A value chain analysis of the solar water heater industry in the Western Cape:

Investigating opportunities for local economic development, poverty alleviation and energy conservation

by
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Declaration

By submitting this thesis/dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

December 2010

Abstract

Low-income households in the Western Cape primarily use small electrical kettles to heat water for bathing and cleaning. This energy usage pattern is problematic in that;

- It is based on unsustainable energy sources that cause environmental degradation,
- Electricity is becoming more expensive in South Africa which strains the limited income of poorer households and
- The national utility, Eskom, is struggling to meet the demand for electricity.

If energy-intensive development paths are followed these problems will escalate further.

Solar water heating offers a synergic (Max-Neef 1991), if partial, solution for the situation. By decoupling hot water usage from increased electricity usage, solar water heaters (SWHs) can reduce electricity demand and thus environmental degradation. The large quantities of hot water (relative to electrical kettles) that they provide also fulfil a developmental service by improving quality of life and personal health. The manufacturing and installation of solar water heaters could serve as a further catalyst for development by providing opportunities for economic development.

Unfortunately the high capital cost of SWHs remains a barrier to the rollout of the technology in lower income groups. The objective of this thesis is to contribute to the elimination of this barrier through providing insight into; the hot water requirements of low-income households, the potential electricity and carbon emission savings that solar water heaters present, and the cost drivers and job creation potential of the solar water heating value chain. The research hypothesis is that: *Solar water heaters (SWHs) are a potential synergic satisfier to achieve sustainable development in low income communities by providing an improved energy service, reducing environmental degradation and creating employment opportunities. The high price of the technology makes intervention in the form of subsidies and/or regulation from the appropriate level(s) of government critical for the realisation of this potential.*

The methodology used to test the hypothesis is quantitative and qualitative in nature with data obtained through a survey of 90 low-income households in Stellenbosch, a behavioural study of two households wherein solar water heaters were installed and a value chain analysis of the SWH industry in the Western Cape.

The key findings of the research include that, SWHs offer a real improvement in quality of life for low-income households and that they reduce electricity consumption relative to a level of development. The key barrier to cost reductions in the solar water heating industry is found to be the small size of the industry which leads to an inability to source material, especially copper, at competitive prices. It is proposed that government sponsored rollout programs could alleviate this barrier, leading to the development of a robust industry. Job creation potential is found to be relatively small but a suggested rollout programme for SWHs in the Western Cape shows that the benefits of the technology can be realised and several thousand jobs created in a fiscally prudent manner.

The thesis is focuses on households from LSM categories 5-8 in the Western Cape Province. Stellenbosch Municipality is used as a specific case study area.

OPSOMMING

Lae-inkomste huishoudings in die Wes-Kaap gebruik klein elektriese ketels as hul primêre water verhittingstoestel vir bad en skoonmaak aktiwiteite. Hierdie energie verbruik patroon is problematies in dat;

- Dit gebaseer is op onvolhoubare energie bronne wat skadelik is vir die omgewing,
- Elektrisiteit duurder word in suid afrika, en sodoende druk plaas op die beperkete inkomste van armer huishoudings en
- Die nasionale elektrisiteitsdiensverskaffer, eskom, sukkel om te voldoen aan die vraag vir elektrisiteit.

As energie-intensiewe ontwikkelings paaie gevolg word sal hierdie probleme verder vererger.

Son water verhitting bied ´n sinergiese (Max-Neef 1991), dog gedeeltelike, oplossing vir die situasie. Deur warm water verbruik te ontkoppel van toenemende elektrisiteitsverbruik kan son water verwarmers (SWVs) die vraag na elektrisiteit en dus omgewingskade verminder. Die groot hoeveelhede warm water (relatief tot ´n elektriese ketel) wat die toestelle voorsien vervul ook ´n ontwikkelingsdiens deur verbeterde lewenskwaliteit en persoonlike gesondheid mee te bring. Die vervaardiging en installeering van SWVs kan dien as ´n verdere katalisator vir ontwikkeling deur geleenthede vir ekonomiese ontwikkeling te skep.

Ongelukkig bly die hoë kapitaal koste van SWVs ´n struikelblok tot die verspreiding van die tegnologie in lae inkomste groepe. Die doelwit van hierdie tesis is om by te dra tot die verwydering van hierdie struikelblok deur insig te gee oor; die warm water benodigheid in lae-inkomste huishoudings, die potensiële elektrisiteit-en koolstofbesparings wat SWVs inhou, en die koste drywers en werkskepping potensiaal van die sonwaterverwarmer waarde ketting. Die navorsingshipotese is dat: *Son water verwarmers ´n potensiële sinergiese bevrediger is vir die bereik van volhoubare ontwikkeling in lae-inkomse gemeenskappe deurdat dit ´n verbeterde energie diens voorsien, omgewingskade verminder en werksgeleenthede skep. Die hoë prys van die tegnologie verorsaak dat ingryping deur die toepaslike vlak(ke) van regering, deur middel van subsidies en/of regulasie, benodig word om die potensiaal daarvan te verwesenlik.*

Die metodologie wat gebruik word om die hipotese te toets is kwantitatief en kwalitatief van aard met data wat verkry word deur ´n opname onder 90 lae-inkomste huishoudings in Stellenbosch, ´n gedragstudie van twee huishoudings waarin SWVs geinstalleer is en ´n waardekettinganalise van die SWV industrie in die Wes-Kaap.

Die sleutel gevolgtrekkings van die navorsing sluit in dat, sonwaterverwarmers ´n werklike verbetering in die kwaliteit van lewe van lae-inkomste huishoudings meebring en dat hulle elektrisiteitsverbruik relatief tot ´n vlak van ontwikkeling verminder. Die hoof struikelblok tot koste verminderings in die SWV industrie word gevind in die klein grootte van die industrie wat lei tot die onvermoë om materiaal, veral koper, teen kompeterende pryse aan te koop. Dit word voorgestel dat regeringsondersteunde verspreidingsprogramme hierdie struikelblok kan verwyder en dat dit sal lei tot die ontwikkeling van ´n gesonde industrie. Werkskeppingspotensiaal word gevind om relatief klein te wees, maar ´n voorgestelde verspreidings program vir SWVs in die Wes-Kaap wys dat die voordele van SWVs gerealiseer kan word en etlike duisend werksgeleenthede geskep kan word op ´n finansieel verantwoordelike wyse.

Die tesis fokus op huishoudings in die LSM kategorieë 5-8 in die Wes-Kaap provinsie. Stellenbosch munisipaliteit word gebruik as ´n spesifieke gevallestudie area.

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ACRONYMS USED IN THE THESIS

CDM	Clean Development Mechanism
CEF	Central Energy Fund
CERs	Certified Emission Reduction certificates
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COP 15	15^{th} United Nations Climate Change Conference
CRSES	Centre for Renewable and Sustainable Energy Studies
DEADP	Western Cape Department of Environmental Affairs and Development Planning
DEEE	Deep Ecology and Environmental Ethics
DME	Government of South Africa Department of Minerals and Energy
EF	Ecological Footprint
EIA	Energy Information Administration
ESKOM	South African electricity public utility
EV	Evacuated Tube
FP	Flat-plate
GDP	Gross Domestic Product
GEF	Global Environment Facility
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LPI	Living Planet Index
LSM	Living Standard Measure
MTOE	Million Tonnes of Oil Equivalent
NASA	Government of the United States of America National Aeronautics and Space Administration
NERSA	National Energy Regulator
NMBM	Nelson Mandela Bay Municipality
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing Power Parity
PV	Photo-voltaic cells
RDP	Reconstruction and Development Programme
RSE	Renewable sustainable energy
SABS	South Africa Bureau of Standards

SANS	South African Bureau of Standards National Standard
SEA	Sustainable Energy Africa
STATSSA	Statistics South Africa
SWH	Solar Water Heating
SWHs	Solar Water Heating Systems
USA	United States of America
VCA	Value chain Analysis
WCED	World Commission on Environment and Development
WEC	World Energy Council
WWF	World Wildlife Fund

UNITS USED IN THE THESIS

kWh	-	Kilowatt hour
Mtoe		Million Tonnes of oil equivalent
MWh	-	Mega Watt hour
m^2	-	Square Meter
m^3	-	Cubic Meter
MJ/m^2	-	Mega Joules/Square meters
R	-	South African Currency Rand
MW	-	Megawatt
kW	-	Kilo Watt
°C	-	Degrees Celsius
Ppm	-	Parts per million
Ppmv	-	Parts per million by volume
GW	-	Giga Watt
GW_{th}		Giga Watt thermal
GWh	-	Giga Watt hour
MWp	-	Mega Watt Peak

CLARIFICATION OF CONCEPTS

Gini coefficient: The Gini coefficient can vary between 0 and 1. If incomes are distributed perfectly equally the Gini coefficient is zero. If the total income goes to one individual the Gini coefficient is equal to one (Mohr 2005, p.172). Thus the lower the value of the Gini coefficient the more equal income distribution is in the sample population

Greater Stellenbosch: The term refers to the ± 900 square kilometres municipal area that includes the towns of Stellenbosch, Franschhoek and settlements such as Klapmuts, Koelenhof, Kylemore, Johannesdal, Pniel, Jamestown and Raithby (Stellenbosch Municipality 2010).

Low income households: For the purpose of this thesis the term "low income household" is used to refer to a family that falls into LSMs 5-7, and live in formal structures with brick walls and a solid roof.

Value chain: The linked set of value-creating activities all the way from basic raw material sources for component suppliers through the ultimate end-use product delivered into the final customers' hands (Dekker 2001, p.4).

Renewable and Sustainable energy:

Renewable energy refers to those primary fuel sources that are considered 'inexhaustible' (Park 2008, p.378). They are considered 'inexhaustible' because all renewable energy originates from the electromagnetic radiation created via fusion inside the sun, a process that is expected to survive for countless years. Renewable energy sources produce power without producing harmful waste emissions such as greenhouse gases (Interacademy Council 2007, pp.91-92).

Conventional energy This refers to the dominant energy sources that currently generate electricity including fossil fuels (coal, oil and natural gas), nuclear energy and large hydro energy.

Climate change Climate change (Aubrecht 2006, pp.331-381) refers to the geographical process whereby average climatic conditions change. Climate change has occurred throughout history and is regarded as an expected geographical phenomenon due to natural forces (biological, geological and cosmological). However, the term is currently associated with the induced effect of anthropogenic factors that have accelerated the rate of accumulation of greenhouse gases in the atmosphere that leads to an increase in average global

	temperatures (global warming) therefore induces changes in weather patterns.
Synergic Satisfier	A term developed by Max Neef (1991) to describe a change or intervention that improves quality of life by satisfying multiple fundamental human needs simultaneously.

1 INTRODUCTION

The OECD and EIA (2008, p.37) assert that *"...it is not an exaggeration to claim that the future of human prosperity depends on how successfully we tackle the two central energy challenges facing us today: securing the supply of reliable and affordable energy; and effecting a rapid transformation to a low-carbon, efficient and environmentally benign system of energy supply. What is needed is nothing short of an energy revolution."*

1.1 PROBLEM STATEMENT

This thesis deals with a complex multi-dimensional sustainability problem of energy security, poverty alleviation and climate change and environmental degradation in the context of the Western Cape Province in South Africa.

A key part of our unsustainable use of natural resources is modern energy-use patterns. Many scientists concur that fossil fuel based energy generation releases greenhouse gasses, such as carbon dioxide, into the atmosphere that are changing the earth's climate by causing an increase in global average temperatures (Aubrecht 2006; IPCC 2007a; IPCC 2007b). The potential long-term effects of climate change due to the rise in average temperatures range from falling agricultural productivity in many developing regions, reduced freshwater availability, more severe storms and heat waves to the eventual collapse of large parts of the polar ice shelves leading to a catastrophic rise in sea levels. In order to avoid further anthropogenic changes to the earth's climate alternative sources of energy that are renewable and sustainable that do not harm the environment need to be developed to the extent where they can replace conventional energy technologies.

