on the financial savings each year is also shown in the table 2.4 below. These price hikes have been taken into account for the long term NPV calculations.

Table 2.4: The effect of increasing electricity tariffs on savings for each technology

Retrofit Option	**Electricity savings/year (kWh)**	**Savings/ year (2010/11) (R)**	**Savings/ year (2011/12) (R)**	**Savings/ year (2012/13) (R)**
Electronic ballast & T8 (28W) light	31 000	29 000	36 000	45 000
CFL (28W)	8 000	7 000	9 000	11 000
Power management software for POS	9 000	9 000	11 000	13 000
Fridge curtains (1.8m)	84 000	78 000	97 000	121 000
Fridges with doors (closed)	295 000	271 000	340 000	423 000
Heat reclamation from refrigeration	225 000	207 000	258 000	323 000
Electronic controls and monitoring (refrigeration)	126 000	117 000	145 000	182 000
Heat pump geyser (150L)	151 000	145 000	180 000	226 000
Evaporative cooling A/C	270 000	248 000	310 000	388 000
CO_2 fridges	253 000	233 000	290 000	363 000

[11] Refer to the Appendix 1 for detailed calculations on the NPV.

Results of the other two criteria - ease of implementation and awareness and visibility as well as the *status quo* on the usage of these technologies are summarized in the table below.

Table 2.5: Awareness and ease of implementation of each technology

Retrofit Option	**Ease of implementation**	**Visibility/Awareness**	***Status quo***
Electronic ballast & T8 (28W) light	Directly interchangeable with magnetic ballasts	Very visible	Roll out in most stores
CFL (28W)	Directly interchangeable with incandescent bulbs	Very visible	Roll out in most stores
Power management software for POS	Install programme, no down time	Visible to staff only	Not used
Fridge curtains (1.8m)	Units need to be factory fitted	Visible to staff only	Trialed
Fridges with doors (closed)	New units required and possible change of floor design	Very visible	Few units in most stores
Heat reclamation from refrigeration	Easy to install, no/little downtime, but technician required	Hidden	Trialed
Electronic controls and monitoring (refrigeration)	Easy to install, no/little downtime, but technician required	Visible to staff only	Trialed
Heat pump geyser (150L)	Easy to install, no/little downtime, but technician required	Hidden	Trialed
Evaporative cooling A/C	Easy to install, little downtime, but technician required	Hidden	Trialed
CO_2 fridges	Complete retrofit, long downtime	Hidden	Trialed

2.4 Discussion

The survey of the food retailers and consultants who participated revealed the various reasons that retailers in SA are reducing their electricity consumption and carbon footprint. These reasons are no different to retailers in the rest of the world (Zipplies, 2010). Although all the retailers recognized the importance of carbon reduction and climate change, and in particular their part in carbon mitigation, some were leaders while some preferred to delay the programme to actively reduce their footprint, due to experiential learnings, or until the market favoured the economic profitability of their programmes substantially, or until it was mandatory. Furthermore, the "leaders" had more pronounced sustainability goals leading to bigger targets for electricity and carbon reduction. Retailers were also cognizant of the costs associated with these reductions, especially since the food retail sector has small profit margins of between 1-2% (Bradshaw, 2011), however the “leaders” were more willing to accept longer payback timeframes for projects, as long as these projects showed large financial rewards in the future.

There is currently a lack of policy to enforce electricity and carbon reduction in organizations. Those companies that do include reductions do so as it is viewed as a good business strategy as it allows them to save costs (Incite Sustainability, 2010). Although at the moment, reporting on carbon emissions and reductions is voluntary, it may become mandated in future. When this happens, it will result in a radical shift in the needs and requirements of retailers that have been found in this study. This change has already started to happen with the electricity tariffs and carbon taxes proposed.

Although the carbon reduction targets for each category of retailer were different, the electricity reduction targets were the same for all retailers surveyed (30% by 2013). The biggest reductions in carbon/electricity for each EE retrofit that was modeled were from closed refrigerators, evaporative cooling, CO_2 and heat reclamation from refrigeration. Using a combination of technologies, electricity reduction targets can be achieved. The 30% electricity target for all retailers requires a saving of 561 600 kWh/annum (total average annual consumption per store = 1.87 million kWh). Using closed fridges saves 300 000 kWh/annum (table 2.2) and heat reclamation from fridges to heat water has a high carbon savings of 225 kWh/annum (table 2.2).

Closed refrigerators have also showed the highest profitability (table 2.3), almost R5 million. Additional benefits are that they are easy to install and allow the store to maintain a comfortable temperature for customers. Closed refrigerators are also at the front end of the store, and customers interact with them directly. Therefore this option is highly recommended. However, it is well known that there is a perception by marketing divisions of retail organizations that closed fridges hamper sales due to their effect on decision making as a result of the inconvenience associated with opening fridges for every item (Smith, 2010). Thus retailers are not keen to install closed fridges throughout the stores. Therefore closed refrigerators are only recommended for a category 1 retailer.

The heat reclamation system would replace an electrical geyser completely and be more efficient and cost effective than SWH or heat pump, as it utilizes waste heat. The heat can also be diverted for use in under floor heating and maintaining thermally comfortable temperatures in the stores, thereby reducing the load on the HVAC system. Furthermore, the heat reclamation system does not require any additional servicing as there are no moving parts, and can be maintained as part of the refrigeration units at the back end of the store. A combination of heat reclamation and closed refrigerators meets the electricity targets for the store.

For category 3 retailers, a combination of heat reclamation (225 tons/year CO_2), electronic controls for refrigeration (126 tons/year CO_2), fridge curtains (84 tons/year CO_2), energy efficient lights (40 tons/year CO_2), and POS power management systems (9 tons/year CO_2) are recommended to meet electricity and carbon targets. All of these technologies are low cost adding up to R140 000 for installation per store, which is the same cost as installing heat reclamation system and closed refrigerators recommended for category 1 retailer. Additionally, the NPV for the combination of technologies for category 3 retailer amounts to R 8 million, slightly less than the technologies recommended for category 1 retailer (R 8.3 million). These technologies are easy to install and require little maintenance. These technologies also complement each other with heat reclamation system saving the majority of electricity and lights being able to meet visibility requirements for all categories. The added advantage is that all of these technologies are mature technologies and their efficiencies and experiences have been well documented. As mentioned, most stores have already installed CFLs, but magnetic ballasts are not very prominent at present, and their use could be extended.

Other technologies not covered in this study but are important include individual electricity metering systems for units, and gas leakage detection systems. Although metering systems are not known as EE technologies, it is usually the first step to reducing consumption as it allows monitoring of the electricity reductions and thus allows them to become more tangible. Furthermore, retailers who have already installed them in stores have saved electricity costs due to correct metering (Smith, 2010). More retailers are considering installing these for individual equipment (Energy Partners, 2010).

Gas leakage detection systems are important as the industry standard on leakages is 25%, however, the leakage can be reduced to 10% with detection systems (Supermarket and Retailer, 2009). Even a small loss is considered substantial since synthetic refrigerants like HFC's have a GWP of tens of thousands higher than CO_2, and last for hundreds to thousands of years in their form in the atmosphere, depending on the blend (US Environmental Protection Agency, 2010). Gas leakages are also included as direct emissions in GHG emission calculations and therefore gas detection systems are an important component for consideration. In other countries, it is illegal to release these gases into the atmosphere (UK Environmental Protection Act (1990), British Standard EN378 and European Regulation 2037:2000). In SA, gas leakage has only recently been outlawed as part of the Occupational Health and Safety Act (Act No. 85 of 1993), but not enforced. As part of health and safety considerations, these systems can also be used to demonstrate that the system is functioning correctly. Also, in terms of electricity consumption, if 15% of refrigerant is lost, this could cause a 100% increase in electricity consumption (Schlemmer, 2010). The retailer should also factor in costs for gas replacements, damage to compressors and loss of product when the gas runs out in the absence of a detection system.

It is important not to overestimate the success of energy efficiency, especially if the high energy consumption is due to low levels of behavioural discipline (Schelly *et al*,. 2011) and/or poor insulation. This behavioural discipline stems from poor management and lack of commitment to electricity reduction, and if these attitudes persist when energy efficient technologies are installed, these technologies will lose efficiency over time due to poor maintenance of equipment. Usually simple and regular cleaning methods by staff as well an annual service by qualified technicians is enough to ensure proper operation of most equipment e.g. fridges and air-conditioners (Schlemmer, 2010). Other behavioural changes that will reduce electricity consumption include, amongst others, switching off equipment that is not in use, maintaining appropriate temperatures for cooling and heating equipment for different times of day and year, and not overloading fridges and freezers thereby blocking off air vents. Research shows that the implementation of EE technologies may sometimes have the reverse reaction in behavior resulting in people consuming more. This is known as the "Rebound Effect". Therefore energy efficiency technologies go hand in hand with increased staff awareness, training and buy-in, introducing this into key performance areas (KPA) for employees and including it in sustainability reporting for organizations. Although this thesis attempted to include criteria such as "Ease of implementation" that assist in the uptake of these selected technologies, this is a technology centric study, and a multi-faceted approach which includes the behaviour of retailers and their staff should also be undertaken.

2.5 Conclusion

To determine which EE options to install in supermarkets, a set of criteria were chosen to aid in the decision making process. Although the relative importance of these criteria varied between the supermarket retailers surveyed, economic profitability was the most important factor for the selection of the technologies in all cases. The other criteria (CAPEX, ease of implementation and visibility) were regarded as secondary criteria. A financial analysis was thus used to select and recommend EE technologies. The criteria identified in this study, however, can be used in future to do a multi-criteria decision analysis (MCDA), when retailers put more emphasis on electricity and carbon reduction, and where cost is not viewed as the limiting factor as it is now.

Due to various retailers having different priorities and requirements/targets for reductions, the retailers were divided into three types. EE technologies were then recommended for each retailer category.

Closed refrigerators showed the highest electricity/carbon savings and the highest profit (NPV), followed by heat reclamation. Both these technologies were recommended for category 1 retailers who have the largest targets for both electricity and carbon reduction and are willing to trial technologies.

A combination of heat reclamation, EE lights, fridge curtains, electronic controls for refrigerators and POS power management systems were recommended for category 3 retailers, that are conservative and only willing to adopt mature technologies which show high economic profitability and low CAPEX. All of these technologies are also easy to easy with little downtime required. Category 2 retailers have intermediate targets and can adopt a combination of the two recommendations to meet targets.

Retailers should also consider natural refrigerants (CO_2) which show significant electricity and carbon reductions and high economic profitability over the lifetime of the technology.

The surveys also revealed the importance of behavioural changes of all staff, which work synergistically with the use of EE technologies. Therefore it is also recommended that a strong educational programme be administered to all staff, especially the store staff that interact with equipment.

Chapter 3: Evaluating the use of renewable energy for supermarkets

3.1 Introduction

In the previous chapter, the needs of retailers were identified and three categories of retailers were formulated depending on their targets and requirements. EE options for supermarkets were evaluated to meet reduction targets and the other criteria identified for different categories. The results of the survey undertaken in the previous chapter also show that retailers recognized the need to diversify their energy sources due to experience from historical load shedding in 2007/8 together with the potential of load-shedding from 2011 due to the electricity supply crisis. During the load shedding events in the past, supermarkets relied on diesel generators as a backup, however, some retailers are now investigating renewable energy as well, or in place of, diesel generators. The reason for finding an alternative to diesel is due to a combination of the cost of diesel and its carbon footprint. In addition to energy security, some retailers who were concerned about their "green" profile expressed the need for having a visual RE presence at the store. Although there are no set targets for RE in commercial businesses set by government, or by the individual retailers, some retailers were following the sustainability business models of international chainstores of Tesco, Walmart, etc. For this reason, conservative RE targets were made for the different categories as below:

- Category 1 – 5%
- Category 2 – 3%
- Category 3 - 0%

It is well known that RE is currently relatively expensive to implement, however, the increase in electricity tariffs and the proposed carbon taxes will make them more attractive as the gap between RE and coal based electricity decreases. Furthermore technology learning will make RE more affordable (Winkler *et al.*, 2009b). The aim of this study was to investigate if RE will be economically feasible when these increases in electricity costs materialize through the tariffs and proposed taxes over the lifetime of the technology. Hybrid PV and wind technologies; solar water heaters (SWHs) and Tradeable Renewable Energy Certificates (TRECs) were evaluated. These technologies were chosen due to South Africa having high wind and solar resources, as well as the government subsidy for SWHs. TRECs were included to compare the costs of on-site RE generation to off-setting. The main criteria used for the selection of the best suited RE technology were carbon reduction potentials and total costs.

3.2. Cost evaluation of an on-site hybrid RE system.

3.2.1. Method

For electricity generation, a grid-connected hybrid system that consisted of PV and wind was evaluated. Grid-connected systems have the advantage of being able to feed the electricity back into the grid when there is excess electricity being produced. Grid-connected systems are also able to use the grid when there is a deficit of on-site electricity. Therefore, there is no need for a battery bank and battery accessories, which are costly and need to be replaced often. In addition, hybrid systems allow for the utilization of more than one type of natural resource, which is suitable for areas that have good sources of both solar and wind energy e.g. the Western Cape.

Due to the high cost of PV/wind energy and its intermittent supply, a small electricity load composed of lights and POS systems was chosen to be supplied by RE. By using energy efficiency and demand side management (DSM) measures, a smaller amount of RE was required to provide the same end use. For example, if no EE measures were undertaken, the daily load for POS and lights would be as follows:

Table 3.1: Load demand for POS and lights without EE and DSM

Components	Units	kW	total kW	hours	kWh/day
POS	10	0.06	0.6	24	14.4
Incandescent	5	0.1	0.5	24	6
T12	55	0.04	2.2	24	52.8
TOTAL					**73.2**

The total load would be 73.2 kWh. In contrast, if EE and DSM measures are implemented, the load would be composed of 45 x T8 lights (28W each) and 5 x CFLs (28W each) during store operation times only. Between 8pm and 8am, only 10 x T8 lights would remain on. The daily profile is shown in Fig. 3.1. The total load of 31 kWh/day and 2.5 kWp was modeled. Table 3.2 shows the load in detail.

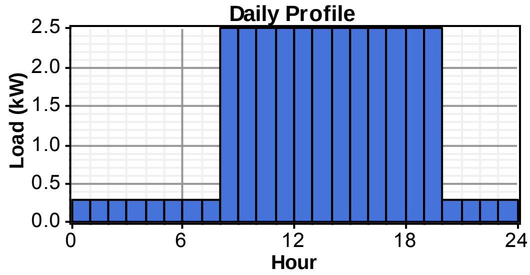

Fig. 3.1: Hourly profile for lights and POS

Table 3.2: Load demand for POS and lights with EE and DSM

Components	Units	kW	total kW	hours	kWh/day
POS	10	0.06	0.6	12	7.2
CFL	5	0.028	0.14	12	1.68
T8 8am-8pm	45	0.028	1.26	12	15.12
T8 all day	10	0.028	0.28	24	6.72
TOTAL					**30.72**

Using EE and DSM by itself reduces the electricity load and carbon emissions more than 50%.

There are a number of software programmes available to determine optimum configurations of hybrid RE systems (Connolly *et al.,* 2010). Of these, there are currently three that are used and are available on the internet at no cost: HOMER, RETScreen and Hybrid2. These programs evaluate the cost and technical feasibility of RE systems and each rely on a different modeling approach to simulate the performance of RE-based power systems. These programs are widely used by a range of academics and professionals (Gilman, 2007; Connolly *et al.,* 2010). Each model performs a different modeling function. HOMER optimizes system designs based on the fundamental economics of each design option; while Hybrid2 simulates the performance of hybrid power systems with a focus on the timing of the operation of power equipment and batteries; and RETScreen estimates energy delivered by different power sources to use as a basis for calculations in project feasibility studies (Gilman, 2007). HOMER is the most suitable software to assess and design an optimal grid-connected hybrid RE system to meet variable loads throughout the day by basing it on the technical and economic needs (Gilman, 2007; Connolly *et al.,* 2010). Therefore the HOMER software package (v2.68 beta developed by the National Renewable Energy Laboratory, US,) was chosen to determine an optimum hybrid system that had the least cost and most energy and monetary savings, providing the greatest independence from the grid as possible.

3.2.1.1. Hybrid System Configuration Inputs

Fig. 3.2 illustrates the RE system designs for Point of Sales (POS) and main store lighting, which were used in the HOMER programme. Each system input is described in detail below.

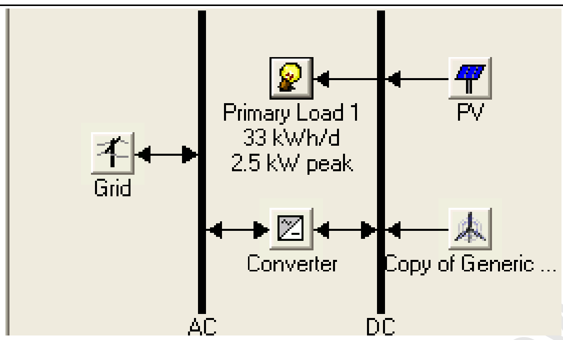

Fig. 3.2: System components for both load demand options.

3.2.1.2. System Input -The grid

To allow the RE system to meet demands throughout the year, a grid-tied system was chosen for reasons described above. In the event of a load-shedding however, it was envisaged that a diesel generator would supply the electricity for POS and lights and the rest of the store as well. A diesel generator was not included for the purposes of this study as only normal day-to-day operation was considered.

The cost of electricity was modeled at R1.45 which is the projected electricity tariff in 2013 after the price hikes (NERSA, 2009). This tariff, together with different carbon taxes (see below) was used to determine if RE would be more economically feasible at these costs. No feed-in tariff was applied as the RE installation was only 2.5 kW which is less than the minimum size of 1 MW approved by NERSA for compensation under the REFIT scheme (NERSA, 2009b). HOMER does not allow for continuously increasing costs of electricity per year, so this could not be taken into consideration in the model. This is a serious limitation of the study and needs to be addressed with further research. Nevertheless, it was decided to continue with the analyses to determine whether at the various electricity prices kept static (and taxes), on-site RE would be viable - keeping in mind that the continuously increasing prices would only make on-site generation more attractive.

3.2.1.3. System Input – solar and wind resources

The hybrid system considered for this study was a grid-connected wind/PV system. The monthly solar radiation for Cape Town, which was chosen as a default location for this study is shown in Fig. 3.3 below. These monthly profiles were used to input into HOMER.

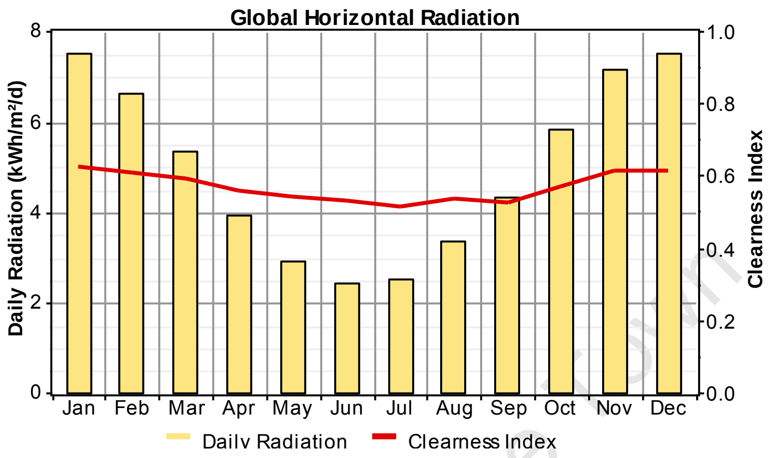

Fig. 3.3: Mean monthly solar radiation for Cape Town

(Council for Scientific and Industrial Research, 2010)

Fig. 3.4 shows the monthly wind speeds. The wind data was acquired from Cape Town International Airport location (Windfinder, 2010).

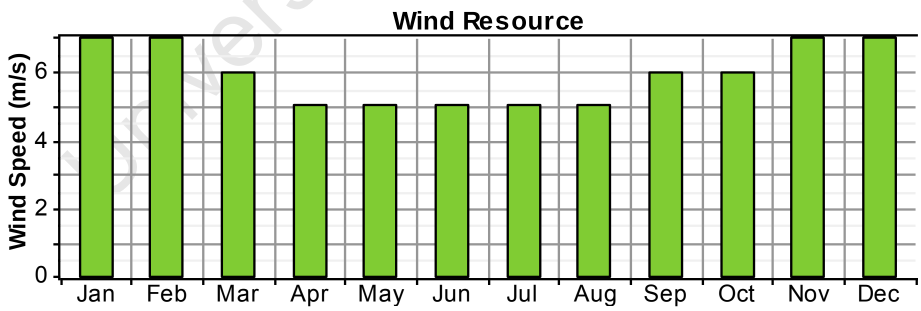

Fig.3.4: Mean wind speeds (m/s) for Cape Town

An anemometer height of 10m was chosen, as micro wind turbines will typically be placed on the roof of the stores where there is space and where wind speeds are higher. Surface roughness, which is the effect of a frictional surface on the wind speed, was set at 1.5m, typical of that associated with suburban areas (HOMER, 2009).

HOMER accommodates for variability in resource availability as well as variability in demand by oversizing the system by 2%. If there is a higher deficit, then electricity is sourced from the grid.

3.2.1.4. System Input - PV system

The capital cost of PV system included panels, mounting, wiring and installation. The replacement costs were assumed to be the same and the Operation and Maintenance (O&M) were set to be zero as there are negligible costs associated with PV systems (Dalton *et al.*, 2009). The lifetime was set at 25 years. The derating factor which accounts for any discrepancy between the rated performance and the actual performance of the module due to dust, high temperature, shading, aging, wiring losses etc. was 90%. The slope which is the degree of tilt that the panels are mounted to the horizontal in order to face the sun was set at 20° (Dekker, 2010). No tracking device was chosen and, effect of temperature was not considered. All prices were obtained from solar PV manufacturing and installation companies in SA.

3.2.1.5. System Input - Wind Turbines

A capacity factor of 30% was used (van Niekerk, 2008) and wiring losses of 10% (Dalton *et al*., 2009). Lifetime was set at 25 years (Dalton *et al*., 2009). Fig. 3.5 shows the power curves for a 3kW (e400) wind turbine from Kestrel that were used in HOMER.

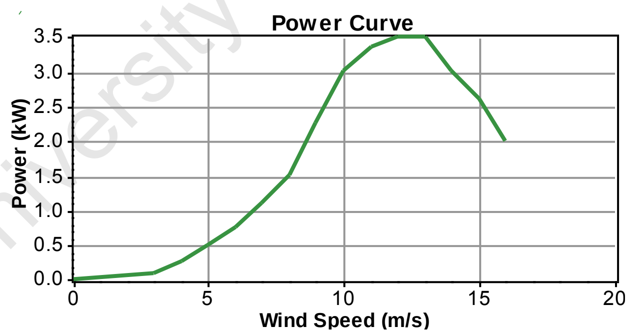

Fig. 3.5: Power curves for 3kW wind turbines from Kestrel

Costs were sourced from Kestrel (Ghouws, 2010), for installation, labour, wiring, tower and the wind turbines. Capital and replacement costs for all of the above for a 3kW turbine were quoted at R73 000. O&M cost over 25 years was R7300, per year or 10% of the capital cost (Ghouws, 2010; Koegelenberg, 2011).

3.2.1.6. System Input - Inverter

The inverter converts the electricity into either a DC or AC component depending on the direction of power flow. Both the turbines and the PV system produce DC, which the inverter converts into useable AC, for the POS and lights. Two grid-tied converters (inverters) were modeled, each one attached to either the PV panel or the turbine. Capital and replacement costs included the converter, installation, labour and wiring and other accessories and were estimated to be R 12 000 each (Koegelenberg, 2011). O&M costs were negligible and thus not included. Inverter lifetime was 15 years and efficiency was set at 90% (Dalton *et al*., 2009).

3.2.1.7. Inputs - Economics

HOMER uses the total Net Present Cost (NPC)[12] to represent the life-cycle cost of the system, assumes that all prices escalate at the same rate and takes the ‘‘annual real interest rate” which is adjusted for the effect of inflation rather than the ‘‘nominal interest rate” which does not. Therefore, this method allows takes into account inflation (Dalton *et al.*, 2009). The NPC also takes into account any salvage costs. The salvage cost is the value remaining in a component of the system at the end of the project lifetime. HOMER assumes a linear depreciation of components, meaning that the salvage value of a component is directly proportional to its remaining life. It also assumes that the salvage value is based on the replacement cost rather than the initial capital cost (Gilman, 2007).

HOMER modeled each individual system configuration by performing an hourly time-step simulation of its operation for a one year duration. The available renewable power was calculated and was compared to the required electrical load. Where the RE system was assessed to be satisfying the demand, any excess electricity was then fed into the grid. Where demand could not be satisfied, grid generation was sought to fill the deficit. Following calculations of one-year duration, any constraints on the system were then assessed e.g. the fraction of the total electrical demand served or the proportion of power generated by renewable sources (HOMER, 2009).

HOMER used the Net Present Cost (NPC) over the entire lifespan of project operation as the main criterion to determine the most feasible solution. NPC includes all expenses relating to components, installation, component replacements, operation and maintenance (O&M) costs over the life span of the project.

[12] NPC takes into consideration discounted costs only, whereas NPV includes discounted incomes or savings.

The NPC was calculated within HOMER using the following equation:

$$NPC = TAC/CRF$$

where TAC = the total annualised cost (which is the sum of all annualised costs of each system component).

The capital recovery factor (CRF) is given by:

where *N* is the number of years and *i* is the annual real interest rate (%). It was assumed that all prices escalate at the same rate, and uses 'annual real interest rate' rather than the 'nominal interest rate'.

The NPC was calculated using a discount rate of 12% similar to the commercial rate of return (Winkler *et al*., 2009b).