Much of the environmental degradation caused across the globe is due to the unsustainable resource consumption patterns of a wealthy minority of the world's population[1] and undoubtedly their consumption patterns need to change, but if we are to uplift the billions still living under extremely difficult circumstances we also need to find new paths of development that would allow them to attain a higher quality of life without placing further strain on the earth's natural resources. While acknowledging that the poor of the world are largely not responsible for most current environmental degradation the particular focus of this thesis lies in contributing to the sustainable development of low-income communities. How vital it is that we find ways to uplift the world's poor without placing undue further strain upon the natural environment is illustrated by OECD/IEA (2008: 45-46) projections that "world greenhouse-gas emissions... are projected to grow from 44 Gt CO_{2e} in 2005 to 60 Gt CO_{2e} in 2030 [if consumption patterns remain unchanged], an increase of 35% over 2005". 97% of the increase in energy-related CO_2 emissions will arise in non-OECD countries.

Environmental concerns are however not the only motivation for reducing dependence on fossil fuels. These materials are non-renewable[2] and will eventually be exhausted. Oil

[1] The OECD countries accounted for 44.9% of global CO2 emissions in 2007, China and the former Soviet Union countries contributed 21% and 8.3% respectively whilst the rest of the world contributed only 25% (IEA 2009, p.47).

[2] Within a human timeframe. It is possible that if natural processes were to be allowed to continue unabated fossil fuel resource bases could be replenished over millions of years but they are irreplaceable over a time frame of tens of thousands of years

production growth is already slowing down and it is projected that conventional oil production will reach its theoretical peak level in the next decade or two (OECD/EIA 2008, pp. 40-41). Thereafter the supply of oil will no longer be able to match increased demands brought by economic growth of economies based on fossil fuels. Oil availability and prices are likely to become increasingly volatile. Countries and communities that successfully wean themselves off oil derivatives and other non-renewable fossil fuels will ensure their own energy security and continued development. Similar to crude oil, coal is a finite resource that will eventually be depleted. Though there is still a relatively abundant amount of coal available, economically extractable deposits of the resource will eventually be depleted. The World Coal Institute (2009) estimates that sufficient coal is available to satisfy all demand for another 130 years. The Energy Watch Group (2007), an independent advisory group to the German parliament, estimates that coal reserves could only meet the growth in demand until 2025. Whatever the extent of the available reserves, it is clear that coal will eventually run out and that it is in any nation's strategic interest to develop alternative energy sources.

Though South Africa has relatively abundant coal reserves, there are strong incentives for a move to renewable energy technologies. 90% of the country's electricity is generated in coal-fired power stations and due to the size of its economy the country is the largest emitter of greenhouse gasses in Africa and one of the highest emitters per capita in the world (SEA 2009, p.2). In 2007 the country was the 13th largest contributor to global carbon emissions and the 45th highest contributor on a per capita basis (UNSD 2010). At the Copenhagen conference on climate change the South African government committed to change this state of affairs by reducing national greenhouse gas emissions by 42% from "business as usual" levels by 2025 (The Presidency 2009a).

The country also faces an immediate electricity generation capacity shortage that has already led to rolling blackouts during 2008. Given that government has promised to provide electricity in every house in the country by 2014 (Government of South Africa 2010, p.9), and assuming that economic growth returns to more than 4% in the medium term, the shortage of electricity generation capacity will be a major obstacle to development in the country. If the government is to fulfil its international obligations, ensure continued economic growth and improve the quality of life of the poor citizens, alternative sources of energy will have to be supported. New coal power stations take years to construct and will add to the unsustainability of South African economy through increased usage of coal and thus more greenhouse gas emissions. Renewable energy technologies offer a potential partial panacea for all the challenges faced through the provision of energy that is not generated from the combustion of fossil fuels. The energy challenges faced by the South African government exist within the context of a country where millions still live in poverty and are excluded from the formal economic sector. Though South Africa has been able to achieve relative socio-political stability and robust economic growth since its first democratic election in 1994, the country has struggled to reduce income inequality and poverty levels. Unemployment remains stubbornly high at 23% (STATSSA 2009b)[3] and many people still live without basic services, including access to the benefits of modern energy sources (19% of the population still does not have access to electricity (Government of South Africa 2010, p.9). Any intervention that is proposed in the country has to take this context into account and

[3] According to the official narrow definition which excludes discouraged work seekers that are not actively seeking employment (STATSSA 2009b).

the creation of employment opportunities should be a primary objective of any development policy.

Solar water heating systems (SWHs), the focus of this thesis, are an excellent example of the potential of renewable energies to address the concerns discussed above. In developed countries, they are typically introduced to reduce greenhouse gas emissions, but in developing nations such as South Africa they also address the additional challenge of reducing peak electricity demand (and thus the total required grid capacity) whilst providing an energy service in households where hot water was a scarce necessity, thus improving quality of life. By creating savings on monthly electricity accounts, SWHs could also free up additional disposable income in poor communities (Prasad 2007, p.1). Through the creation of jobs in the manufacturing, installation and servicing of systems the SWH industry could become a integrated, systemic solution to the interrelated problems of poverty, unemployment and unsustainable energy use patterns (Gallopin 2003). This thesis investigates these potential benefits of SWHs in low income communities in greater detail, specifically in communities consisting mostly of state subsidised low-cost houses such as those delivered under the Reconstruction and Development Programme (RDP). Although larger emission reductions can be achieved in the mid -to high income groups, future growth in emissions will originate from those who are currently energy poor and alternative development trajectories need to be identified before their development leads to further environmental destruction. In the South African context it is also politically difficult to institute a technology rollout programme that could reduce monthly living costs but that excludes low-income households. SWH rollouts for both high and low income communities need to be researched but the particular focus of this thesis is on the low-income sector. This delineation is made because SWH technology is relatively accessible for higher income consumers whilst it remains financially unattainable for low-income consumers. In the low-income context the technology provides a quality of life improvement through the provision of bulk water heating services that are not presently available. In higher income homes large volumes of hot water are already available from electrical geysers. External interventions are thus more necessary in the low-income sector from a developmental perspective.

The thesis will investigate the obstacles to achieving a mass rollout of SWH systems in low income communities and quantify the costs and benefits of a potential rollout. This is done to develop an understanding of the contribution that SWHs can make to address the challenges faced by South Africa.

Though the problems of energy security, poverty relief and environmental degradation are global, the Western Cape Province in South Africa and Stellenbosch Municipal area in particular are the focus areas of the research. The town serves well as a reflection of the greater South African context as it faces high levels of poverty and inequality as well as strong population growth. To address these challenges drastic expansion of the amount of available housing developments are required. Such housing developments will place further strain on an electricity grid that is already running at maximum capacity and energy alternative are key to the long-term success of development strategies (Sustainability Institute & Probitas Real Estate Finance Education CC 1996). There are also several existing networks that can be tapped into for the research process. Several businesses involved in the solar water heater supply chain are located in or near Stellenbosch and the locally available expertise of the Sustainability Institute (SI) and the Centre for Renewable and Sustainable

Energy Studies (CRSES) at Stellenbosch University provides access to academic assistance. Established contacts between Stellenbosch University, the Sustainability Institute, Stellenbosch Municipality and local communities[4] provide strategic entry points to investigate the barriers, costs and potential benefits of SWH technology.

[4] The selection of Stellenbosch as a case study is further justified in chapter 3

1.2 RESEARCH OBJECTIVE

Following from the problem statement, this thesis will attempt to contribute to the solution of two categories of challenges facing South Africa. The first, that of climate change and energy security, is a global concern that also affects South Africa. The second, the challenge of chronic high unemployment and poverty, though not unique to the country, will be considered from a South African perspective, specifically that of Stellenbosch Municipality and the Western Cape.

Renewable and sustainable energy and SWH in particular is proposed as a partial solution to the challenges. Of the renewable energy technologies that are currently available solar thermal energy for direct heating, such as domestic solar water heating, is currently the nearest to cost competitive with fossil fuels in countries with high levels of solar radiation (Khambalkar, Gadge and Karale 2009), such as South Africa. Though these systems offer benefits for all income groups the particular focus of this thesis is on solar water heaters for low-income households living in formal houses. The environmental and energy security benefits of introducing SWHs are higher in high income groups that use more electricity for water heating. The primary barrier to SWH uptake in this market is the low cost of electricity, as these homes could afford the relatively high initial capital expenditure if they wanted access to the savings provided by the technology (McCallum 2010, Hertzog 2009). In the lower income context some level of government assistance is required to overcome the capital expenditure barrier to ensure that low-income households gain access to the benefits of SWH technology (McCallum 2010, Hertzog 2009).

In the long run it is as important to place currently developing communities on a more environmentally friendly development path as it is to reduce the environmental impact of currently "developed" communities. For low income groups the technology is also more than just a "green" alternative to existing energy services as it would be in higher income groups. In low-income households[5] the technology provides quality of life improvement through the provision of bulk water heating services. This reduces expenditure on the electricity, paraffin or gas that is normally used to heat water and the easily accessible, large quantities of hot water make daily activities such as bathing, laundry and cleaning simpler and easier (Kuyasa CDM Project 2009). By reducing the use of electricity to heat hot water, SWHs can also relieve some of the strain on South Africa's overburdened national electricity grid and reduce the combustion of coal to generate said electricity. This will in turn reduce the carbon emissions that the country produces and improve energy security.

Unfortunately, though the cost of energy delivered through such systems is relatively low over the lifetime of a system, the upfront capital cost of procuring a system remains exceedingly high, especially for low income households. The primary purpose of the thesis is to quantify the potential benefits of large SWH rollouts in low-income communities and the costs and cost-drivers of such programmes. It is hoped that these findings will contribute to the creation of a thriving SWH industry in the Western Cape that will alleviate poverty, reduce environmental degradation and create entrepreneurial and employment opportunities for large numbers of unskilled and semi-skilled workers who are currently excluded from the formal economy.

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[5] The focus of this thesis is specifically on free standing housing units, such as those constructed in the RDP housing programme. Heat pumps and centralised large solar water heating systems offer economical alternative water heating in high-density residential blocks but these fall beyond the scope of this thesis.

Based on the discussion above, grounded in the Stellenbosch and Western Cape context, the objectives of the research can be summarised as follows:

i. To develop an understanding of what the hot water requirements, current and suppressed, are in low income households and which currently available solar water heating systems can fulfil these needs most cost effectively. This would allow the quantification of the potential benefits of a SWH rollout programme.
ii. To conduct a value chain analysis of the existing solar water heating industry to;
   a. Find the barriers to cost reductions in the industry so that policymakers can focus incentive measures at strategic leverage points that will have the largest positive effects,
   b. To give industry players an overall picture of the industry context so that they can position themselves best to gain access to low-income markets, thereby benefitting both the low-income consumers and the industry,
   c. To develop an understanding of the entrepreneurial and employment generating potential of the solar water heating industry, especially for unskilled and semi-skilled labour.
iii. To quantify the potential electricity and carbon emission savings that a large scale SWH rollout in low-income communities would provide.
iv. To develop a model that will quantify the costs and benefits of a large SWH rollout program in low-income communities.

1.3 HYPOTHESIS

The central hypothesis of the thesis is that:

Solar water heaters (SWHs) are a potential synergic satisfier to achieve sustainable development in low income communities by providing an improved energy service, reducing environmental degradation and creating employment opportunities. The high price of the technology makes intervention in the form of subsidies and/or regulation from the appropriate level(s) of government critical for the realisation of this potential.

1.4 RESEARCH QUESTIONS:

Leading from the research objective and the research hypothesis the following research questions are investigated.

Primary Questions:

1. What are the potential benefits of solar water heaters for low income communities?[6]

2. What roles, if any, should the different levels of government play in ensuring that the potential benefits of solar water heaters be realised in low income communities?[7]

These primary questions can be further broken down into secondary questions focusing on the demand and supply side of the solar water heating value chain as follows:

Demand Side:

1.1. What are the benefits of SWH for a low-income household?

1.2. What would be the extent of electricity savings if a mass rollout of SWHs is achieved for all low-income households in Stellenbosch or the Western Cape?

1.3. What would the environmental benefits be of achieving a mass rollout of SWHs for all low-income households in Stellenbosch or the Western Cape?

Supply Side:

1.4. What is the job creation potential of the SWH value chain?

2.1. What are the barriers to cost reductions in the SWH value chain?

2.2. Which government interventions are necessary to overcome the barriers to cost reductions that would make solar water heaters an affordable developmental intervention?

6 Secondary questions arising from this question are marked 1.1-1.4 in the secondary question list below.

7 Secondary questions arising from this question are marked 2.1 and 2.2 in the secondary question list below.

1.5 DELINEATION

The research conducted focuses specifically on water heating in low-income households living in formal dwellings in the Western Cape Province of South Africa. Low-income households considered in this thesis fall into the Living Standard Measure (LSM) groups 5-9 (SAARF 2010). These groups were chosen as the focus area of the study because running water and a sturdy formal house with a strong roof are requirements for most SWHs. Higher income groups were excluded as different types of interventions are required for uptake in these market segments. In the lower income groups considered, running hot water is currently not available. SWHs therefore offer an additional developmental service in this context. The research population for the developmental impact of SWHs consists of low-income households in Stellenbosch.

The value chain analysis conducted is for manufacturers of components of flat-plate SWHs in the Western Cape Province. All the manufacturers considered manufacture both expensive and low cost systems but the particular focus of the thesis is on low cost direct thermosyphon systems without electrical backup. Greater South Africa is considered where employment opportunity creation due to the mining and manufacturing of input materials such as glass, copper and aluminium is evaluated. As the thesis envisions the development of the South African SWH industry the focus of the value chain analysis is on local manufacturers and not importers. Where importers are interviewed it is for the purpose of comparing their job creation potential with that of local manufacturers. All solar water heater manufacturers in the Western Cape as well as a sample of distributors and independent installers were interviewed. Manufacturers were the primary focus as they have distribution and installation capacities internally. Independent installers and distributors are therefore not essential for the achievement of large scale, low cost solar water heater rollouts.

The level of government intervention investigated is primarily local and provincial. The role of national government is only discussed in areas where national-level intervention cannot be substituted by actions at local levels.

Alternative water heating devices, such as heat-pumps and centralised solar water heating systems, are available, especially for high-density residential and commercial developments, but these are considered to fall outside the scope of this research.

The ecological impacts of the components, that SWHs are manufactured from, should inform decisions on whether and how SWH technology should be rolled out but such analysis is not included here. The focus is instead on the job creation potential of the value chain as well as the cost barriers therein. It is recommended that a life-cycle cost analysis should be conducted to complement the findings of this thesis.

1.6 SIGNIFICANCE OF RESEARCH

The ultimate goal of the research is to contribute to the improvement of the quality of life of the thousands who live in relative poverty in the Western Cape (Between 32% and 28.8% of the population (Armstrong, Lekezwa & Siebrits 2008, Schwabe 2004) without causing increased environmental degradation through the use of unsustainable energy sources such as fossil fuels. Though recognising that the research itself cannot eradicate poverty, the underlying intent of the research is transformational in nature.

In order to achieve this, the research aims to identify the potential benefits of solar water heaters in terms of the contribution that they can make to

- a reduction in fossil fuel usage and thus carbon emissions and
- the contribution that the technology can make in terms of job creation opportunities.

As the technology has not achieved any private low-income market penetration to date, beside several pilot projects, (Holm 2005, Winkler 2006) the assumption is that government would need to become involved at some level for the benefits of SWH to be realised in lower income groups. This thesis will identify if such an assumption holds true and, if so, what intervention is required. In order to identify which interventions and at what level government involvement might be necessary, the focus area of the research will be Stellenbosch Municipality as an example of local government; while the Western Cape province will be considered to evaluate the necessity for intervention from higher levels of government. Stellenbosch is selected as a focus area due to indications from the local council that it is dedicated to achieving sustainable development. To this end there are ongoing dialogues between the locally based Sustainability Institute, the CSIR and the University of Stellenbosch to develop strategies to ensure that future development of the area is economically, socially and environmentally sustainable. The incentive to find innovative solutions to the challenges of unsustainable development is particularly strong in Stellenbosch as the area faces an acute housing shortage, high unemployment and social inequity and a shortage of electricity capacity (Sustainability Institute & Probitas Real Estate Finance Education CC 2006).

This context presents a strategic opportunity for the introduction of solar water heating as a potential systemic, though partial, solution to the problems mentioned. By providing an overview of the entrepreneurial and employment creation potential of the SWH industry, the potential energy savings and the quality of life improvement that the technology offers, the thesis could inform the decisions of policymakers about investments in energy services and local economic development initiatives. By providing insights into strategies to induce cost reductions in the price of SWHs for the low-income market, the research could bring the widespread rollout of SWHs closer to realisation. This is done by investigating how government subsidies or regulatory incentives could be most effectively applied to realise the benefits of SWH technology for low-income communities.

Ideally the research would be a key part of a process that would eventually lead to the rollout of millions of SWHs for low-income homes across South Africa, creating thousands of jobs in the process, improving the quality of life in poor communities by providing access to "free[8]" hot water, reducing the demand for electricity, particularly during peak electricity demand times[9], and reducing the carbon emissions produced by the South African economy. It is hoped that the understanding of the SWH value chain offered will also eventually contribute to the development of a strong industrial sector with export and sustained employment creation potential.

[8] The hot water from a SWH is free in the sense that consumers do not pay per unit of hot water used. After the initial capital investment has been made there are thus no further costs for hot water used. System maintenance may be required infrequently but systems have been proven to last in excess of 15 years without maintenance (Holm 2005, Anthony 2009a). In low income communities where personal care activities may be inhibited by the unit cost of heating water in electrical devices SWHs thus have the potential of improving quality of life by removing the cost barrier to using sufficient qualities of hot water.

[9] Between 6am and 10am and 6pm and 10pm (Eskom 2006, p.37)

1.7 THESIS OUTLINE

The thesis begins with an introductory chapter that clearly delineates the research objective and a hypothesis on the role that SWHs can play in achieving sustainable development. From this hypothesis several specific research questions are identified that need to be answered in order to test the components of the hypothesis. These questions are the guiding framework for the research completed. Before the actual practical research is discussed a literature review is conducted in order to contextualise the research by emphasising the need for sustainable energy solutions on global, national and local levels. The particular focus is on South Africa, the Western Cape and Stellenbosch municipal levels. This contextual overview also provides a first indication of the specific contribution that SWH can make in terms of the available solar energy resource in South Africa and the contribution that SWH can make towards achieving sustainable development in the context that is sketched.

The contextual overview shows that an alternative approach to human development is necessary in order to sustainably overcome the environmental and social challenges confronting South Africa and the world. Such an alternative approach to sustainable human development is developed for this thesis based on an integration of systems theory and Human Scale Development approach of Manfred Max-Neef (1991) as discussed in Section 2.4. This approach is adopted as the theoretical framework according to which the potential of SWHs as a lever to achieve sustainable development is evaluated.

This systems theory approach to sustainable development is then used throughout the rest of the literature review to show how SWH can help in overcoming the challenges faced at the different levels of human society in the Western Cape. Systems theory allows for the investigation of SWH as a systemic, if partial, solution to complex interrelated challenges of poverty, energy delivery services, environmental degradation and improving quality of life.

In order to evaluate the potential contribution of SWH towards sustainable development an understanding of the technology is required. The literature review therefore continues a short discussion of renewable energy technology which is used to inform a specific discussion of solar energy and eventually solar water heating. A short section on the current international experience of SWH is included thereafter to illustrate the maturity of the technology and how South Africa has fallen behind in its application. The structure thus develops a philosophical point of departure on sustainable development which is used to inform subsequent discussions on the potential of renewable energy to contribute to more sustainable development. The discussion of the role of renewable energy proceeds from the broad to the specific, from renewable energy in general to solar water heating in particular.

After discussing the state of SWH technology and the role that it can play in achieving sustainable development the literature review considers in some detail what the specific potential benefits of SWH for low-income communities could be. Once these benefits are identified a literature overview of the existing literature on the solar water heating industry in South Africa is conducted to identify gaps therein and to identify the contributions that this thesis can make. The literature review chapter ends with an overview of existing SWH rollout programs for low-income communities in South Africa. These examples illustrate that the technology has been proven in the South African context in terms of its ability to satisfy fundamental human needs and in terms of the efficacy of the thereof.

The research methodology chapter is used to discuss and justify the approach taken during research activities. It first discusses the overall research methodology that informed the research design before the specific research methods are explained and discussed. The chapter ends with an identification of the limitations of the research methods used.

Based on gaps identified in the existing literature, the Research Findings chapter:

- Evaluates the potential benefits of SWH in Stellenbosch, a town in the Western Cape Province, through an analysis of the demand for hot water in low-income households.

- Identifies opportunities that would make the realisation of the potential benefits of SWH a reality through a supply-side value chain analysis investigation of the SWH value chain in the Western Cape

The data from these studies is then used to develop a proposed model for the rollout of SWHs in low-income housing developments in Stellenbosch and the Western Cape. The findings of the demand analysis and the proposed rollout model are used in the Conclusion chapter to provide answers for the research questions and thus to critically re-evaluate the research hypothesis. The Conclusion chapter also provides some suggestions for suggested next steps to realise the benefits of SWH and suggests possible future research opportunities arising from this work.

2 LITERATURE REVIEW

2.1 INTRODUCTION

Since at least the 1700s there have been theorists such as Thomas Malthus (1766-1834) and David Ricardo (1772-1823) who argued that prevalent economic systems were unsustainable and that resource scarcity would eventually force finite limits on economic growth. During the 20th century it became increasingly apparent that the link between humankind and its natural environment could no longer simply be ignored. By the 1970's the chorus of voices warning against the destruction of the natural environment gained momentum with publications like the Club of Rome's *Limits to growth* (Meadows 1972) being widely read and studied. The publication became a watershed by popularising the realisation that the planet earth is a finite, closed system. The doomsday predictions of *Limits to Growth* failed to realise but worrying levels of pollution, resource scarcity (especially of oil reserves) and the possible impact of human activities on climatic changes, such as global warming, ensure that concerns about environmental impacts of development continue to feature in academic and international discussions of development (Bartelmus 1994).

The rapid economic growth of China and India over the past few decades has created concern that the planet earth cannot sustain 6-8 billion people living a "middle-class" European or American lifestyle (UNEP 2007). At the same time no one can deny the billions of poor in the developing world the opportunity to improve their quality of life, especially since the global communications revolution has made more people aware of the glaring inequalities in levels of economic development across the world (Bartelmus 1994). The paradox between finite resources, environmental degradation and intolerable levels of economic poverty can only be resolved if ways are found for people to improve their quality of life without significantly increasing the absolute levels of resource consumption on earth (Bartelmus 1994,p.29, Gallopin 2003).

Theories like that of Max-Neef (1991), which focuses on fulfilling fundamental human needs, and technologies such as renewable energy generation provide alternatives for the upliftment of the less-privileged without placing further strain on the carrying capacity of natural systems. Solar water heaters, in particular, provide a direct energy service, that of heating water, without leading to greenhouse-gas emissions and they offer potential employment creation opportunities that could contribute to poverty alleviation (Prasad & Visagie 2005). Unfortunately the technology remains too expensive for low-income groups, in part because the prevalent economic structures do not allow for the reflection of social and environmental benefits in prices. The literature review below investigates the research conducted on renewable energies and solar water heating in the South African, Western Cape and Stellenbosch contexts. The literature is used to emphasize the need for alternative sustainable development initiatives to relieve poverty and thereafter to develop an understanding of the potential of SWH to improve quality of life in low-income communities. Studies that have been completed on the South African SWH industry are also reviewed to show where this research makes a contribution and to inform possible policy initiatives to realise the benefits of SWH for poor communities.

2.2 CHAPTER SUMMARY

The literature review completed below starts with a discussion of the urgent need to pursue alternative development trajectories by providing background information on the challenges facing the entire world, South Africa, the Western Cape Province and Stellenbosch Municipality. Thereafter a systems approach to sustainable development is discussed in order to develop a theoretical basis for the discussion conducted in the rest of the thesis. Subsequently, solar energy and solar water heating in particular are discussed as alternative energy sources that could contribute to more sustainable development. The specific contributions that SWHs can make are then discussed before the existing literature is reviewed in order to identify the gaps in therein. Overall the structure of the review thus goes from a problem statement, through the establishment of a theoretical framework, to the discussion of a possible solution and what research is necessary to bring the solution closer to fruition.