3.2.1.8. Other Inputs

Carbon emissions[13] were calculated to be 11 300 kg/year based on electricity consumption of 31 kwh/day. Using a 20% reduction of emissions, a limit of 9000 kg/year CO_2 was set.

3.2.1.9. Sensitivity Analyses

Sensitivity analyses were done on parameters that could affect the costs of technologies significantly. Besides the electricity tariffs, different carbon taxes were modeled. Simulations included 1) no emissions tax, 2) tax of R75/ton and 3) R200/ton[14] CO_2 according to SA's proposed carbon rates (Department of National Treasury, 2010). A simulation was also undertaken using a carbon tax of R750/ton in line with the recommended tax level in the LTMS (Department of National Treasury, 2010). These tax levels were used to determine if they would allow on-site RE to become economically feasible. A tentative analysis of the discount rate showed that it did not affect NPC prices drastically and thus was not investigated further (see appendix).

[13] 1 kWh = 0.98 kg/CO_2 (Eskom, 2010a).
[14] 2011 Rand value

3.2.1.10. Analyses of Outputs

Using all of the above parameters, HOMER produced the optimum hybrid PV/wind/grid system configuration for each RE fraction; electricity cost and carbon tax. With this information and the choice of component sizing and pricing, HOMER was able to simulate the most economically and technically feasible solution for a typical 1500m^2 supermarket in Cape Town, South Africa.

Attaining a configuration that meets both the least cost option as well as the highest RE fraction was addressed by an iterative process of utilizing a series of simulations with different RE fractions constraints (25, 50, 75, and 100%) and evaluating them thereafter. The RE fraction of the total hybrid system was preferred to be as high as possible without considerable increases in the cost. Cost curves were used as a visual aid to determine the degree of change in costs. After several iterations, a 98% RE fraction was also included as it was found to be significantly cheaper than a 100% system (table 3.3).

3.2.2.Results

There are several benefits of installing a PV/wind hybrid power supply system. These include the ability to optimize the sizing of components (PV panels and size, wind turbine size and number, inverter etc.) to achieve the desired output and hence obtain the most economically viable solution. HOMER was able to optimize the sizings of these components based on the least cost, energy and monetary savings, and reliability and independence from the grid for each RE fraction, electricity price and carbon tax modeled.

Table 3.3 below is a summary of the results produced by HOMER with increasing proportions of RE. Detailed results can be found in Appendix 2.

Table 3.3: Costing of RE systems designed by HOMER

RE (%)	Configuration	RE Components	NPC (R)
0	100% grid	None	145 000
25	54% wind, 46% grid	0.01kW PV, 3kW wind	225 000
50	54% wind, 46% grid	0.01kW PV, 3kW wind	225 000
75	78% wind, 22% grid	0.01kW PV, 6kW wind	303 000
98	24% PV, 74% wind, 2% grid	7kW PV, 12kW wind	845 000
100	20% PV, 80% wind	8kW PV, 18kW wind	1 150 000

The cost of grid electricity was 1.45/kWh and emissions tax was R75/ton

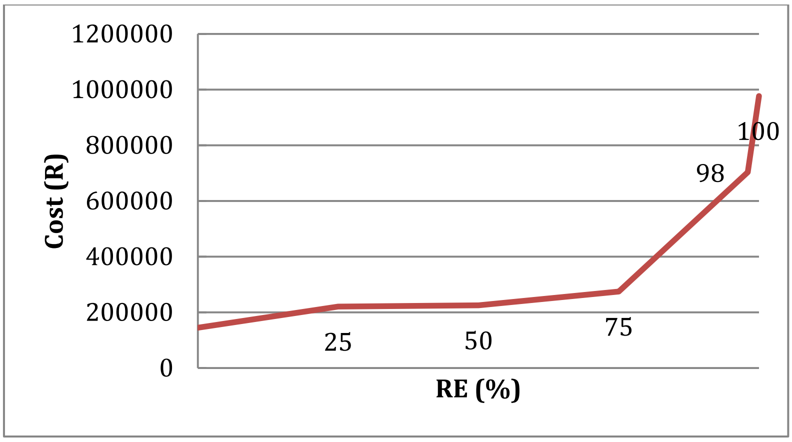

Fig. 3.6: Curves showing the changes in cost relating to varying compositions of on-site RE systems

Diversifying the energy mix to meet a small load of 31 kWh comes at a significant cost, even with a R75/ton carbon tax and electricity tariff of R1.45/kWh. Grid electricity was calculated to cost R145 000 over the 25 year period. Using a 50% diversion of wind and solar PV energy, costs increased by about 60%. The cost curve (Fig. 3.6) shows that at 98% RE in the mix, the cost increases considerably from 75%. At 100% RE, the price continues to increase exponentially with only a 2% increase in RE, resulting in the price being more than R1 million or almost 10 fold as much as grid electricity. The sudden increase in the price from 75% to 98% and to 100% can be ascribed to the inclusion of significant number of PV panels and wind turbines. At 50 and 75%, the PV fraction is negligible (0.1 kW) however at 98%, PV replaces the grid almost completely.

Table 3.4: Sensitivity analyses showing impact of the proposed carbon taxes on cost of electricity using different RE fractions.

	Carbon Tax			
RE fraction (%)	**R0**	**R75**	**R200**	**R750**
0	138 000	145 000	157 000	210 000
25	222 000	225 000	226 000	230 000
50	222 000	225 000	229 000	250 000
75	305 000	303 000	301 000	291 000
98	853 000	845 000	831 000	770 000
100	1 150 000	1 150 000	1 150 000	1 150 000

The influence of the proposed carbon taxes on NPC is illustrated in Table 3.4. The NPC increases for 0 and 50% RE system, but decreases for the 75 and 98% hybrid systems with the decrease becoming more considerable towards grid independent configurations. There is no effect on the 100% RE system as no grid electricity is being used and thus no carbon is emitted. RE hybrid systems were still prohibitive at R200/ton. Only at R750/ton, do RE systems start to become worthy of consideration as the cost differential between coal based grid electricity and 50% RE is only R40 000, or almost half the original cost where no carbon tax was implemented.

3.3. Costing of Tradeable Renewable Energy Certificates (TRECs)

An alternative to on-site RE generation is the purchase of RE through the grid, which is available in the form of TRECs. Although TRECs are considered an offset, they are in essence a form of RE, as the RE is produced elsewhere and fed into the national grid. The customer then purchases the RE in the form a certificate, where a surcharge for the certificate is added on to the normal electricity tariff. Therefore TRECs were considered as an option to facilitate carbon reduction. The cost of TRECs was calculated to compare it to that of on-site RE systems and SWHs.

3.3.1. Methods

The cost of TRECs to offset 5% of emissions were calculated at 25c/kWh (City of Cape Town, 2010) over and above the normal Eskom tariff of R1.45/kWh. Therefore total TRECs were R1.70/kWh. Prices including carbon taxes of R75; R200 and R750/ton CO_2 were also calculated. The total annualized cost was calculated over 25 years. The continuously increasing costs of electricity every year was not taken into account, as HOMER did not include this option. Therefore, further research is required to take continuously increasing prices into consideration. A discount rate of 12% was used (Winkler *et al.*, 2009b). Changes in the price of the TREC itself was not included as this is uncertain (City of Cape Town, 2010). In order to compare to the 50% hybrid on-site RE in section 3.2, the cost of TRECs to offset 17kWh/day was calculated.

3.3.2 Results

Table 3.5 shows that if TRECs are purchased to offset 5% emissions, instead of using a 50% hybrid on-site RE generation, the annualized cost of TRECs over the lifetime of the RE installation of 25 years is cheaper (TRECs = R91 500 compared to RE = R222 000) (Table 3.3 and 3.5). Even when the carbon tax of R750 was imposed, TRECs were cheaper than on-site electricity generation (Tables 3.4 and 3.5).

Table 3.5: NPC of purchasing TRECs over 25 years at different carbon tax levels.

	No tax	R75[15] tax	R200[16] tax	R750[17] tax
Cost of Electricity Plus TRECs	R1.70/kWh	R1.78/kWh	R1.90/kWh	R2.45/kWh
Total electricity usage/year (kWh)	6 205	6 205	6 205	6 205
Cost of TRECs for year1 (R)	10 050	11 045	11 800	15 202
Annualised cost of TRECs over 25 years (R)	**91 500**	**96 000**	**102 300**	**132 000**

Refer to Appendix 6

3.4. Cost evaluation of Solar Water Heaters (SWHs) as an alternative to on site RE and TRECs

SWHs were included as a renewable form of energy where water is heated as a direct result of solar radiation converted to heat. Unlike with RE on-site generation or TRECs, SWHs do not generate electricity. SWHs are a popular RE technology, especially in SA with high levels of solar resources between 5 800 and 8 000 Wh/m^2/day (Fluri, 2009). The purpose of including SWHs in this study was not to compare it to the cost of hybrid RE systems or TRECs, but to provide a contrast to the high amount of RE that SWHs can provide at low cost against the small amount of RE generated from on-site RE electricity production or TRECs at high cost. Furthermore, SWHs are included due to its support from government, who have provided subsidies for the purchasing and installation of SWH for both the residential and commercial sectors. SWH were thus evaluated as an alternative to both on-site RE and TRECs.

3.4.1. Method

In order to calculate the lifecycle costs of SWHs, the following assumptions were made. The average hot water consumption for the bakery in a store was 300L (Webber, 2010). Using this consumption, a 250L flat plate SWH was recommended by suppliers (Webber, 2010). The cost of a 250L SWH with installation is R26 000 excluding the Eskom rebate. The lifetime was extended to 25 years in order to compare costs to hybrid RE and TRECs, but a 15-20 year lifespan is normal. Maintenance costs of R1500/year were included for annual servicing (Webber, 2010) with 4% inflationary increases per year (Darmalingam, 2011). Hot water requirements contribute to 12% of total store electricity consumption (Pick n Pay, 2010). Electricity savings on water heating were 70% (Webber, 2010) as electricity was used as a backup. Electricity costs were based on

[15] R75/tons CO_2 = additional cost of 8c/kWh
[16] R200/tons CO_2 = additional cost of 20c/kWh
[17] R750/tons CO_2 = additional cost of 75c/kWh

R1.45/kWh. Due to HOMER not being able to incorporate the rising cost of electricity every year, it was decided that in order to make the results comparable, the rising costs of electricity would not be included. Again, it is acknowledged that this is a major omission and that further investigations are required. A discount rate of 12% was used (Winkler *et al.*, 2009b) (Refer to Appendix 3 for calculations). The NPC was also calculated when carbon taxes of R75, R200 and R750 were imposed.

Electricity costs =

[(Annual store consumption (kWh) x

% hot water consumption end use) – SWH electricity saving]

x electricity cost/kWh (R)

3.4.2. Results

The life time annualized cost of SWHs was compared to the electricity costs of a currently installed electrical geyser. Table 3.6 shows the costs for CAPEX, maintenance, and electricity (refer to Appendix 3 for calculations).

Table 3.6: NPC estimation for SWHs

	SWH	**Electric geyser**
Units required	1	
Initial CAPEX/unit (R)	17 000*	
Product life time	25	
Annualised Maintenance Costs (R)	17 700	
Total costs for all units	**34 700**	
Electricity costs/month (R)	1100	3 300
Annualised Electricity costs over life	**107 200**	**355 000**
Total costs (R)	**141 900**	**368 300**

* Initial Capex/unit = R26 000 –R9000 (rebate) = R17 000. Installation costs included.

Over the operational lifetime, a SWH with electrical backup would cost R141 900 (Table 3.6). The majority of the costs are attributable to fuel (electricity). Comparatively, using an electric geyser would cost more than double, the electricity costs amounting to R 368 000.

The effect of the carbon taxes on the price of electricity for the SWH with electricity backup is shown in Table 3.7.

Table 3.7: NPC for SWHs at different carbon tax levels

Tax	**R0**	**R75**[18]	**R200**[19]	**R750**[20]
Annualised unit costs (R)	34 700	34 700	34 700	34 700
Annualised electricity costs (R)	107 200	112 500	122 300	163 400
Total costs (R)	**143 900**	**147 200**	**167 000**	**208 100**

Due to SWH being backed up with an estimated 30% electricity, carbon taxes have a substantial influence on the total cost of electricity used to heat water as well as the NPC over 25 years.

Using a SWH would save 151 tons CO_2/year and almost 4000 tons CO_2 over its lifetime, reducing the electricity consumption and carbon footprint of the store by 8.4% (Appendix 4). These savings are quite sensitive to weather conditions. Depending on the time of year, SWH may be more reliant on electricity. Although the average usage of electricity over the year is 30%, the seasonal variations make SWHs sensitive to increasing electricity prices.