2.3 BACKGROUND

The following paragraphs provide an overview of the global, South African, Western Cape and eventually Stellenbosch context. The context is provided to emphasize the urgency and need for research into sustainable development alternatives such as renewable energy technologies, including solar water heating, and to provide insight into the complex challenges facing people from the local to the global level. By identifying these challenges, the proposal to utilise SWH technology as a synergic satisfier to achieve sustainable development is justified.

2.3.1 GLOBAL CONTEXT

The WWF (2006) developed two indices to measure the impact of the "development" of human civilisation on the carrying capacity of the earth, the Ecological Footprint[10] and the Living Planet Index (LPI). The Living Planet Index reflects the health of the planet's ecosystems by measuring long-term trends in the Earth's biological diversity. It tracks populations of 1 313 vertebrate species[11] globally, calculating separate indices for terrestrial, marine, and freshwater species before averaging trends across the three indices to create an aggregated index. Although vertebrates represent only a fraction of known species, it is assumed that trends in their populations are typical of biodiversity overall. The aggregated index serves as a monitor for the health of ecosystems (WWF 2006).

The Ecological Footprint tracks levels of human consumption and waste generation in terms of the area of biologically productive land and water needed to provide the ecological resources and services consumed by humankind[12]. The Earth's bio-capacity is calculated as the amount of biologically productive area that is available for use as cropland, pasture,

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[10] Defined as "...humanity's demand on the biosphere in terms of the area of biologically productive land and sea required to provide the resources we use and to absorb our waste." (WWF 2006, p.14)

[11] Vertebrates include fish, amphibians, reptiles, birds and mammals

[12] Ecological resources and services measured include; food, fibre, timber, land on which to build and land to absorb carbon dioxide (CO_2) released by burning fossil fuels (WWF 2006).

forest, and fishing - in essence the productive land and sea area that is available to meet the needs of living organisms on earth. The total supply of productive area or the bio-capacity of the earth was estimated at 11.2 billion global hectares in 2003 (WWF 2006).

In the 2006 Living Planet Report published by the WWF both these indices paint an ominous picture. Between 1970 and 2003, The Living Planet Index (LPI) fell by roughly 30 per cent[13], while the Ecological Footprint has exceeded the Earth's 11.2 billion global hectares[14] bio-capacity since the 1980s, overshooting bio-capacity[15] by 25% by 2003 (refer to Figure 1) (WWF 2006). Hawken et al (1999) found similar indications.70% of the world's coral reefs are dying, freshwater and marine ecosystems are disappearing at rates of 6 and 4% per annum respectively. For nearly three decades humankind has been creating waste from resources faster than nature can regenerate those resources and turn the waste back into useful compounds. Such overconsumption is only possible for short periods of time while there is sufficient natural capital available to draw down. Natural capital stocks are built up over millennia and the harvesting of resources at rates faster than their regeneration rates reduce the ability of the natural systems to regenerate and the surplus that can be drawn down sustainably shrinks even further. Essentially the present annual amount of resources consumed by human civilization took roughly a year and three months to be produced by the earth's natural systems and processes and the waste generated annually will only be broken down over a year and three months (WWF 2006, p.14, Hawken et al 1999).

The impact of this over-usage is evident in the decline of biodiversity on earth as shown by the falling LPI. The rate of degradation has already reached a level unprecedented in human history and shows no sign of abating –our impact on the environment has increased threefold since 1961 and other life-forms on earth are struggling to survive due our overexploitation of the available bio-capacity (WWF 2006, p. 2).

The largest part of humankind's ecological footprint is caused by the way in which it generates and uses energy. Climate-changing emissions caused by the combustion of fossil fuels for the generation of energy account for 48% of the total global ecological footprint of human civilisation (WWF 2006, p. 1). This is thus the area where drastic change is most urgently required.

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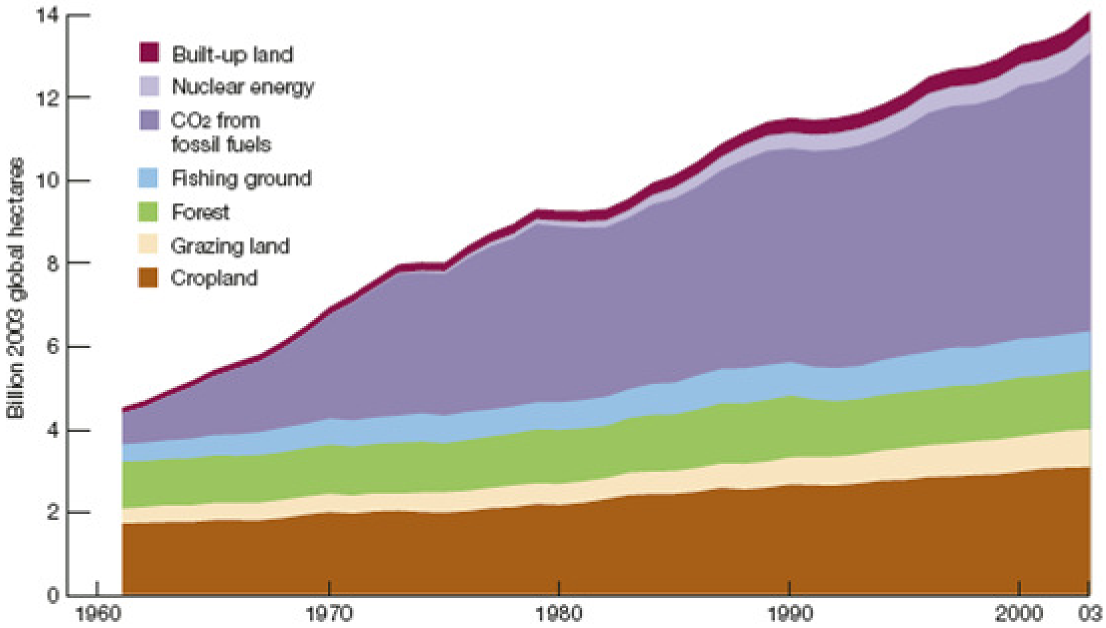
[13] Reflecting the reduction of the total population of vertebrates (excluding humans) by a third

[14] Given current technology levels

[15] Estimated at 11.2 billion global hectares in 2003

Figure 1 Global Ecological Footprint by Component 1961-2003 (WWF 2006, p.15)

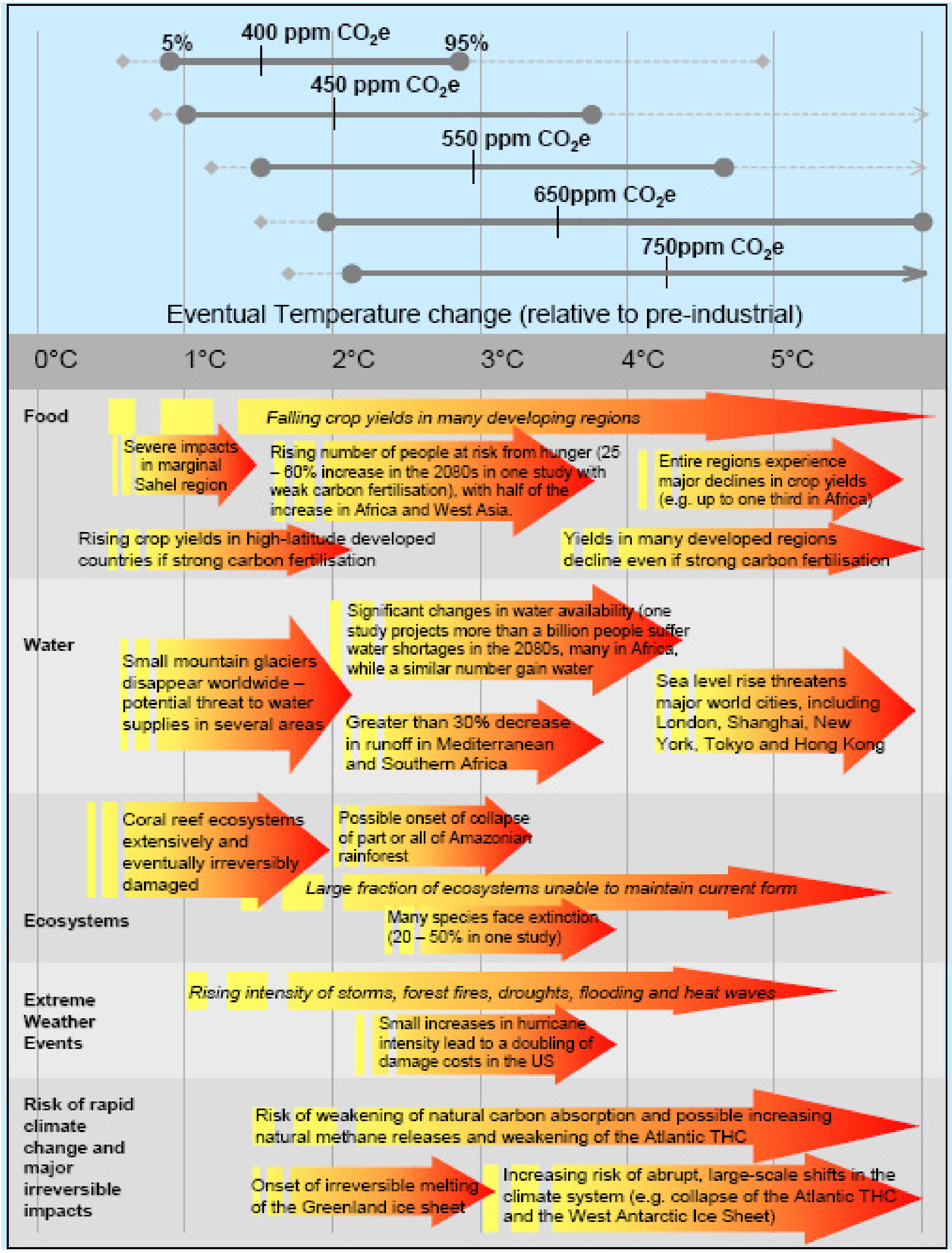


James Leape (cited in WWF 2006, p.1) places the blame for humankind's large ecological footprint at the door of the short-sighted development policies pursued by nations. He asserts that, *"what we currently accept as 'high development' is a long way away from the world's stated aim of sustainable development. As countries improve the wellbeing of their people, they are bypassing the goal of sustainability and...using far more resources than the planet can sustain.*" If the world continues to strive for "development" at the cost of the natural environment, natural resources will become ever scarcer and poor countries will find it increasingly difficult to improve the livelihoods of their citizens while rich countries will struggle to sustain the levels of material prosperity that they have already achieved.

> *"...global warming is now irreversible...nothing can prevent large parts of the planet becoming too hot to inhabit, or sinking underwater, resulting in mass migration, famine and epidemics."*
> (Lovelock cited in Aitkenhead 2008)

If humankind is to continue its attempts to improve the quality of life of all people on earth new ways of development that place much less strain on the natural environment will have to be found. Some scientists such as James Lovelock (cited in (Aitkenhead 2008) argue that irrevocable damage has already been caused and that catastrophic climate change can no longer be averted. This is due to the long-lasting nature of infrastructure that locks economies into specific paths of resource consumption (WWF 2006, p.3). To make future societies more sustainable the infrastructure created today needs to take environmental concerns into account (Bartelmus 1994, p.6). Figure 2 provides an indication of changes one can expect to see if current development paradigms are not altered to include environmental parameters.

Figure 2 Stabilisation Levels and Probability Ranges for Temperature Increases (Stern 2006, p.v)



The Stern report (Stern 2006, p.iii) estimated that the total stock of greenhouse gasses[16] would reach 550 ppm CO_2e[17] (double pre-industrial levels) by 2050 at the prevalent rate of emission growth. If greenhouse gas concentrations increase to such high levels temperature increases exceeding 2°C are highly likely[18] with devastating implications for people and ecosystems (Stern 2006). When one considers that global average temperatures are now only about 5'C warmer than during the last ice age (Stern 2006) the implications of such an increase become disconcerting.

Figure 2 from the Stern report (2006, p.v) illustrates the range of possible impacts that can be expected at different levels of atmospheric greenhouse gas concentrations. The top panel shows the range of temperatures projected at greenhouse gas concentration levels between 400ppm and 750ppm CO_{2e}. The solid horizontal lines indicate the 5 - 95% certainty range based on climate sensitivity estimates from the IPCC in 2001 and a Hadley Centre ensemble study. The vertical line indicates the mean of the 50th percentile point. The dashed lines show the 5 - 95% range based on recent studies. The bottom panel illustrates the range of impacts expected at different levels of warming due to increased greenhouse gas concentrations. The figure indicates that temperature rises above 4°C would significantly affect human life on earth with dire economic and social consequences. Greenhouse gas concentrations are approaching 400 ppmv CO_{2e} (UNEP/GRID Arendal 2009, CO^2 now 2010) and if these are not moderated temperature increases are very likely, as shown in Figure 2.

The impacts of such increases are already becoming evident with the shrinking of the Atlantic polar ice cap during summer as is shown in Figure 3 and Figure 4. In 2007 the IPCC found that observed changes in the earth's climate and its effects already show in many natural systems that are exhibiting signs of being affected by regional climatic changes. It concludes that[19] (IPCC 2007a, p.30) *"...warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level."*

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[16] For a description of how the greenhouse effect works please refer to the document entitled *The Greenhouse Effect* on the CD accompanying this thesis.

[17] CO_2e refers to "Carbon Dioxide equivalent" is the metric measurement unit for greenhouse gas emissions. The global warming impact of all greenhouse gasses is measured in terms of equivalency to the impact of carbon dioxide (CO_2) (Carbonpositive 2010b).

[18] The Stern report (2006) estimates the probability of a more than 2ºC increase due to such high concentrations of greenhouse gasses at 77%-99%.

[19] The research findings of the IPCC have recently been heavily criticised but the scope of this thesis does not allow for a critical scientific discussion of the findings of the panel. The assumption is that the findings of the IPCC and other reputable organisations such as the American National Academy of Sciences, The American Meteorological Society, the American Geophysical Union, and the American Association for the Advancement of Science as well as the work by authors such as (Levinski 2001) and Lovelock is credible. For a list of authors contesting the anthropogenic causes of climate change see Jaworowski (2007) and the US Senate Committee on Environment and Public Works (2009).

Figure 3 Artic Polar Ice-Cap 2003 (NASA 2003)

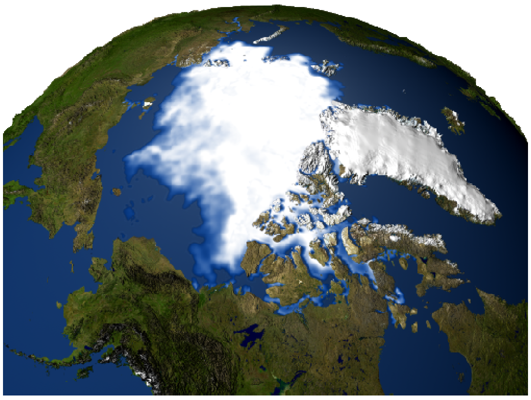
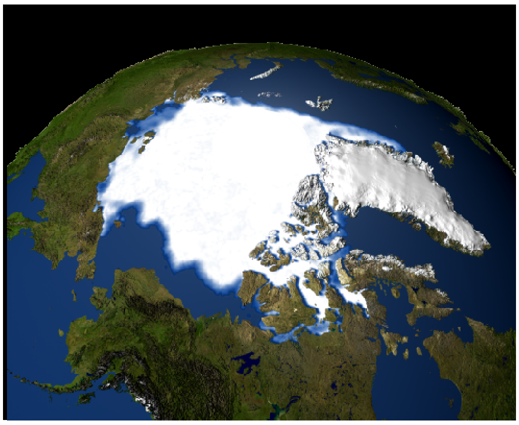


Figure 4 Artic Polar Ice Cap 1979 (NASA 2003)



The WWF (2006, pp.18, 19) have identified five intervention areas that could mitigate and eventually reverse the overshoot and resulting environmental degradation. These are: reduced population growth; reduced per capita levels of resource consumption; reduced footprint intensity[20]; increased bio-productive area and increased bio-productivity per hectare. Each of these areas should be targeted to achieve sustainable development objectives, but the focus of this thesis is on reducing per capita levels of resource consumption and footprint intensity by reducing the amount of electricity used in residential consumption. The technology for reducing these exists with solar water heating serving as a prime example. SWH presents a viable alternative energy source that can supply reliable, affordable and low carbon energy directly for water heating, reducing the need for fossil fuel generated electricity (Prasad and Visagie 2005).

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[20]. An "**Ecological Footprint**" is a measure of "how much biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates using prevailing technology and resource management practices. The Ecological Footprint is usually measured in global hectares. Because trade is global, an individual or country's Footprint includes land or sea from all over the world. Ecological Footprint is often referred to in short form as Footprint (not footprint)" (Global Footprint Network 2010). The footprint intensity of production can be significantly reduced through energy efficiency measures, waste minimization, recycling and improved logistical arrangements

Aside from concerns about ecological overshoot, there are also other strategic justifications for a shift to renewable energy sources. Non-renewable energy sources are becoming scarcer and more expensive to extract due to rising demand. Early signs are appearing that the finite limits of resource availability are approaching. The most prominent example is oil and the pending oil production peak[21] which serves as a stark reminder that fossil fuel resources are finite and exhaustible (Ivanhoe 1995, EIA 2009, Wakeford 2007). At some point the amount of resources that can be extracted economically from the earth will reach a maximum level at which point growth in demand will start to exceed growth in supply and prices will spiral upwards. Jeremy Wakeford, chair of the Association for the Study of Peak Oil (ASPO) in South Africa states that coal production in South Africa could peak within a decade, leading to strong increases in the cost of generating electricity from coal (Davie 2010). From an energy security perspective countries, including South Africa, have to find alternative sources of energy.

Over the past two decades the institutional foundations have been laid for an alternative development paradigm through national commitments to emission reductions (NRDC 2010) and international accords and agreements such as the Kyoto protocol signed in Kyoto, Japan, on 11 December 1997. 184 countries ratified the Kyoto protocol which committed developed nations to set emission reduction targets while encouraging developing nations to attempt emission reductions wherever possible (UNFCC 2010). The protocol expires in 2012 and a successor agreement was to be negotiated during December 2009 at the 15^{th} United Nations Climate Change Conference (COP 15) in Copenhagen[22] (UNFCC 2009).

The ultimate goal of the Copenhagen conference was that it should "*culminate in an ambitious and effective international response to climate change"* (UNFCC 2009). According to Winkler (2010) and Dimitrov (2010) the conference seems to have failed that vision with most countries only conceding to voluntary emission reductions in a regime with less enforcement power than the existing Kyoto protocol. Seemingly the political and economic conditions were not amendable for the development of a breakthrough agreement (Winkler 2010). An official negotiation text for further negotiations is to be drawn up and completed during 2010. The Kyoto protocol remains nominally active but countries can now choose more or less freely whether to implement its stipulations or not and the EU, once the leading party in its implementation has indicated that it would effectively abandon the protocol (Winkler 2010, Dimitrov 2010).

At the COP 15 negotiations South Africa, one of the highest emitters of CO_2 per capita (SEA 2009, p.2), committed itself to a 42% reduction in emissions from a business as usual level (The Presidency 2009a, NRDC 2010). If the country is to achieve this goal a range of interventions will have to be instituted including the development of energy efficiency strategies and renewable energies such as solar water heating. This will be necessary as the country currently sources 90% of its electricity from coal-fired power stations (Winkler 2006). These power plants are large sources of CO_2 emissions (SEA 2009). In order to fulfil its international objectives the country will thus have to reduce its dependency on electricity

[21] For a slightly more comprehensive discussion of oil peak theory and the relevance thereof please refer to the document entitled Oil Peak Production on the CD accompanying this thesis

[22] For a slightly more detailed overview of the problems of the Kyoto Protocol and the COP 15 negotiations please refer to the document entitled *The Kyoto Protocol and COP 15* on the attached CD.

generated in coal powered power plants. Solar water heating can play a role in such a strategy by substituting for the use of electrical geysers or kettles to heat water for bathing and cleaning.

2.3.2 SOUTH AFRICAN CONTEXT

The wider South African Context will be discussed briefly to inform the reader about the general circumstances relevant to renewable energy, low income housing developments, economic circumstances and solar water heating in South Africa. In terms of the structure of the argument followed it is important to note that South Africa is facing several serious development challenges. Unemployment and poverty levels remain high (as shown in the box below), the ecological footprint of the economy exceeds the available bio-capacity (WWF 2006) and the national electricity supply grid is under severe stress (Eskom 2009). These factors are discussed as they motivate the study of solar water heating as a systemic intervention that can contribute to sustainable development in the country.

Key indicators for South Africa

- *Estimated population* in 2009: 49,32 million (STATSSA 2009a, p.3)
- *Estimated GDP per capita* at Purchasing Power Parity in 2008: U$ 10 100 (ranked 105th in the world behind countries like Botswana and Mauritius (CIA 2009)
- The relatively high GDP per capita figure belies the high level of inequality in the country as indicated by the *Gini coefficient* value of 0.77 (2001 figure). (Human Sciences Research Council 2004)
- *Unemployment level:* 23.6% of the economically active population. Another 4.9% of the population of people of an economically active age is comprised of discouraged work-seekers who are not counted as part of the official unemployed but who are nonetheless unemployed and not otherwise occupied (such as enrolled in an educational programme). (STATSSA 2009b)
- *Poverty level:* In 2001 57% of households in SA survived below a poverty line set at R1 290 per month for a household of 4 persons. 32% of the households in the Western Cape survived on an income below the poverty line. (Human Sciences Research Council 2004). Preliminary findings by the National Treasury reflect a similar level of poverty calculated with data from 2000 (STATSSA & National Treasury 2007, p.10).

2.3.2.1 Socio Political Context

Unemployment in the country officially stands at 23.6% while an additional 4.9% of the population of people between the economically active ages of 15 and 64 are “discouraged work-seekers” who have given up hope of finding a job (STATSSA 2009). At the time of the last census, in 2001, more than 50% of the population were living below a poverty line of R322 per person per month (STATSSA 2009). At the same time part of the population enjoyed very high incomes, making South Africa one of the most unequal countries in the world with a high Gini coefficient level of 0.77 in 2001 (Human Sciences Research Council 2004; STATSSA & National Treasury 2007). It is estimated that the Gini coefficient had fallen to 0.68 by 2005 (Bhorat and Van der Westhuizen 2006) and 0.66 by 2008 (The Presidency 2009b).

Since its election to power in 1994, the ANC government has embarked on various programmes to alleviate poverty in the country. These included a national electrification programme to give all households access to modern energy services as well as a national housing programme, intended to ensure that all South Africans have access to formal housing, both launched as part of the Reconstruction and Development Programme (RDP) (Prasad & Visagie 2005, p.i). Though these programmes have achieved some remarkable successes, such as providing more than a million houses and increasing access to electricity to 70% of the total population from a level of 36% (DME 2001; Prasad & Visagie 2005, p.iv)[23], poverty remains stubbornly endemic. Unfortunately it was found that many households with new electricity connections continued to burn paraffin and biomass to meet their energy needs because electricity was too expensive. To overcome this challenge Government introduced a Free Basic Electricity Policy which provided low-income homes with 50 kWh of free electricity per month[24] (Prasad 2007, p.4; Prasad & Visagie 2005, p.vii).

2.3.2.2 Vulnerability and Contribution to Climate Change

Mitigating climate change and achieving sustainable development should not be a distant concern for developed nations. The South African economy remains vulnerable to climatic conditions and changes as it generates a significant part of the total GDP from climate dependent activities such as agriculture, tourism and fishing (DEADP 2007, p. 21). The potential impacts of climate change on South Africa and the Western Cape Province are briefly discussed below.