Summary – Comparison of the costs of on-site RE electricity, SWHs and TRECs

The table below compares the NPCs of the three RE options considered in this study as well as grid electricity. At no point does on-site RE nor TRECs become cheaper than grid electricity. Infact, the increasing electricity and proposed carbon taxes do not decrease the cost differential between grid and the alternative options significantly. This is due to 50% of the on-site electricity being sourced from grid, and TRECs being sensitive to increasing electricity prices. However, TRECs are a more cost effective way of reducing the carbon footprint than on-site generation. TRECs are less than half the cost of on-site generation without carbon taxes imposed, and even with a high carbon tax of R750/ton, TRECs are still cheaper (Table 3.8 below). This is due to economies of scale of RE production associated with TRECs. The NPC of SWHs is higher than TRECs but still less than on-site generation. Importantly, SWH will contribute 8.4% RE compared to the other two which will only lower the electricity consumption by a negligible amount (73/ 150 000 kWh) and at a small increase in the NPC. Therefore, SWHs are the best option to reducing the electricity consumption and the carbon footprint of a store.

[18] Electricity cost: R1.45 + 8c = R1.52
[19] Electricity cost: R1.45 + 20c = R1.65
[20] Electricity cost: R1.45 + 75c = R2.20

Table 3.8: Comparison of the NPC of the RE technologies evaluated at increasing carbon tax levels

		NPC (R)		
Carbon tax	**Grid (50%)**	**On-site RE (50%)**	**TRECs**	**SWH**
R0	70 000	222 000	91 000	143 900
R75	72 500	225 000	96 000	147 200
R200	78 500	229 000	102 300	167 000
R750	105 000	250 000	132 000	208 100

R1.45 kWh used for all calculations

3.5 Discussion

The modeling demonstrated that wind and PV in combination with grid-supply was able to meet the demand load of both a POS systems and lights for an average supermarket in Cape Town, SA, but at considerably higher costs than coal based grid electricity, even with the high electricity tariffs and carbon taxes modeled. The carbon tax variables of R75, R200 and R750 used in this study show that even at these high levels, RE is still more expensive. However, as mentioned, it is important note that a base cost of R1.45/kWh was used for these calculations as HOMER was unable to include the continuously increasing costs. Therefore its inclusion into the model would decrease the gap between grid electricity and RE costs more a system that is less dependent on grid electricity – as seen in table 3.8, for 50% on-site RE, the cost differential does not decrease. When a less grid dependent system is compared to grid, the differential decreases, although minimally (Appendix 5). Thus higher carbon taxes and/or electricity prices are required to make on-site RE economically feasible. The decreasing costs of RE technologies such as wind and PV, through technology learning, were also not factored into these calculations. These costs are very important since technology learning of all commercial RE technologies has resulted in their costs decreasing significantly. Since these technologies have not reached market maturity, their costs are expected to decrease further (Greenpeace International, 2007). A decline in prices is also expected due to economies of scale, i.e. the cost of RE will be lower per kWh for installations larger than those required to meet the electricity demands of POS and lights.

A 50% diversification of electricity supply for POS and lights results in a 60% increase in the cost. The cost increases more than 7x at 98% compared to no RE. At 100% RE, the NPC is almost 10x more than grid electricity with only a marginal increase in RE fraction compared to 98%. This is due to the inclusion of large solar PV panels at 98 and 100%. Diversifying the electricity supply is thus not recommended at present. In the future, if the carbon tax level is set to R200/ton of CO_2, then the retailer could take a 50% RE system composed of 0.1kW PV and 3 kW wind into consideration.

The cost of TRECs compared to on-site RE system are less than half. This is due to economies of scale, i.e. the certificates are attributable to RE that is generated in large centralized power plants, typically in MW size (GreenX Energy, 2010). TRECs are sensitive to price increases as the consumer still needs to pay for the TRECs over and above the normal electricity bill. However, it is important to remember that the price of TRECs itself may decrease in future due to economies of scale, however, the differential between the Eskom tariff and the TRECs will always be maintained (GreenX Energy, 2010). In addition, the ability to buy TRECs over on-site production is more convenient and many organizations have used this facility to offset emissions. It is worthwhile to invest in TRECs in the interim until market forces such as a combination of carbon, electricity prices, learning curves, etc. make on-site RE more favourable.

The installation of SWH is able to reduce the carbon emissions of the store by 8.4%. SWHs saved 70% of costs linked to water heating. Over its lifetime, the costs were R143 900 which is almost half that of a 50% RE hybrid system, however, the capital costs were minimal (R17 000 compared to over R100 000 for the 50% RE – see appendix 1). The majority of the costs associated with SWH were due to the electricity costs, where 30% of grid electricity was estimated as a backup. Thus SWHs are very sensitive to increasing electricity costs.

Due to HOMER not being able to incorporate increasing electricity tariffs into the model, this important factor was omitted in all the calculations. It is expected that if the increasing costs are included, the cost differential between grid and alternative RE technologies will decrease. A more detailed study needs to be done using a different programme that can include this for a more realistic analysis of RE electricity generation feasibility, which can determine at which carbon tax and electricity tariff, alternative RE technologies can be economically viable.

3.6. Conclusion

An on-site RE hybrid grid connected system composed of 50% RE was found to be the best option, although the cost of the on-site system was still more expensive than grid electricity. Under no carbon tax level modeled, did on-site RE out compete grid. However, as HOMER was unable to include the increasing cost of electricity, the results are inconclusive, and further research is needed to determine at what coal-based/grid electricity cost, on-site would be viable. Using a tariff of R1.45/kWh and carbon tax of R75, the cost of this system was compared to TRECs as an alternative method of RE. The cost of TRECs were cheaper than on-site, however it was still very vulnerable to increasing electricity tariffs, as was the 50% RE on-site system.

The cost of TRECs and on-site RE were also contrasted against the cost of SWHs which are able to reduce the electricity/emissions by more than 8%. Due to the low cost of SWHs and the high carbon emissions saved, SWHs are therefore recommended.

Chapter 4: Final Conclusion and Recommendations

As international negotiations on climate change and global warming continue, and South Africa takes steps to reduce GHG emissions, together with consumers becoming more aware of the impact they have on the environment, local retailers are being pressed to implement environmentally friendly and sustainable business practices in order to adapt to changing market conditions and customer demands. Coupled with the electricity price hikes of 25% year on year for the next three years and the possible onset of carbon taxes, food retailers are faced with urgent decisions on how to reduce their electricity consumption and carbon footprint. The big food retail companies in SA have been investigating various measures, but with little research or local case studies available in the local context, retailers are looking to international companies for direction. Thus there is a need for research to determine technologically appropriate measures for South Africa, specifically focusing on the feasibility assessments for electricity and carbon reduction in different climatic regions of the country, and thereafter the types of plans of actions, their procedures and/or processes, all of which need to be undertaken for successful execution. This study not only attempted to answer the first part of these issues by performing a techno-economic feasibility assessment of reduction options, but also suggests how electricity and carbon reduction should be tackled using these technologies together with the supporting structures and behavioural changes.

The review of the literature at the beginning of this project found that besides the disincentives of electricity tariffs and proposed carbon taxes, government is simultaneously providing incentivizing tools such as subsidies and rebates for SWH's and heat pumps; preferential electricity prices for those using energy efficient lights, and feed-in tariffs etc., which aid in creating an enabling environment for the uptake of these technologies. Besides having lower CAPEX costs due to subsidies and rebates, the identification of these particular technologies by government indicates their approval and appropriateness for application in South Africa, i.e. these technologies work well in the SA climate resulting in high efficiencies in electricity savings. Additionally, these technologies are or will be easily available and accessible, with supported after sales service. Therefore these types of technologies were concentrated on from the outset.

Furthermore, a survey identified other criteria which were important to South African food retail companies. These included costs related to maintenance; the ease of implementation; carbon and electricity savings; long term financial rewards (economic profitability) and employee and customer awareness and visibility. All of these criteria were thus key to devising a basis for the creation of a shortlist of technologies to consider. Using this approach, the needs of the different retailers with regards to each of these criteria were used to then segregate retailers into different categories. In this way, recommending a set of technologies for the retailers in a "blanket fashion" was averted resulting in more appropriate technologies being chosen for the different retailer categories, and thus increasing the likelihood that these technologies would be accepted for uptake.

While doing the survey to determine essential criteria for technology selection, the survey revealed the concerns and attitudes of the retailers towards climate change, carbon and electricity reduction and energy security. Due to the business model of the big retailers studied, retailers had very different drivers and reactions towards climate change, and its threats and opportunities. While some retailers were proactive in addressing these concerns, others preferred to wait until there was government policy or until the market favoured these measures. Furthermore, some retailers were prepared to take on more risk than others, experimenting with less developed technologies.

4.1 Recommendations on Technology Uptake

Profiling of the big food retailers, together with government policy and mandates, and Eskom's Demand Side Management programme, helped to create a shortlist of technologies. The analysis shows that from the shortlist, closed refrigeration units showed the biggest carbon/electricity and long term financial savings, followed by evaporative cooling, natural refrigerants (CO_2) and heat reclamation from the refrigeration process to heat water. Other interventions such as energy efficient lighting and heat pumps also showed good profitability with short pay back periods, however, they did not decrease the electricity consumption as aggressively as the former group of technologies. Depending on the drivers and targets for reductions of the retailer, different technology options were recommended. A combination of closed refrigerators (which retailers perceive to present a negative customer shopping experience) and heat reclamation from refrigeration, clearly show the highest carbon/electricity savings and economic profitability, and are thus recommended for category 1 retailers, who are progressive and willing to experiment.

A combination of energy efficient lights, POS power management systems, fridge curtains, electronic monitoring controls for refrigeration and heat reclaim meet the electricity targets and are recommended for category 3 retailers that are conservative and operate on lean business models. These technologies are proven, cheap to install, operate easily, with almost the same CAPEX and NPV as those technologies recommended for category 1 retailers.

After considering energy efficiency options, a feasibility study on the applications of renewable energy technologies was also undertaken. While renewable energy remains an extremely expensive venture, renewable energy for electricity generation is still being considered and even trialed by some food retail companies, this mostly due to solar PV and wind turbines making appearances in international supermarkets such as Walmart and Tesco. Due to several places in South Africa having good wind and solar resources, the design and cost of a grid-connected hydrid solar PV-wind system was attained using the HOMER software package. HOMER was able to match the renewable energy outputs to varying load demands during the day which is typical of supermarkets. This software, which is freely available for download on the internet, was used to demonstrate its appropriateness to the supermarket environment in South Africa, as well as its ease and user friendliness. However, the continuously projected electricity costs could not be factored into the model and thus, the use of HOMER is limited. By using the information that was attained, the costs of the hybrid wind-solar grid tied systems produced by HOMER, were then compared to the costs of an equivalent amount of Tradeable Renewable Energy Certificates (TRECs), a mechanism used for offsetting. At all RE fractions modeled, the cost of TRECs outcompete on-site RE production. Grid electricity was still cheaper than on-site RE even with increased electricity tariffs of R1.45/kWh and a carbon tax of R750/ton CO_2, however, depending on the dependence of the hybrid system on grid electricity, the differential between the two costs (grid and RE) decreased. It is expected that if the increasing costs of electricity was able to be factored into the model, then the cost differential between RE and grid would further decrease (depending on the RE fraction of the system). The actual tariff required in order for on-site RE to compete with the costs of grid electricity requires further investigation.

The costs of the amount of TRECs and on-site RE to reduce the emissions of the store by less than 0.5% were also judged against the cost of solar SWHs which is able to reduce carbon emissions by 8%. SWHs were orders of magnitude cheaper than the former two technologies, and thus offered a lucrative alternative to reducing the carbon footprint through RE. Therefore SWHs is the only RE technology that is recommended currently for all retailers.

However, taking all technologies into consideration, heat pumps can be more efficient that a SWH depending on location. With the new government subsidy for heat pumps making them cheaper than SWHs currently, it is recommended that heat pumps be used instead of SWHs. Therefore, where appropriate, only EE technologies should be currently considered, until the market favours the production of RE technologies. As with all countries and all sectors, the research findings are consistent with EE technologies being the most effective way to reduce electricity consumption and mitigate carbon emissions currently and in the future. It will take drastic market changes to make on-site RE generation more affordable and cost competitive.

Because there were many generalizations and assumptions used in this analysis, this research forms a preliminary investigation into the techno-economic feasibility of electricity and carbon reduction in the supermarkets. A major pitfall of this study was the inability to incorporate increasing electricity costs in the HOMER software package to correctly reflect the costs associated with on-site generation. Furthermore, in future, as carbon reduction becomes mandatory, a MCDA approach rather than a pure financial analysis may be more appropriate to determine the best technology options. Nevertheless, it is hoped that this analysis will provide a guide and spur on further research for refinement in specific companies and in specific locations in SA.

4.2. Recommendations to support the uptake of EE and RE technologies for successfully reducing electricity consumption and carbon emissions.

Although the potential for electricity and carbon mitigation is substantial in the sector, owing to the sheer size of the industry, these undertakings cannot be achieved without a change in the mindset of individuals within the company from top management to the people working in the stores. Education, awareness and buy-in are essential to make these efforts a success. Technology options alone cannot function correctly and at optimal efficiency if strict procedures for operation, maintenance and care are not adhered to. A lack of buy-in usually results in carbon reduction being side-lined. Thus if there is no priority given to electricity and carbon reduction, the messages do not get filtered down resulting in staff who are not educated and inadequately prepared to care for equipment. Therefore action plans become necessary. Once the most suitable electricity reduction technologies have been identified, daily electricity consumption profiles should also be scrutinized to determine if there are peaking periods, and if this is due to behavioural reasons. This will give insight into what staff behavioural changes are required which will thus provide direction for administering policies and procedures within the supermarkets and ultimately give effect to support the efficient use of technologies.