On a macro level, the western parts of the Western Cape are likely to become drier and droughts more frequent (DEADP 2007). "Increased evaporation and possible decreases in rainfall in many parts of the province will adversely affect water supply, agriculture and the survival of key species. Water quality may also be affected by increased soil erosion" (DEADP 2007, p. 11).Water resources are already overstretched (according to the WWF (2006) South Africa withdraws 25% of all available water), droughts are a frequent occurrence and the DEADP (2007, p. 11) estimates that agricultural water shortages are likely to occur once every three years. In a changed climate, when rain does fall, it is likely to do so in shorter, heavier spells (Desanker 2002, SouthSouthNorth 2005). Due to more intensive precipitation over shorter periods of time flooding in the south-western and southern coastal areas of the Western Cape is likely to become more frequent due to climate change (SouthSouthNorth 2005). Such changed rainfall patterns could adversely affect human habitation and infrastructure in low-lying areas in the southern coastal regions from the Cape Flats to Plettenberg Bay through flooding (DEADP 2007, p. 12).

The African continent in general is expected to experience global mean surface temperature increases of between 1.5°C and 6°C by 2100 (Desanker 2002). Although historical temperature data in the Western Cape is sparser than the data for precipitation, the historical temperature records show a warming trend in most areas in the Western Cape, with greater increases further away from the coast (DEADP 2007, p. 25). Figure 5 provides an example of the increasing temperatures. It illustrates increasing minimum temperatures over the last 50 years for a location in the Swartland in the Western Cape. The strongest trends are recorded in warmer minimum temperatures and further warming is expected to be most pronounced in the spring and summer months. Increased temperatures have direct effects on economic

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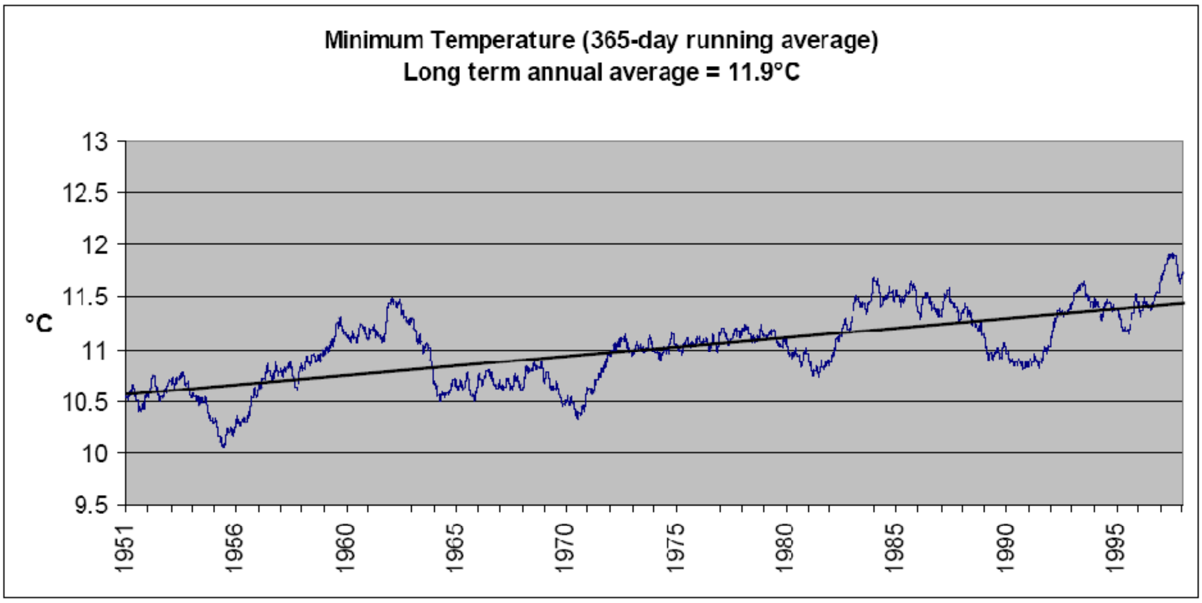
[23] The strategy is still some way from completion with 20% of the urban and 50% of the rural population still not having access to electricity as recently as 2006 (Winkler 2006, p.13).

[24] This amount was deemed sufficient for the operation of a black-and-white television, radio and occasional basic cooking[24] (Prasad 2007, p.4).

development in the province through increased crop burning, as well as increased incidence of pests such as the fruit fly (DEADP 2007, p. 25).

Figure 5 Daily minimum temperatures for a location in the Swartland (DEADP 2007, p. 26).



The impacts of changed rainfall patterns and increased average temperatures are most acutely relevant of the Agriculture and Tourism sectors.

In the agriculture sector climate changes leading to reduced annual rainfall, altered rainfall distribution and higher average temperatures have further knock-on effects through reduced soil and water quality, increased risk of droughts and floods as well as increases in weeds, pests and diseases. These changes could all lead reductions in yield, reproductive success and product quality (DEADP 2007). Certain crops will be specifically vulnerable to changes in their environment including small grains, rooibos tea, apples and pears (DEADP 2007). Kiker (2005) finds that maize crop yields in South Africa are likely to at best remain the same and at worst decrease by an average of up to 20% per annum.

The tourism sector is likely to be affected by the increased incidence of adverse weather events, such as floods, that cause damage to tourism-related infrastructure (e.g. promenades and waterfront developments, beach resorts and facilities; coastal routes and attractions). In extreme climate change scenarios rising sea levels and the related impacts on beaches and estuaries could greatly affect coastal tourism (DEADP 2007). Eco-tourism will be particularly vulnerable as flowering seasons become shorter and more erratic and endemic species become endangered due to habitat loss (DEADP 2007). Dryer weather could lead to more frequent wildfires which devastate landscapes. Lower rainfall would also effects estuaries leading to loss of bird and freshwater fish biodiversity (DEADP 2007).

Kirker (2005, p.20) finds that the fynbos and Succulent Karoo Biome would be at risk of widespread species extinction due to climate change while the Savannah grasslands in the North East would be exposed to invasion by Savannah tree species. Animal species are also adversely affected by predicted climate change. Kirker (2005) finds that out of 179 species examined 80% are likely to experience range contractions varying from 0 - 98% due to climate change. According to Kirker (2005) A Kruger National Park case study revealed that

66% of all species found in the park could disappear due to extreme climate change scenarios (< 50 % probability of occurrence).

Further unique impacts can be expected in coastal and marine environments. Expected risks include increased frequency and intensity of extreme weather events, increased saltwater intrusion and raised groundwater tables, greater tidal influence, increased flooding and increased coastal erosion (DEADP 2007). Sea levels on the African coast are projected to rise by 15 to 95 centimetres by 2100 (Desanker 2002). Most estuary environments in South Africa have already been degraded and climate change could greatly exacerbate existing threats through changes in salinity and estuary mouth cycles DEADP 2007, Kirker 2005). Heavier storms may critically affect salinity and closed/open estuary mouth status (DEADP 2007). Infrastructure such as sea walls that protect housing, promenades and road and rail embankments close to the sea may be structurally damaged by under-scouring. Similarly, managed dunes that provide protection for inland coastal areas will come under threat (DEADP 2007).

Fishery resources, already under pressure from over exploitation, face further threats from climate change. Climate change effects fish populations through changes in sea surface temperature, habitat change leading to species change, adverse weather, circulation patterns, and recruitment. These changes could likely lead to a reduction in Catch per Unit of Effort (CPUE) and catch rates. Reduced catch rates will impact heavily on lower-income fishing communities that are unable to adapt to the disappearance of their main source of income. Fishing stocks, biodiversity and ecosystems are likely to adapt very slowly to climate change (DEADP 2007, Kirker 2005).

Desanker (2002) argues that "Climate change will have significant impacts on biodiversity and food security in Africa," and that "The conservation of African biodiversity will ensure delivery of ecosystem goods and services necessary to human life support systems (soil health, water, and air). An integrated approach to environmental management is needed to ensure sustainable benefits for Africa." As part of the African continent South Africa faces the same challenge and further climate change poses a real threat to the further development of the country (DEADP 2007). The South African government therefore has an interest in and a responsibility to do its part in limiting anthropogenic climate change through pursuing alternatives such as renewable energy sources, including solar water heating.

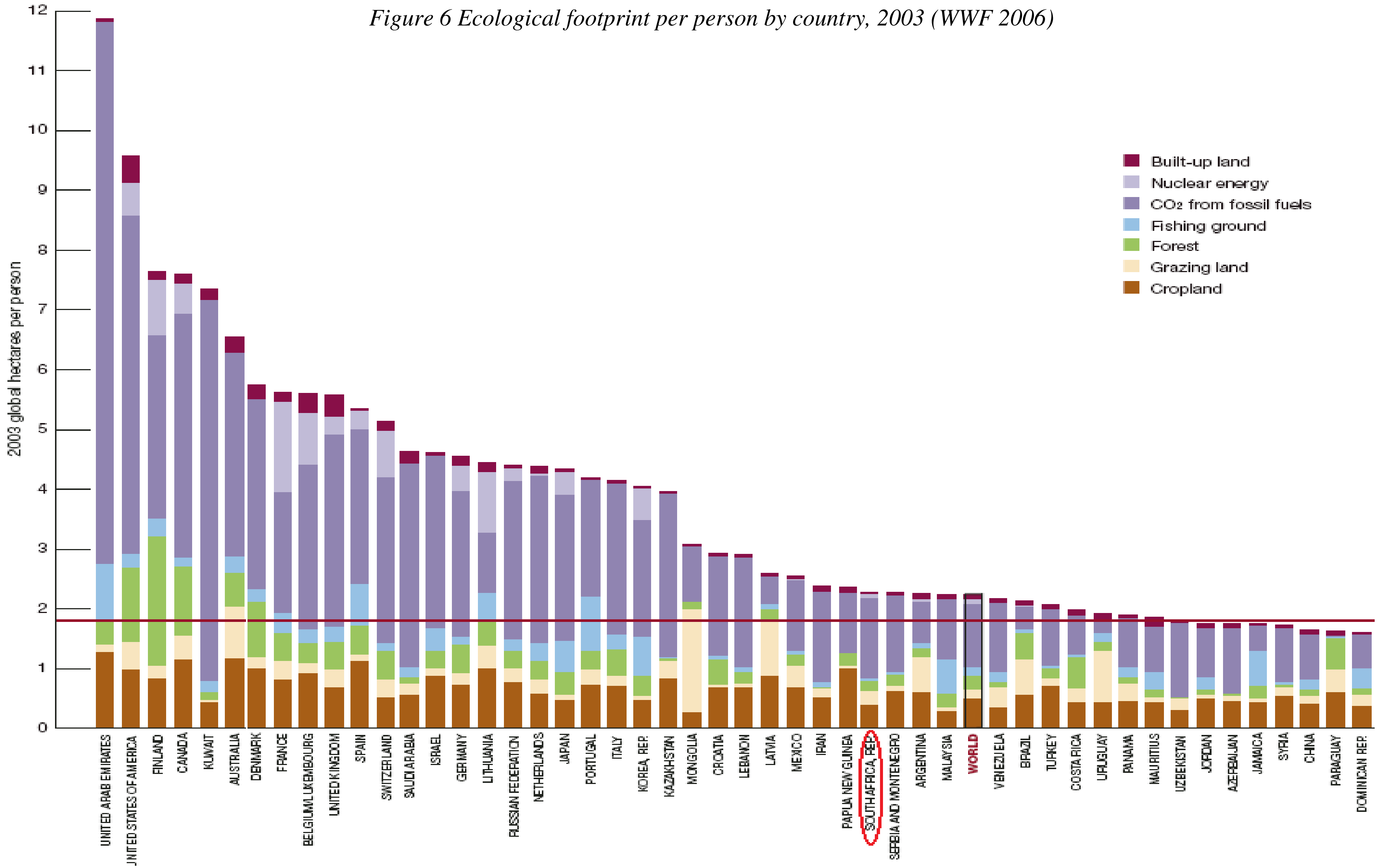
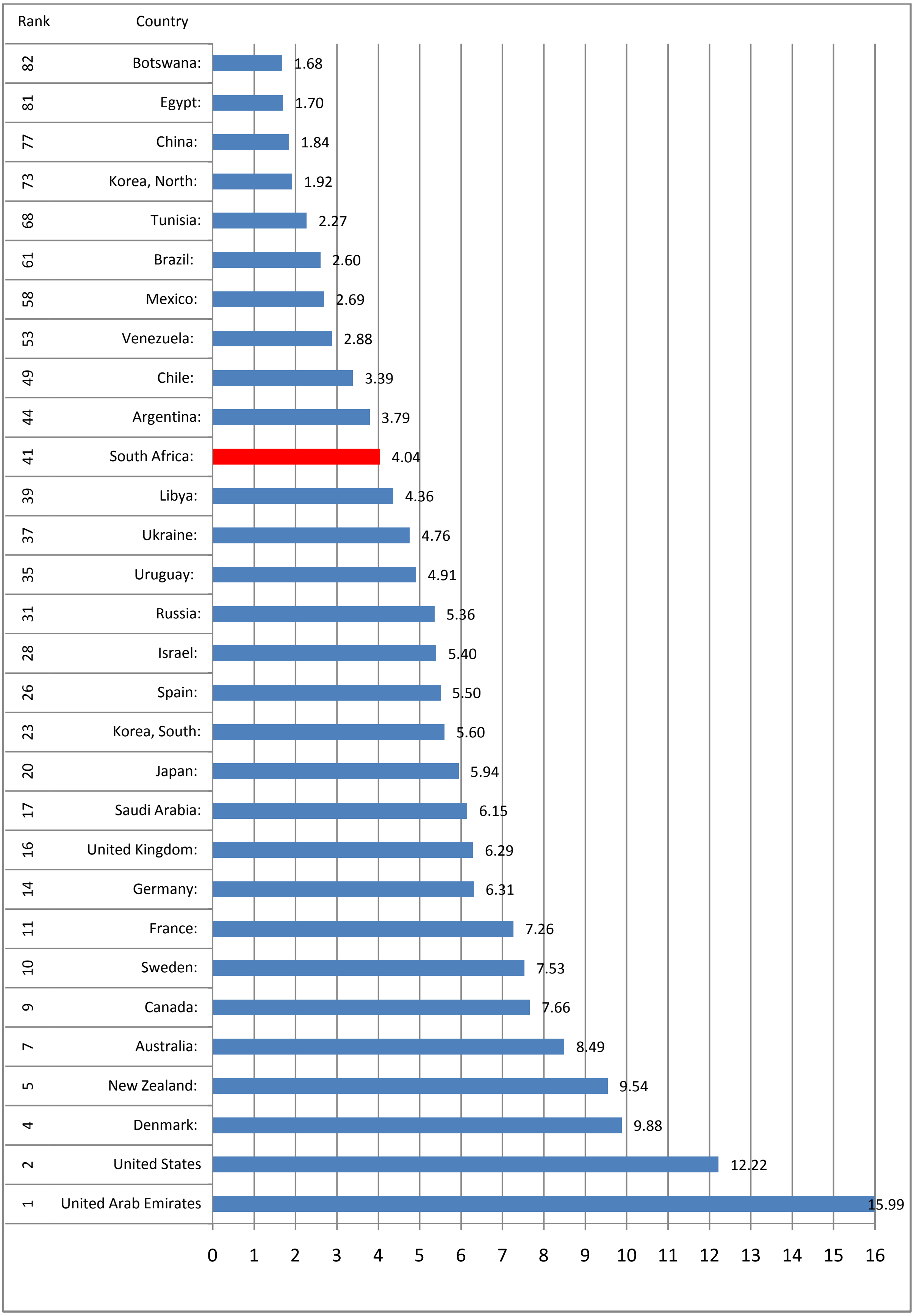