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Appendices

Appendix 1: NPV calculations for EE technologies

Net Present Value (NPV): Electronic Ballast & T8 light						
Solution: NPV of Project is: R 494,841.82						
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 10,200	R 28,795	Not Applicable	R 10,200	R 28,795	R 18,595
Year 1		R 35,994	9.4%	R 0	R 32,901	R 32,901
Year 2		R 44,993	9.6%	R 0	R 37,525	R 37,525
Year 3		R 49,492	10.7%	R 0	R 37,287	R 37,287
Year 4		R 54,442	11.1%	R 0	R 36,918	R 36,918
Year 5		R 59,886	11.4%	R 0	R 36,454	R 36,454
Year 6		R 65,874	11.7%	R 0	R 35,899	R 35,899
Year 7	R 13,423	R 72,462	11.8%	R 6,543	R 35,321	R 28,779
Year 8		R 79,708	12.0%	R 0	R 34,691	R 34,691
Year 9		R 87,679	12.1%	R 0	R 34,041	R 34,041
Year 10		R 96,446	12.0%	R 0	R 33,433	R 33,433
Year 11		R 106,091	12.0%	R 0	R 32,836	R 32,836
Year 12		R 116,700	11.8%	R 0	R 32,307	R 32,307
Year 13		R 128,370	11.7%	R 0	R 31,816	R 31,816
Year 14		R 141,207	11.6%	R 0	R 31,359	R 31,359

Net Present Value (NPV): **CFL**

Solution: NPV of Project is:				**R 125,742.11**		
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	-R 257.00	R 7,026.00	Not Applicable	-R 257.00	R 7,026.00	R 7,283.00
Year 1		R 8,783.00	9.4%	R 0.00	R 8,028.34	R 8,028.34
Year 2		R 10,979.00	9.6%	R 0.00	R 9,156.61	R 9,156.61
Year 3	-R 289.09	R 12,076.90	10.7%	-R 217.80	R 9,098.71	R 9,316.51
Year 4		R 13,284.59	11.1%	R 0.00	R 9,008.63	R 9,008.63
Year 5		R 14,613.05	11.4%	R 0.00	R 8,895.41	R 8,895.41
Year 6	-R 325.19	R 16,074.35	11.7%	-R 177.22	R 8,760.03	R 8,937.25
Year 7		R 17,681.79	11.8%	R 0.00	R 8,618.99	R 8,618.99
Year 8		R 19,449.97	12.0%	R 0.00	R 8,465.08	R 8,465.08
Year 9	-R 365.79	R 21,394.97	12.1%	-R 142.02	R 8,306.50	R 8,448.52
Year 10		R 23,534.46	12.0%	R 0.00	R 8,158.17	R 8,158.17
Year 11		R 25,887.91	12.0%	R 0.00	R 8,012.49	R 8,012.49
Year 12	-R 411.47	R 28,476.70	11.8%	-R 113.91	R 7,883.49	R 7,997.40
Year 13		R 31,324.37	11.7%	R 0.00	R 7,763.51	R 7,763.51
Year 14		R 34,456.81	11.6%	R 0.00	R 7,652.20	R 7,652.20

Net Present Value (NPV): Power Management software						
Solution: NPV of Project is: R 140,306.82						
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 1,600	R 6,900	Not Applicable	R 1,600	R 6,900	R 5,300
Year 1	R 300	R 10,764	9.4%	R 274	R 6,307	R 6,033
Year 2	R 312	R 13,455	9.6%	R 260	R 8,977	R 8,717
Year 3	R 324	R 14,801	10.7%	R 244	R 10,137	R 9,893
Year 4	R 337	R 16,281	11.1%	R 229	R 11,040	R 10,811
Year 5	R 351	R 17,909	11.4%	R 214	R 10,902	R 10,688
Year 6	R 365	R 19,699	11.7%	R 199	R 10,736	R 10,537
Year 7	R 380	R 21,669	11.8%	R 185	R 10,563	R 10,378
Year 8	R 395	R 23,836	12.0%	R 172	R 10,374	R 10,202
Year 9	R 411	R 26,220	12.1%	R 159	R 10,180	R 10,020
Year 10	R 427	R 28,842	12.0%	R 148	R 9,998	R 9,850
Year 11	R 444	R 31,726	12.0%	R 137	R 9,819	R 9,682
Year 12	R 462	R 34,899	11.8%	R 128	R 9,661	R 9,534
Year 13	R 480	R 38,389	11.7%	R 119	R 9,514	R 9,395
Year 14	R 500	R 42,228	11.6%	R 111	R 9,378	R 9,267

Net Present Value (NPV): Fridge curtains						
Solution: NPV of Project is: R 1,296,882.08						
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 30,000	R 77,500	Not Applicable	R 77,500	R 77,500	R 0
Year 1	R 300	R 96,900	9.4%	R 274	R 88,574	R 88,300
Year 2	R 312	R 121,100	9.6%	R 260	R 100,999	R 100,739
Year 3	R 324	R 133,210	10.7%	R 244	R 100,360	R 100,116
Year 4	R 337	R 146,531	11.1%	R 229	R 99,366	R 99,138
Year 5	R 351	R 161,184	11.4%	R 214	R 98,118	R 97,904
Year 6	R 365	R 177,303	11.7%	R 199	R 96,624	R 96,426
Year 7	R 380	R 195,033	11.8%	R 185	R 95,069	R 94,884
Year 8	R 395	R 214,536	12.0%	R 172	R 93,371	R 93,199
Year 9	R 411	R 235,990	12.1%	R 159	R 91,622	R 91,463
Year 10	R 427	R 259,589	12.0%	R 148	R 89,986	R 89,838
Year 11	R 444	R 285,547	12.0%	R 137	R 88,379	R 88,242
Year 12	R 462	R 314,102	11.8%	R 128	R 86,956	R 86,828
Year 13	R 480	R 345,512	11.7%	R 119	R 85,633	R 85,514
Year 14	R 500	R 380,064	11.6%	R 111	R 84,405	R 84,294

Net Present Value (NPV): **Fridge with doors**						
Solution: NPV of Project is: R 4,719,021.93						
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 100,000	R 271,252	Not Applicable	R 100,000	R 271,252	R 171,252
Year 1		R 339,066	9.4%	R 0	R 309,932	R 309,932
Year 2		R 423,823	9.6%	R 0	R 353,473	R 353,473
Year 3		R 466,205	10.7%	R 0	R 351,238	R 351,238
Year 4		R 512,826	11.1%	R 0	R 347,761	R 347,761
Year 5		R 564,108	11.4%	R 0	R 343,390	R 343,390
Year 6		R 620,519	11.7%	R 0	R 338,164	R 338,164
Year 7		R 682,571	11.8%	R 0	R 332,719	R 332,719
Year 8		R 750,828	12.0%	R 0	R 326,778	R 326,778
Year 9		R 825,911	12.1%	R 0	R 320,656	R 320,656
Year 10		R 908,502	12.0%	R 0	R 314,930	R 314,930
Year 11		R 999,352	12.0%	R 0	R 309,307	R 309,307
Year 12		R 1,099,288	11.8%	R 0	R 304,327	R 304,327
Year 13		R 1,209,216	11.7%	R 0	R 299,695	R 299,695
Year 14		R 1,330,138	11.6%	R 0	R 295,398	R 295,398

Net Present Value (NPV): Heat reclamation from refrigeration						
Solution: NPV of Project is: R 3,631,707.94						
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 40,000	R 206,668	Not Applicable	R 40,000	R 206,668	R 166,668
Year 1		R 258,336	9.4%	R 0	R 236,139	R 236,139
Year 2		R 322,920	9.6%	R 0	R 269,319	R 269,319
Year 3		R 355,212	10.7%	R 0	R 267,616	R 267,616
Year 4		R 390,733	11.1%	R 0	R 264,966	R 264,966
Year 5		R 429,807	11.4%	R 0	R 261,636	R 261,636
Year 6		R 472,787	11.7%	R 0	R 257,655	R 257,655
Year 7		R 520,066	11.8%	R 0	R 253,506	R 253,506
Year 8		R 572,072	12.0%	R 0	R 248,979	R 248,979
Year 9		R 629,280	12.1%	R 0	R 244,315	R 244,315
Year 10		R 692,208	12.0%	R 0	R 239,952	R 239,952
Year 11		R 761,428	12.0%	R 0	R 235,668	R 235,668
Year 12		R 837,571	11.8%	R 0	R 231,873	R 231,873
Year 13		R 921,328	11.7%	R 0	R 228,344	R 228,344
Year 14		R 1,013,461	11.6%	R 0	R 225,071	R 225,071

Net Present Value (NPV):Electronic controls and monitoring						
Solution: NPV of Project is: R 2,005,330.97						
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 60,000	R 116,251	Not Applicable	R 60,000	R 116,251	R 56,251
Year 1		R 145,314	9.4%	R 0	R 132,828	R 132,828
Year 2		R 181,642	9.6%	R 0	R 151,492	R 151,492
Year 3		R 199,806	10.7%	R 0	R 150,534	R 150,534
Year 4		R 219,787	11.1%	R 0	R 149,043	R 149,043
Year 5		R 241,766	11.4%	R 0	R 147,170	R 147,170
Year 6		R 265,942	11.7%	R 0	R 144,930	R 144,930
Year 7		R 292,536	11.8%	R 0	R 142,597	R 142,597
Year 8		R 321,790	12.0%	R 0	R 140,050	R 140,050
Year 9		R 353,969	12.1%	R 0	R 137,427	R 137,427
Year 10		R 389,366	12.0%	R 0	R 134,973	R 134,973
Year 11		R 428,302	12.0%	R 0	R 132,563	R 132,563
Year 12		R 471,133	11.8%	R 0	R 130,428	R 130,428
Year 13		R 518,246	11.7%	R 0	R 128,443	R 128,443
Year 14		R 570,070	11.6%	R 0	R 126,602	R 126,602

Net Present Value (NPV): H**eat pump-geyser**							
Solution: NPV of Project is:				**R 2,543,596.34**			
	User Data Input Area:			Automatic Calculation Area:			
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 18,000	R 144,668	Not Applicable	R 18,000	R 144,668	R 126,668
Year 1	R 1,000	R 180,835	9.4%	R 914	R 165,297	R 164,383
Year 2	R 1,040	R 226,044	9.6%	R 867	R 188,523	R 187,656
Year 3	R 1,082	R 248,648	10.7%	R 815	R 187,331	R 186,516
Year 4	R 1,125	R 273,513	11.1%	R 763	R 185,476	R 184,714
Year 5	R 1,170	R 300,865	11.4%	R 712	R 183,146	R 182,433
Year 6	R 1,217	R 330,951	11.7%	R 663	R 180,358	R 179,695
Year 7	R 1,265	R 364,046	11.8%	R 617	R 177,454	R 176,838
Year 8	R 1,316	R 400,451	12.0%	R 573	R 174,286	R 173,713
Year 9	R 1,369	R 440,496	12.1%	R 531	R 171,021	R 170,489
Year 10	R 1,423	R 484,545	12.0%	R 493	R 167,967	R 167,473
Year 11	R 1,480	R 533,000	12.0%	R 458	R 164,967	R 164,509
Year 12	R 1,539	R 586,300	11.8%	R 426	R 162,311	R 161,885
Year 13	R 1,601	R 644,930	11.7%	R 397	R 159,841	R 159,444
Year 14	R 1,665	R 709,423	11.6%	R 370	R 157,549	R 157,180

Net Present Value (NPV): Evaporative A/C						
Solution: NPV of Project is: R 2,518,372.89						
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 275,000	R 159,000	Not Applicable	R 275,000	R 159,000	-R 116,000
Year 1	R 5,500	R 199,000	9.4%	R 5,027	R 181,901	R 176,874
Year 2	R 5,720	R 250,000	9.6%	R 4,771	R 208,503	R 203,732
Year 3	R 5,949	R 275,000	10.7%	R 4,482	R 207,184	R 202,703
Year 4	R 6,187	R 302,500	11.1%	R 4,195	R 205,133	R 200,938
Year 5	R 6,434	R 332,750	11.4%	R 3,917	R 202,555	R 198,638
Year 6	R 6,692	R 366,025	11.7%	R 3,647	R 199,472	R 195,826
Year 7	R 6,959	R 402,628	11.8%	R 3,392	R 196,261	R 192,869
Year 8	R 7,238	R 442,890	12.0%	R 3,150	R 192,756	R 189,606
Year 9	R 7,527	R 487,179	12.1%	R 2,922	R 189,145	R 186,223
Year 10	R 7,828	R 535,897	12.0%	R 2,714	R 185,768	R 183,054
Year 11	R 8,141	R 589,487	12.0%	R 2,520	R 182,450	R 179,931
Year 12	R 8,467	R 648,436	11.8%	R 2,344	R 179,513	R 177,169
Year 13	R 8,806	R 713,279	11.7%	R 2,182	R 176,781	R 174,598
Year 14	R 9,158	R 784,607	11.6%	R 2,034	R 174,246	R 172,213

Net Present Value (NPV): **CO_2 fridge**						
Solution: NPV of Project is: -R 869,328.07						
	User Data Input Area:			Automatic Calculation Area:		
Year Number	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounte d flow by specific year
Year 0	R 5,000,000	R 232,502	Not Applicable	R 5,000,000	R 232,502	-R 4,767,498
Year 1		R 290,628	9.4%	R 0	R 265,656	R 265,656
Year 2		R 363,285	9.6%	R 0	R 302,984	R 302,984
Year 3		R 399,614	10.7%	R 0	R 301,068	R 301,068
Year 4		R 439,575	11.1%	R 0	R 298,087	R 298,087
Year 5		R 483,532	11.4%	R 0	R 294,341	R 294,341
Year 6		R 531,886	11.7%	R 0	R 289,861	R 289,861
Year 7		R 585,074	11.8%	R 0	R 285,195	R 285,195
Year 8		R 643,582	12.0%	R 0	R 280,102	R 280,102
Year 9		R 707,940	12.1%	R 0	R 274,855	R 274,855
Year 10		R 778,734	12.0%	R 0	R 269,946	R 269,946
Year 11		R 856,607	12.0%	R 0	R 265,126	R 265,126
Year 12		R 942,268	11.8%	R 0	R 260,857	R 260,857
Year 13		R 1,036,495	11.7%	R 0	R 256,887	R 256,887
Year 14		R 1,140,144	11.6%	R 0	R 253,204	R 253,204

NPV if extended over 25 years:

Net Present Value (NPV): **CO_2 fridge**						
Solution: NPV of Project is: R 3,569,639.18						
	User Data Input Area:			Automatic Calculation Area:		
Year Number	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate" % for each year	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 5,000,000	R 232,502	Not Applicable	R 5,000,000	R 232,502	-R 4,767,498
Year 1		R 290,628	9.4%	R 0	R 265,656	R 265,656
Year 2		R 363,285	9.6%	R 0	R 302,984	R 302,984
Year 3		R 399,614	10.7%	R 0	R 301,068	R 301,068
Year 4		R 439,575	11.1%	R 0	R 298,087	R 298,087
Year 5		R 483,532	11.4%	R 0	R 294,341	R 294,341
Year 6		R 531,886	11.7%	R 0	R 289,861	R 289,861
Year 7		R 585,074	11.8%	R 0	R 285,195	R 285,195
Year 8		R 643,582	12.0%	R 0	R 280,102	R 280,102
Year 9		R 707,940	12.1%	R 0	R 274,855	R 274,855
Year 10		R 778,734	12.0%	R 0	R 269,946	R 269,946
Year 11		R 856,607	12.0%	R 0	R 265,126	R 265,126
Year 12		R 942,268	11.8%	R 0	R 260,857	R 260,857
Year 13		R 1,036,495	11.7%	R 0	R 256,887	R 256,887
Year 14		R 1,140,144	11.6%	R 0	R 253,204	R 253,204
Year 15		R 1,254,158	11.6%	R 0	R 278,525	R 278,525
Year 16		R 1,379,574	11.6%	R 0	R 306,377	R 306,377
Year 17		R 1,517,532	11.6%	R 0	R 337,015	R 337,015
Year 18		R 1,669,285	11.6%	R 0	R 370,716	R 370,716
Year 19		R 1,836,213	11.6%	R 0	R 407,788	R 407,788
Year 20		R 2,019,835	11.6%	R 0	R 448,567	R 448,567
Year 21		R 2,221,818	11.6%	R 0	R 493,424	R 493,424
Year 22		R 2,444,000	11.6%	R 0	R 542,766	R 542,766
Year 23		R 2,688,400	11.6%	R 0	R 597,043	R 597,043
Year 24		R 2,957,240	11.6%	R 0	R 656,747	R 656,747

Appendix 2: HOMER results

(Electricity tariff 1.45/kWh; carbon tax R75/ton)

1. **0% RE**

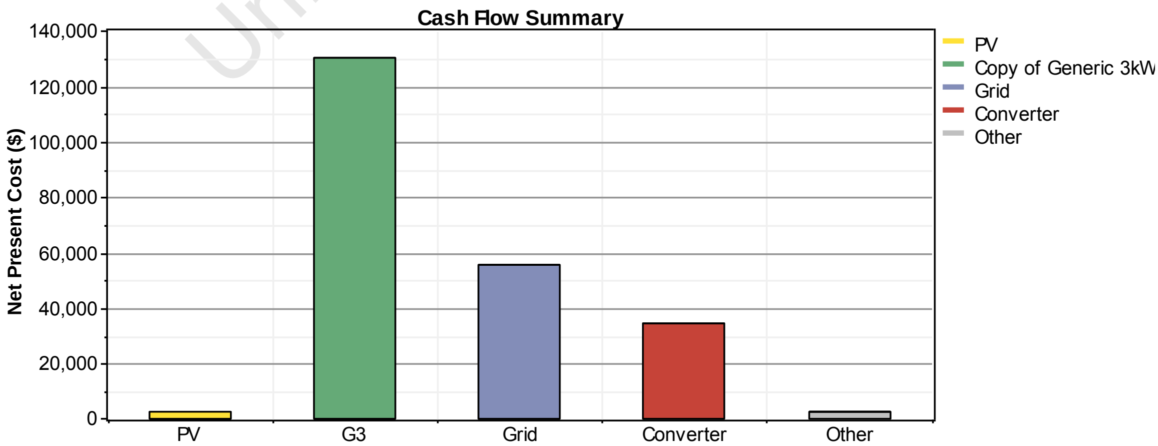
Component	Capital (R)	Replacement (R)	O&M (R)	Salvage (R)	Total (R)
Grid	0	0	138 000	0	138 000
Other	0	0	7 000	0	7 000
System	0	0	145 000	0	145 000

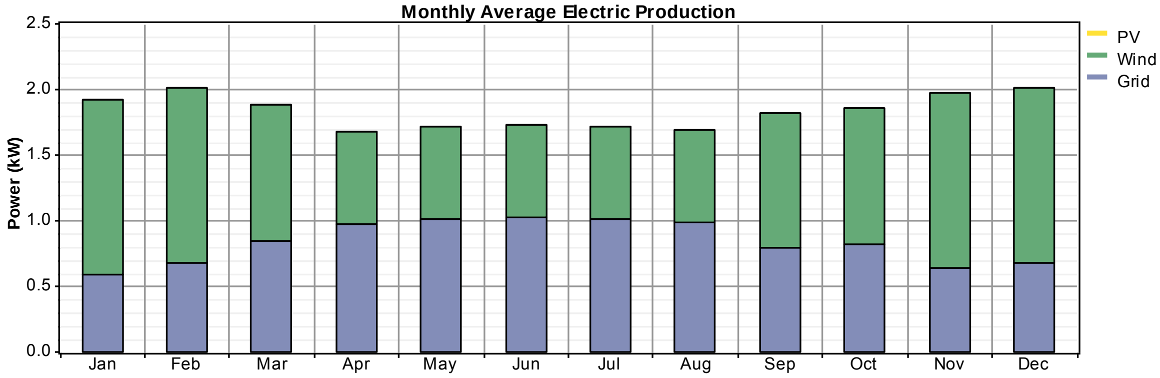
2. **25%**

Component	Capital (R)	Replacement (R)	O&M (R)	Salvage (R)	Total (R)
PV	2,275	0	0	0	2,275
Wind 1kW	73,000	0	57,255	0	130,255
Grid	0	0	55,378	0	55,378
Converter	29,500	5,390	0	-578	34,311
Other	0	0	2,864	0	2,864
System	104,775	5,390	115,497	-578	225,083

Production	kWh/yr	%
PV array	16	0
Wind turbine	8,687	54
Grid purchases	7,364	46
Total	16,067	100

Consumption	kWh/yr	%
AC primary load	12,190	83
Grid sales	2,494	17
Total	14,685	100



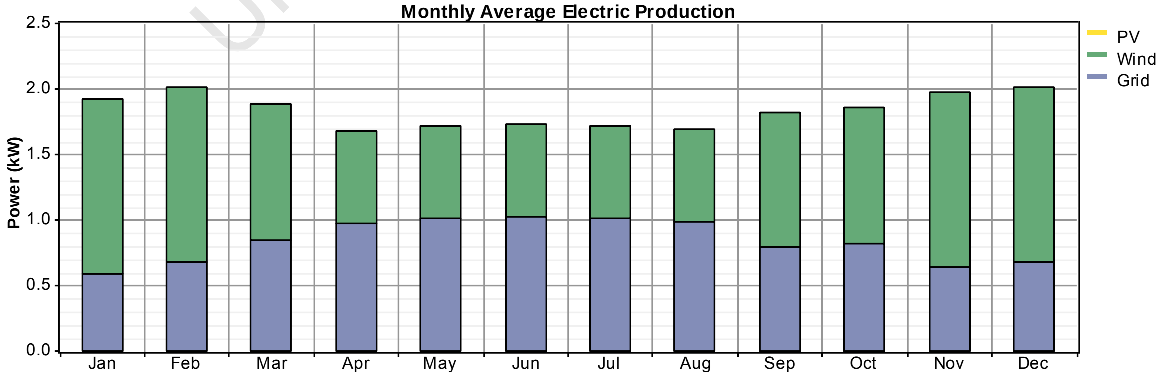


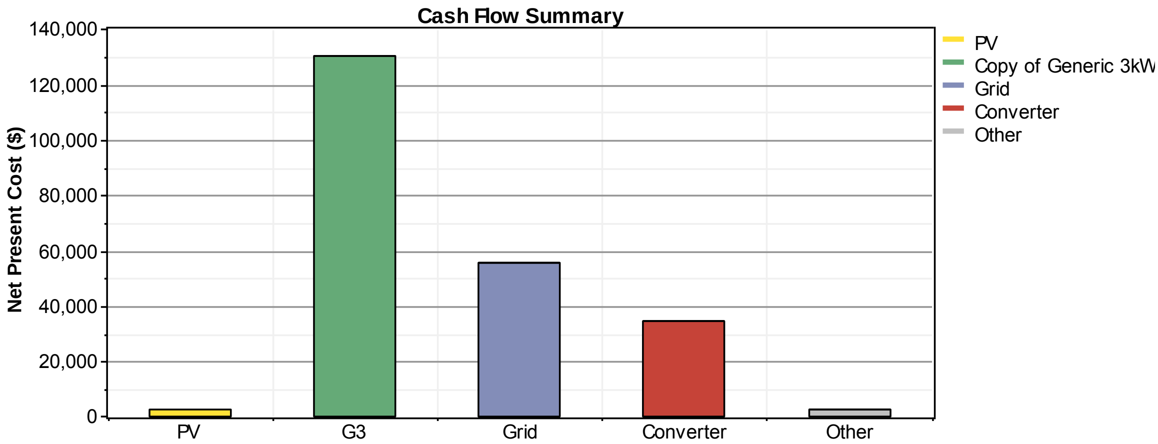
3. **50%**

Component	Capital (R)	Replacement (R)	O&M (R)	Salvage (R)	Total (R)
PV	2,275	0	0	0	2,275
Wind 3kW	73,000	0	57,255	0	130,255
Grid	0	0	55,378	0	55,378
Converter	29,500	5,390	0	-578	34,311
Other	0	0	2,864	0	2,864
System	104,775	5,390	115,497	-578	225,083

Production	kWh/yr	%
PV array	16	0
Wind turbine	8,687	54
Grid purchases	7,364	46
Total	16,067	100

Consumption	kWh/yr	%
AC primary load	12,190	83
Grid sales	2,494	17
Total	14,685	100