Figure 6 Ecological footprint per person by country, 2003 (WWF 2006)

Figure 7 Ecological footprint 2010 (global hectares per capita) (Nationmaster 2010a)



Though developed countries are the largest emitters of greenhouse gasses South Africa is one of the most carbon intensive economies in the world per unit of output and per capita (Winkler 2006). As such the country has to accept part of the responsibility for reducing greenhouse gas emissions. As can be seen from Figure 6 and Figure 7 the South African economy has given rise to an ecological footprint of more than 2 global hectares per person[25] since 2003 and of more than 4GH by 2010. This level of resource consumption exceeds the global average and the carrying capacity of the available ecological space, indicating that the country is a net importer of ecological resources. From Figure 6 it is clear that the overshoot is largely due to carbon emissions from the combustion of fossil fuels. In the South African case this is in large part attributable to the coal that is used to generate 85% of all electricity used in the country (EIA 2010). This reliance on coal combined with the large size and energy inefficiency of the South African economy has made the country the largest emitter of greenhouse gasses in Africa and one of the highest emitters per capita in the world (SEA 2009, p.2). In 2007 the country was the 13th largest contributor to global carbon emissions and the 45th highest contributor on a per capita basis (UNSD 2010).

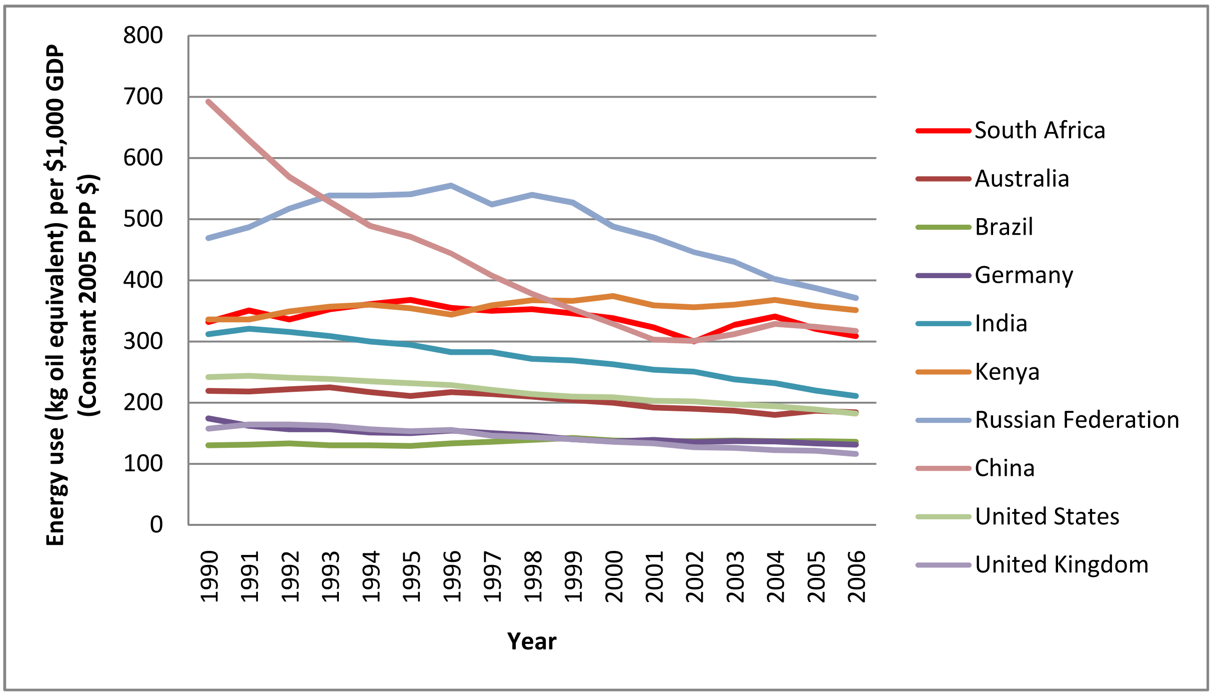
The large amount of fossil fuels consumed is due to the relative energy inefficiency of the South African economy (Winkler 2006). At purchasing power parity (PPP) of GDP in 2001 the South African economy required 0.24 tonnes of oil equivalent to generate production worth $1000 [IEA 2003 quoted in Winkler (2006: 4)] while average energy consumption per capita is roughly 2.4 tonnes of oil equivalent[26]. Figure 8 shows how South African energy consumption per $1000 of GDP output compares to a selection of other countries. Though the country's level of energy consumption is lower than that of some developing and transition countries such as Kenya and the Russian Federation it has failed to reduce its energy intensity whilst other fast growing countries such as China, India and the Russian Federation have successfully reduced the energy intensity of their economies. Large developed countries like the USA and the UK have energy consumption levels of less than 250 kg of oil equivalent per $1000 of GDP output (in 2005 PPP $) whilst most developing countries have much higher levels of energy consumption. The statistics indicate that high levels of energy consumption per GDP may not only be bad for the environment but might also contribute to slow economic development of a country[27] due to high energy costs for production.

[25] On average. These figures hide gross discrepancies between income groups within the South African economy.

[26] Again, this is an average figure that hides inequalities.

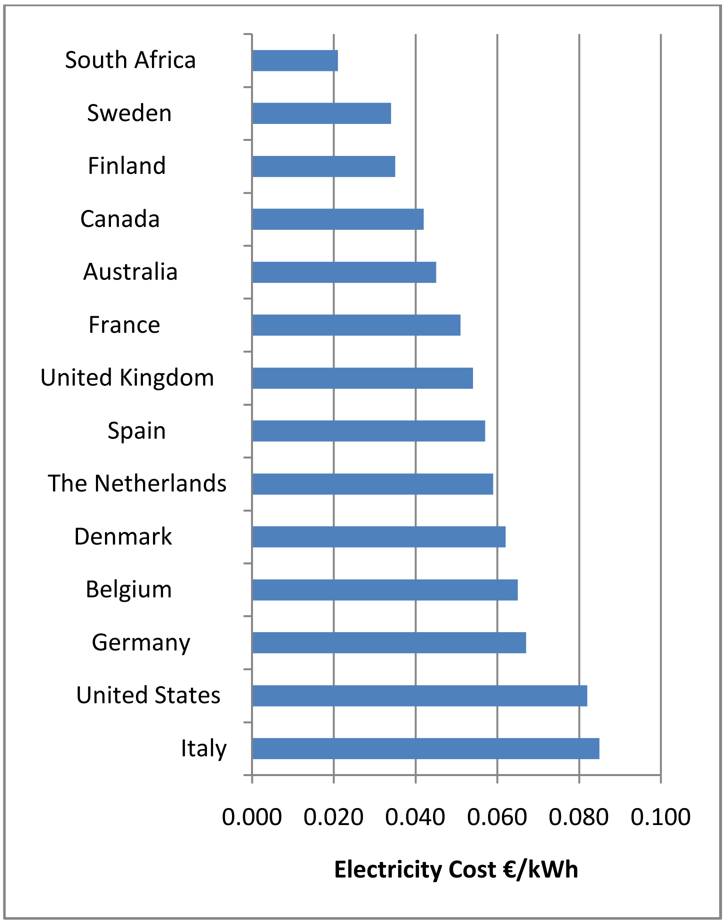
[27] Such a perfunctory analysis can however, offer no insight into the direction of causality and it may be that energy efficiency is a consequence of development rather than a cause.

Figure 8 Country Comparison of Energy Intensity per unit of GDP (United Nations Statistics Division 2009)



The primary reasons for the historic energy inefficiency of the South African economy is that South African coal reserves are relatively easily and economically extractable leading to extraordinarily low input costs for coal power stations (Winkler 2006, p.53). Figure 9 below illustrates how cheap electricity was (before the recent price increases) compared to the cost in many other countries.