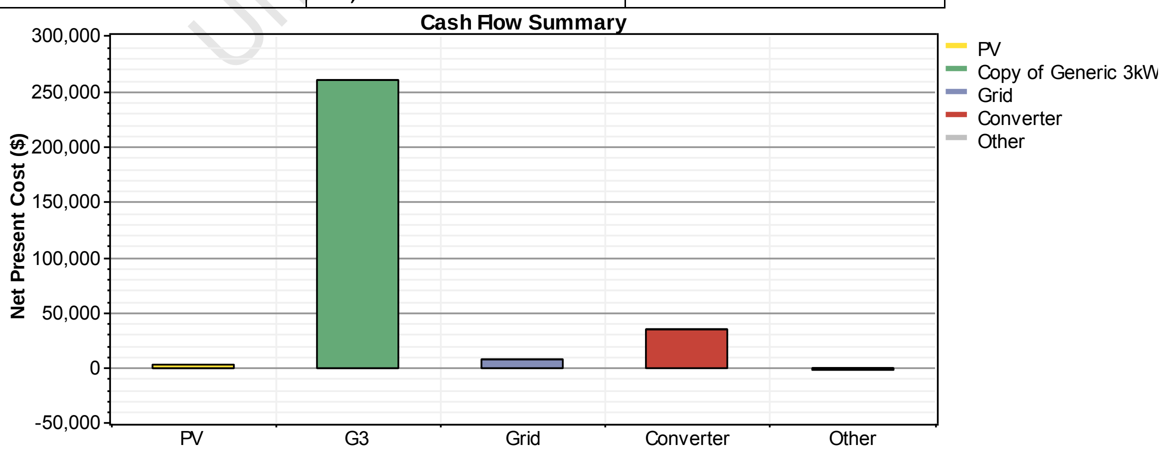


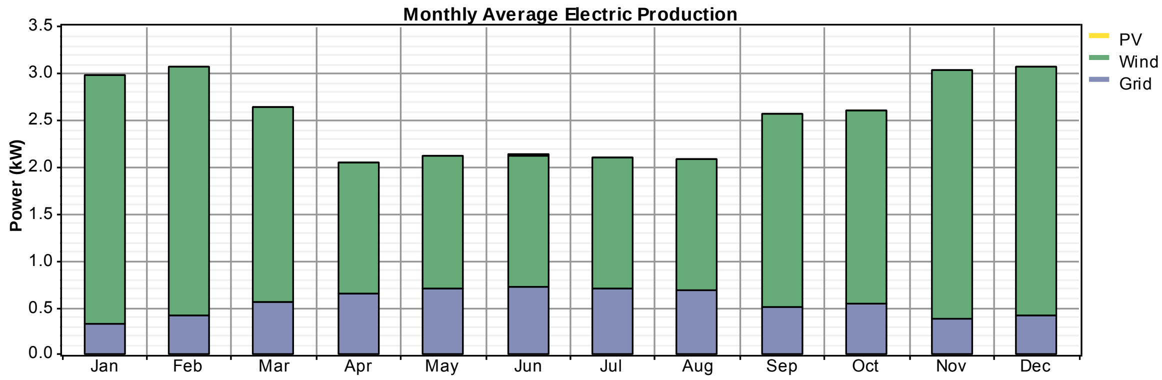
4. **75% RE**

Component	Capital (R)	Replacement (R)	O&M (R)	Salvage (R)	Total (R)
PV	2,275	0	0	0	2,275
Wind 3kW	146,000	0	114,510	0	260,510
Grid	0	0	8,080	0	8,080
Converter	29,500	5,390	0	-578	34,311
Other	0	0	-1,337	0	-1,337
System	177,775	5,390	121,252	-578	303,839

Production	kWh/yr	%
PV array	16	0
Wind turbines	17,375	78
Grid purchases	4,825	22
Total	22,216	100

Consumption	kWh/yr	%
AC primary load	12,190	63
Grid sales	7,098	37
Total	19,289	100



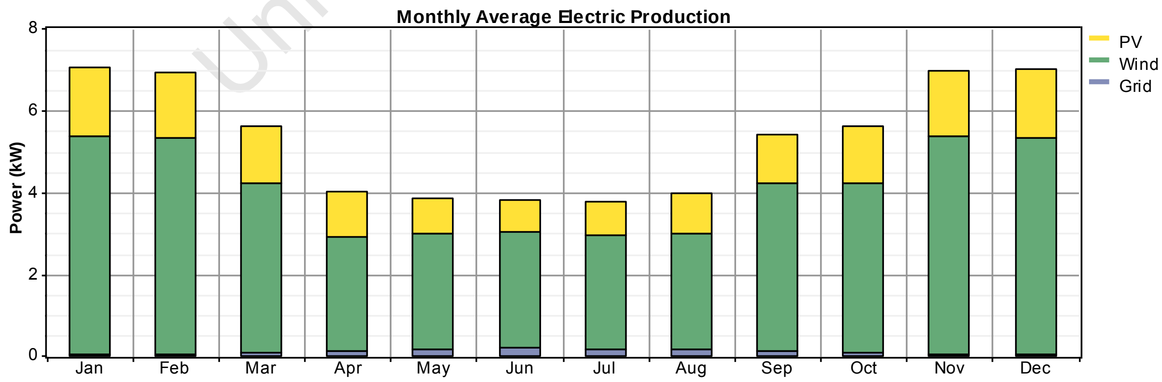


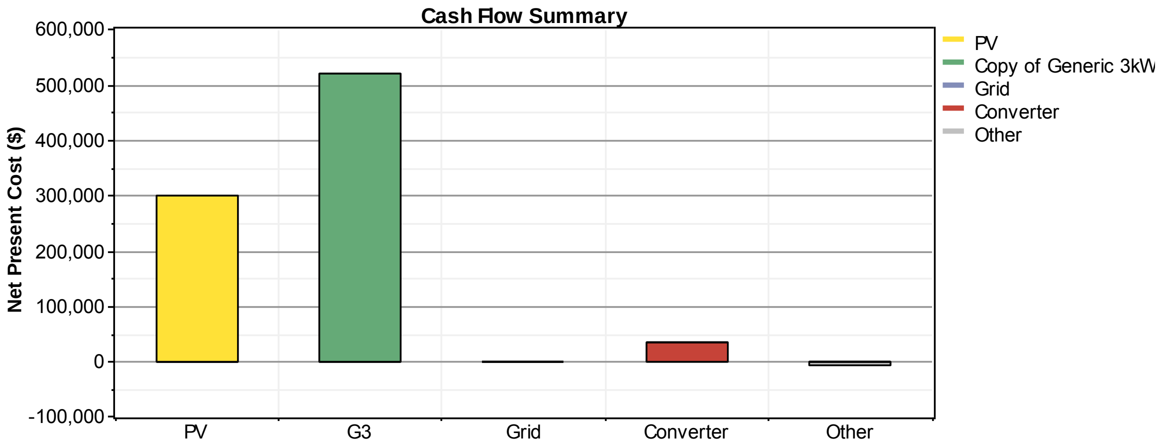
5. **98% RE**

Component	Capital (R)	Replacement (R)	O&M (R)	Salvage (R)	Total (R)
PV	298,513	0	0	0	298,513
Wind 3kW	292,000	0	229,020	0	521,020
Grid	0	0	0	0	0
Converter	29,500	5,390	0	-578	34,311
Other	0	0	-8,494	0	-8,494
System	620,013	5,390	220,525	-578	845,349

Production	kWh/yr	%
PV array	10,992	24
Wind turbine	34,750	74
Grid purchases	928	2
Total	46,670	100

Consumption	kWh/yr	%
AC primary load	12,190	44
Grid sales	15,368	56
Total	27,559	100



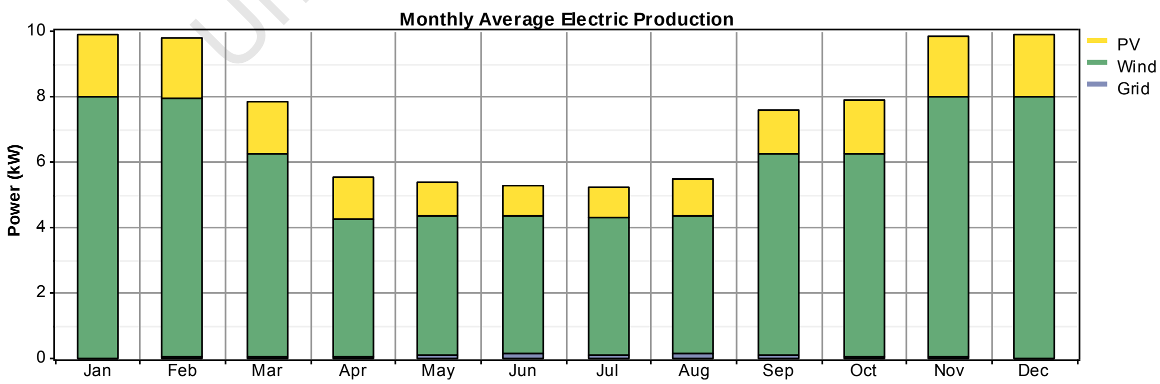


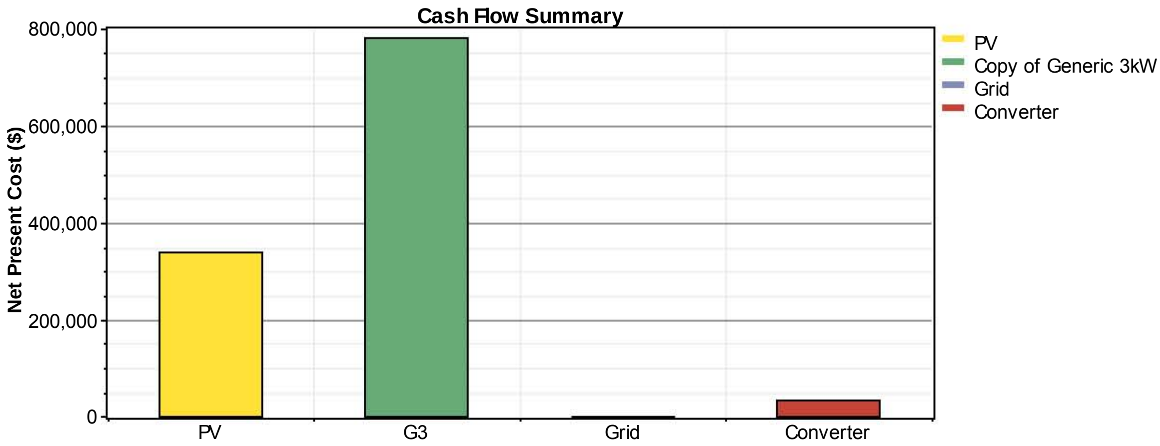
6. **100% RE**

Component	Capital (R)	Replacement (R)	O&M (R)	Salvage (R)	Total (R)
PV	340,763	0	0	0	340,763
Wind 3kW	438,000	0	343,529	0	781,530
Grid	0	0	0	0	0
Converter	29,500	5,390	0	-578	34,311
Other	808,263	5,390	343,529	-578	1,156,603
System	340,763	0	0	0	340,763

Production	kWh/yr	%
PV array	12,562	19
Wind turbines	52,125	80
Grid purchases	627	1
Total	65,314	100

Consumption	kWh/yr	%
AC primary load	12,190	41
Grid sales	17,898	59
Total	30,088	100




Cash Flow Summary
Net Present Cost ($)
800,000
600,000
400,000
200,000
0
PV
G3
Grid
Converter
PV
Copy of Generic 3kW
Grid
Converter

Appendix 3: NPV Calculations

Net Present Cost (NPC): SWH maintenance costs						
Solution: NPV of Project is: -R 17,546.21						
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 1,500		Not Applicable	R 1,339	R 0	-R 1,339
Year 1	R 1,560		12.0%	R 1,393	R 0	-R 1,393
Year 2	R 1,622		12.0%	R 1,293	R 0	-R 1,293
Year 3	R 1,687		12.0%	R 1,201	R 0	-R 1,201
Year 4	R 1,755		12.0%	R 1,115	R 0	-R 1,115
Year 5	R 1,825		12.0%	R 1,036	R 0	-R 1,036
Year 6	R 1,898		12.0%	R 962	R 0	-R 962
Year 7	R 1,974		12.0%	R 893	R 0	-R 893
Year 8	R 2,053		12.0%	R 829	R 0	-R 829
Year 9	R 2,135		12.0%	R 770	R 0	-R 770
Year 10	R 2,220		12.0%	R 715	R 0	-R 715
Year 11	R 2,309		12.0%	R 664	R 0	-R 664
Year 12	R 2,402		12.0%	R 616	R 0	-R 616
Year 13	R 2,498		12.0%	R 572	R 0	-R 572
Year 14	R 2,598		12.0%	R 532	R 0	-R 532
Year 15	R 2,701		12.0%	R 494	R 0	-R 494
Year 16	R 2,809		12.0%	R 458	R 0	-R 458
Year 17	R 2,922		12.0%	R 426	R 0	-R 426
Year 18	R 3,039		12.0%	R 395	R 0	-R 395
Year 19	R 3,160		12.0%	R 367	R 0	-R 367
Year 20	R 3,287		12.0%	R 341	R 0	-R 341
Year 21	R 3,418		12.0%	R 316	R 0	-R 316
Year 22	R 3,555		12.0%	R 294	R 0	-R 294
Year 23	R 3,697		12.0%	R 273	R 0	-R 273
Year 24	R 3,845		12.0%	R 253	R 0	-R 253

Net Present Cost (NPC): SWH electricity costs						
Solution: NPV of Project is:	**-R 107,203.79**					
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 12,204		Not Applicable	R 12,204	R 0	-R 12,204
Year 1	R 12,204		12.0%	R 10,896	R 0	-R 10,896
Year 2	R 12,204		12.0%	R 9,729	R 0	-R 9,729
Year 3	R 12,204		12.0%	R 8,687	R 0	-R 8,687
Year 4	R 12,204		12.0%	R 7,756	R 0	-R 7,756
Year 5	R 12,204		12.0%	R 6,925	R 0	-R 6,925
Year 6	R 12,204		12.0%	R 6,183	R 0	-R 6,183
Year 7	R 12,204		12.0%	R 5,520	R 0	-R 5,520
Year 8	R 12,204		12.0%	R 4,929	R 0	-R 4,929
Year 9	R 12,204		12.0%	R 4,401	R 0	-R 4,401
Year 10	R 12,204		12.0%	R 3,929	R 0	-R 3,929
Year 11	R 12,204		12.0%	R 3,508	R 0	-R 3,508
Year 12	R 12,204		12.0%	R 3,132	R 0	-R 3,132
Year 13	R 12,204		12.0%	R 2,797	R 0	-R 2,797
Year 14	R 12,204		12.0%	R 2,497	R 0	-R 2,497
Year 15	R 12,204		12.0%	R 2,230	R 0	-R 2,230
Year 16	R 12,204		12.0%	R 1,991	R 0	-R 1,991
Year 17	R 12,204		12.0%	R 1,777	R 0	-R 1,777
Year 18	R 12,204		12.0%	R 1,587	R 0	-R 1,587
Year 19	R 12,204		12.0%	R 1,417	R 0	-R 1,417
Year 20	R 12,204		12.0%	R 1,265	R 0	-R 1,265
Year 21	R 12,204		12.0%	R 1,130	R 0	-R 1,130
Year 22	R 12,204		12.0%	R 1,009	R 0	-R 1,009
Year 23	R 12,204		12.0%	R 901	R 0	-R 901
Year 24	R 12,204		12.0%	R 804	R 0	-R 804

Net Present Cost (NPC): Geyser electricity costs						
Solution: NPV of Project is: -R 355,764.79						
	User Data Input Area:			Automatic Calculation Area:		
Year Number:	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 40,500		Not Applicable	R 40,500	R 0	-R 40,500
Year 1	R 40,500		12.0%	R 36,161	R 0	-R 36,161
Year 2	R 40,500		12.0%	R 32,286	R 0	-R 32,286
Year 3	R 40,500		12.0%	R 28,827	R 0	-R 28,827
Year 4	R 40,500		12.0%	R 25,738	R 0	-R 25,738
Year 5	R 40,500		12.0%	R 22,981	R 0	-R 22,981
Year 6	R 40,500		12.0%	R 20,519	R 0	-R 20,519
Year 7	R 40,500		12.0%	R 18,320	R 0	-R 18,320
Year 8	R 40,500		12.0%	R 16,357	R 0	-R 16,357
Year 9	R 40,500		12.0%	R 14,605	R 0	-R 14,605
Year 10	R 40,500		12.0%	R 13,040	R 0	-R 13,040
Year 11	R 40,500		12.0%	R 11,643	R 0	-R 11,643
Year 12	R 40,500		12.0%	R 10,395	R 0	-R 10,395
Year 13	R 40,500		12.0%	R 9,282	R 0	-R 9,282
Year 14	R 40,500		12.0%	R 8,287	R 0	-R 8,287
Year 15	R 40,500		12.0%	R 7,399	R 0	-R 7,399
Year 16	R 40,500		12.0%	R 6,606	R 0	-R 6,606
Year 17	R 40,500		12.0%	R 5,899	R 0	-R 5,899
Year 18	R 40,500		12.0%	R 5,267	R 0	-R 5,267
Year 19	R 40,500		12.0%	R 4,702	R 0	-R 4,702
Year 20	R 40,500		12.0%	R 4,199	R 0	-R 4,199
Year 21	R 40,500		12.0%	R 3,749	R 0	-R 3,749
Year 22	R 40,500		12.0%	R 3,347	R 0	-R 3,347
Year 23	R 40,500		12.0%	R 2,988	R 0	-R 2,988
Year 24	R 40,500		12.0%	R 2,668	R 0	-R 2,668

Appendix 4: Electricity and carbon savings from using a SWH (%)

Electricity and carbon savings from using a SWH (%):

		kWh	Tons CO_2
Current kWh/month		150 000	150
Current Electricity consumed for Hot Water usage	12%	18 000	18
SWH estimated savings	70%	12 600	12.6
Electricity from Hot Water usage with SWH	3.6%	5 400	
Therefore SWH saves 8.4% of total electricity			**Total saving 151 200/year**

Appendix 5: The effect of carbon tax on the cost of electricity from grid and on-site RE

Carbon tax	Grid (98%)	On-site RE (50%)
R0	853 000	222 000
R75	845 000	225 000
R200	831 000	229 000
R750	769 000	250 000

Tariff = R1.45/kWh

Appendix 6: NPC of TRECs

Net Present Cost (NPC) Solution-Calculator Template TRECs no tax						
Solution: NPC of Project is: R 91,545.91						
	User Data Input Area:			Automatic Calculation Area:		
Year Number	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 10,550		Not Applicable	R 9,420	R 0	-R 9,420
Year 1	R 10,550		12.0%	R 9,420	R 0	-R 9,420
Year 2	R 10,550		12.0%	R 8,411	R 0	-R 8,411
Year 3	R 10,550		12.0%	R 7,509	R 0	-R 7,509
Year 4	R 10,550		12.0%	R 6,705	R 0	-R 6,705
Year 5	R 10,550		12.0%	R 5,986	R 0	-R 5,986
Year 6	R 10,550		12.0%	R 5,345	R 0	-R 5,345
Year 7	R 10,550		12.0%	R 4,772	R 0	-R 4,772
Year 8	R 10,550		12.0%	R 4,261	R 0	-R 4,261
Year 9	R 10,550		12.0%	R 3,805	R 0	-R 3,805
Year 10	R 10,550		12.0%	R 3,397	R 0	-R 3,397
Year 11	R 10,550		12.0%	R 3,033	R 0	-R 3,033
Year 12	R 10,550		12.0%	R 2,708	R 0	-R 2,708
Year 13	R 10,550		12.0%	R 2,418	R 0	-R 2,418
Year 14	R 10,550		12.0%	R 2,159	R 0	-R 2,159
Year 15	R 10,550		12.0%	R 1,927	R0	-R1,927
Year 16	R 10,550		12.0%	R 1,721	R0	-R1,721
Year 17	R 10,550		12.0%	R 1,537	R0	-R1,537
Year 18	R 10,550		12.0%	R 1,372	R0	-R1,372
Year 19	R 10,550		12.0%	R 1,225	R0	-R1,225
Year 20	R 10,550		12.0%	R 1,094	R0	-R1,094
Year 21	R 10,550		12.0%	R 977	R0	-R977
Year 22	R 10,550		12.0%	R 872	R0	-R872
Year 23	R 10,550		12.0%	R 778	R0	-R778
Year 24	R 10,550		12.0%	R 695	R0	-R695

Net Present Cost (NPC): TRECs R75 tax						
Solution: NPC of Project is: R 96,480.21						
	User Data Input Area:			Automatic Calculation Area:		
Year Number	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 1,899		Not Applicable	R 1,696	R 0	-R 1,696
Year 1	R 1,899		12.0%	R 1,696	R 0	-R 1,696
Year 2	R 1,899		12.0%	R 1,514	R 0	-R 1,514
Year 3	R 1,899		12.0%	R 1,352	R 0	-R 1,352
Year 4	R 1,899		12.0%	R 1,207	R 0	-R 1,207
Year 5	R 1,899		12.0%	R 1,078	R 0	-R 1,078
Year 6	R 1,899		12.0%	R 962	R 0	-R 962
Year 7	R 1,899		12.0%	R 859	R 0	-R 859
Year 8	R 1,899		12.0%	R 767	R 0	-R 767
Year 9	R 1,899		12.0%	R 685	R 0	-R 685
Year 10	R 1,899		12.0%	R 612	R 0	-R 612
Year 11	R 1,899		12.0%	R 546	R 0	-R 546
Year 12	R 1,899		12.0%	R 487	R 0	-R 487
Year 13	R 1,899		12.0%	R 435	R 0	-R 435
Year 14	R 1,899		12.0%	R 389	R 0	-R 389
Year 15	R 1,899		12.0%	R 347	R 0	-R 347
Year 16	R 1,899		12.0%	R 310	R 0	-R 310
Year 17	R 1,899		12.0%	R 277	R 0	-R 277
Year 18	R 1,899		12.0%	R 247	R 0	-R 247
Year 19	R 1,899		12.0%	R 221	R 0	-R 221
Year 20	R 1,899		12.0%	R 197	R 0	-R 197
Year 21	R 1,899		12.0%	R 176	R 0	-R 176
Year 22	R 1,899		12.0%	R 157	R 0	-R 157
Year 23	R 1,899		12.0%	R 140	R 0	-R 140
Year 24	R 1,899		12.0%	R 125	R 0	-R 125

Net Present Cost (NPC) Solution-Calculator Template TRECs R200 tax						
Solution: NPV of Project is: -R 102,299.53						
	User Data Input Area:			Automatic Calculation Area:		
Year Number	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 11,790		Not Applicable	R 10,526	R 0	-R 10,526
Year 1	R 11,790		12.0%	R 10,526	R 0	-R 10,526
Year 2	R 11,790		12.0%	R 9,399	R 0	-R 9,399
Year 3	R 11,790		12.0%	R 8,392	R 0	-R 8,392
Year 4	R 11,790		12.0%	R 7,492	R 0	-R 7,492
Year 5	R 11,790		12.0%	R 6,690	R 0	-R 6,690
Year 6	R 11,790		12.0%	R 5,973	R 0	-R 5,973
Year 7	R 11,790		12.0%	R 5,333	R 0	-R 5,333
Year 8	R 11,790		12.0%	R 4,762	R 0	-R 4,762
Year 9	R 11,790		12.0%	R 4,251	R 0	-R 4,251
Year 10	R 11,790		12.0%	R 3,796	R 0	-R 3,796
Year 11	R 11,790		12.0%	R 3,389	R 0	-R 3,389
Year 12	R 11,790		12.0%	R 3,026	R 0	-R 3,026
Year 13	R 11,790		12.0%	R 2,702	R 0	-R 2,702
Year 14	R 11,790		12.0%	R 2,412	R 0	-R 2,412
Year 15	R 11,790		12.0%	R 2,154	R 0	-R 2,154
Year 16	R 11,790		12.0%	R 1,923	R 0	-R 1,923
Year 17	R 11,790		12.0%	R 1,717	R 0	-R 1,717
Year 18	R 11,790		12.0%	R 1,533	R 0	-R 1,533
Year 19	R 11,790		12.0%	R 1,369	R 0	-R 1,369
Year 20	R 11,790		12.0%	R 1,222	R 0	-R 1,222
Year 21	R 11,790		12.0%	R 1,091	R 0	-R 1,091
Year 22	R 11,790		12.0%	R 974	R 0	-R 974
Year 23	R 11,790		12.0%	R 870	R 0	-R 870
Year 24	R 11,790		12.0%	R 777	R 0	-R 777

Net Present Cost (NPC) **Solution-Calculator Template TRECs R750 tax**						
Solution: NPC of Project is: -R 131,912.55						
	User Data Input Area:			Automatic Calculation Area:		
Year Number	Cash Investment (Cash flow OUT)	Cash Return (Cash flow IN)	Discount Rate	Cash OUT at discounted value	Cash IN at discounted value	Discounted flow by specific year
Year 0	R 15,202		Not Applicable	R 13,573	R 0	-R 13,573
Year 1	R 15,202		12.0%	R 13,573	R 0	-R 13,573
Year 2	R 15,202		12.0%	R 12,119	R 0	-R 12,119
Year 3	R 15,202		12.0%	R 10,821	R 0	-R 10,821
Year 4	R 15,202		12.0%	R 9,661	R 0	-R 9,661
Year 5	R 15,202		12.0%	R 8,626	R 0	-R 8,626
Year 6	R 15,202		12.0%	R 7,702	R 0	-R 7,702
Year 7	R 15,202		12.0%	R 6,877	R 0	-R 6,877
Year 8	R 15,202		12.0%	R 6,140	R 0	-R 6,140
Year 9	R 15,202		12.0%	R 5,482	R 0	-R 5,482
Year 10	R 15,202		12.0%	R 4,895	R 0	-R 4,895
Year 11	R 15,202		12.0%	R 4,370	R 0	-R 4,370
Year 12	R 15,202		12.0%	R 3,902	R 0	-R 3,902
Year 13	R 15,202		12.0%	R 3,484	R 0	-R 3,484
Year 14	R 15,202		12.0%	R 3,111	R 0	-R 3,111
Year 15	R 15,202		12.0%	R 2,777	R 0	-R 2,777
Year 16	R 15,202		12.0%	R 2,480	R 0	-R 2,480
Year 17	R 15,202		12.0%	R 2,214	R 0	-R 2,214
Year 18	R 15,202		12.0%	R 1,977	R 0	-R 1,977
Year 19	R 15,202		12.0%	R 1,765	R 0	-R 1,765
Year 20	R 15,202		12.0%	R 1,576	R 0	-R 1,576
Year 21	R 15,202		12.0%	R 1,407	R 0	-R 1,407
Year 22	R 15,202		12.0%	R 1,256	R 0	-R 1,256
Year 23	R 15,202		12.0%	R 1,122	R 0	-R 1,122
Year 24	R 15,202		12.0%	R 1,002	R 0	-R 1,002