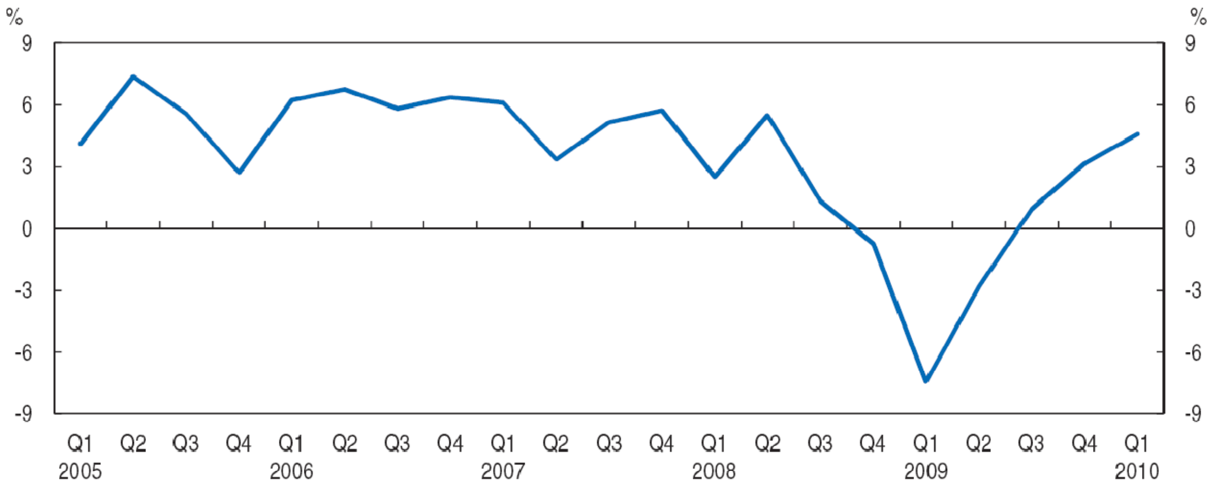
Figure 9 World Domestic Electricity Prices (Dolk 2008)



2.3.2.3 *The Electricity Crisis*

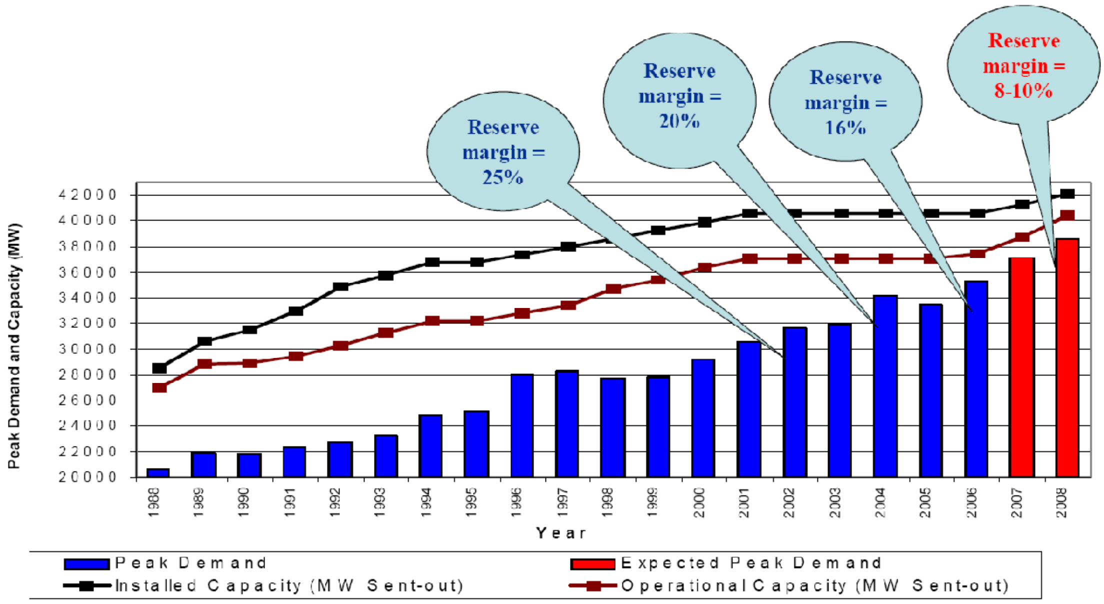
From an energy security perspective it is also critical that alternative energy generation technologies be developed. Figure 10 shows the growth rate of the economy over the past decade, averaging more than 4% between 2004 and 2007, whilst Figure 11 shows how the demand for electricity has grown compared to the growth in generation capacity. It is clear that the energy intensive growth of the economy has placed the national electricity grid under severe pressure with reserve margins shrinking to less than 10%[28] (Eskom 2009). In 2007 the inadequate reserve margin led to rolling electricity blackouts across the country as large power stations had to be shut down for maintenance (Eskom 2008).

Figure 10 South Africa GDP Growth Rate (OECD 2010)



[28] In a recent annual report (for 2008) Eskom admitted that electricity generation capacity reserve margins had shrunk to 5% during 2007 and 2008 (Eskom 2009). International best practice is that an electricity grid should maintain reserve capacity of at least 15% (Eskom 2008) and NERSA recommends a reserve margin of 19% (Eskom 2008).

Figure 11 Historical Growth of Energy Supply and Demand in South Africa (DPE 2008, p.4)

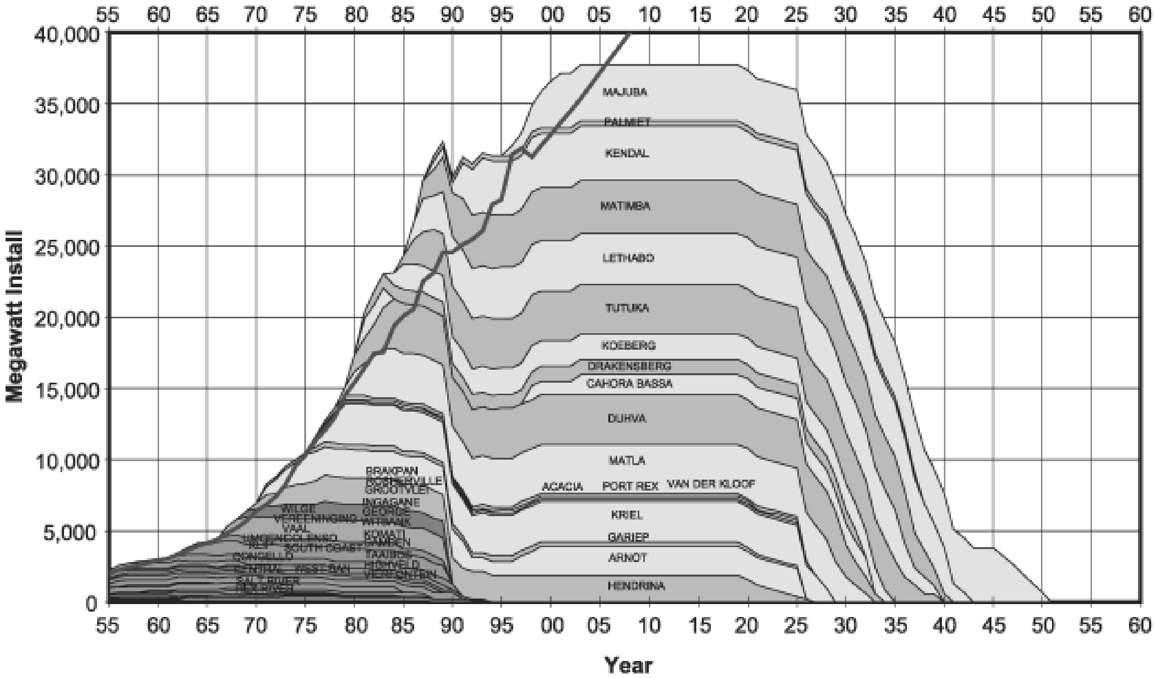


The economic recession of 2008 has offered the national utility some respite as the demand for electricity slowed down in line with shrinking economic output, but the long term forecast of electricity supply remains dire, at least until the new Kusile power station comes online after 2013 (Mundy 2010). Figure 12 provides an illustration of the development of electricity supply in South Africa since the 1950s. The long term forecast paints a dire picture after 2025 when the power stations built in the 1970's and 1980's will become obsolete. At that stage new build power plants will not only have to meet rising demand but also compensate for the loss of capacity due to the decommissioning of existing plants.

Given that new plants take roughly 10 years to construct from the first time that construction is approved (Spiessens 2008, p.1), the national utility faces a long-term energy crisis that could make the impact of the current capacity shortage seem negligible in comparison. Eskom will have to obtain financing to maintain and expand its electricity generation capacity and the loans it accepts will have to be repaid from electricity tariffs. It is thus inevitable that electricity tariffs will have to rise (Holm 2005, p.42). This process has started already with the National Energy Regulator (NERSA) allowing Eskom to increase electricity tariffs by 27% in 2007, 31% in 2008, another 31% in June 2009 and roughly 25% for 2010, 2011 and 2012. NERSA has also made it plain that tariff increases were likely to continue for the foreseeable future (Pringle 2009; PMG 2009; Creamer 2010).

Such increases are particularly painful for low-income households that spend a significant portion (8-15%) of their limited income on electricity (Aboutorabi 2000). Solar water heater rollout programs could partly shelter these vulnerable people from the worst effects of such increases and thus fulfil government energy policies that strive to provide access to energy services for all South Africans.

Figure 12 Predicted Cummulative Capacity of Existing South African Power Stations (Mehlomakulu 2009)



Though residential use only accounts for 15-17% (refer to Figure 13) of total electricity consumption, it constitutes the key component of total electricity demand during peak times (shown in Figure 14) when it accounts for 30% of the total electricity demand[29] (City of Johannesburg 2009, p.20; Eskom 2009). The national energy grid has to have sufficient capacity to fulfil peak demand periods and still maintain a safe reserve margin. Efforts to bring down peak electricity demand will thus have a significant moderating effect on the requirement for new power stations. SWHs can play a large role in this regard by supplanting the use of electricity for water heating during peak times when many people return from work and start using large amounts of water, heated by electrical appliances, for cleaning activities.

29 Typically in the early mornings between 8am and 12 pm and in the early evenings between 6pm and 10pm. Refer to Figure 14.

Figure 13 Components of Electricity Demand (created using data from Mehlomakulu 2009)

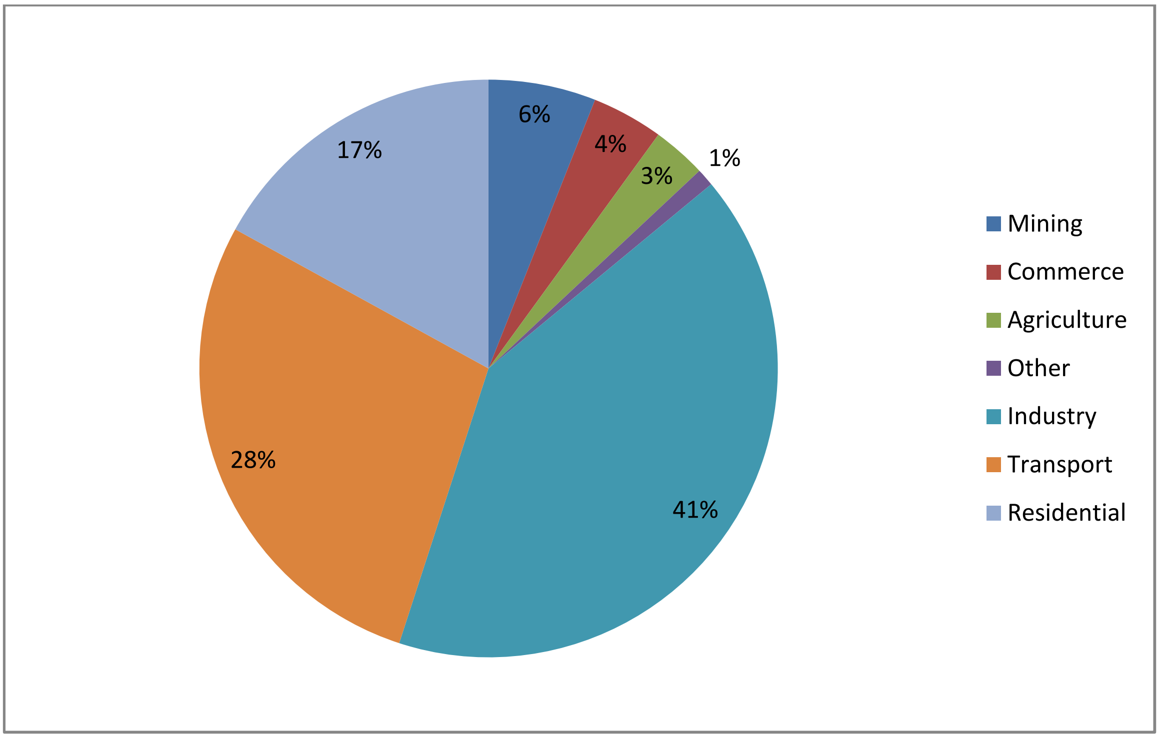
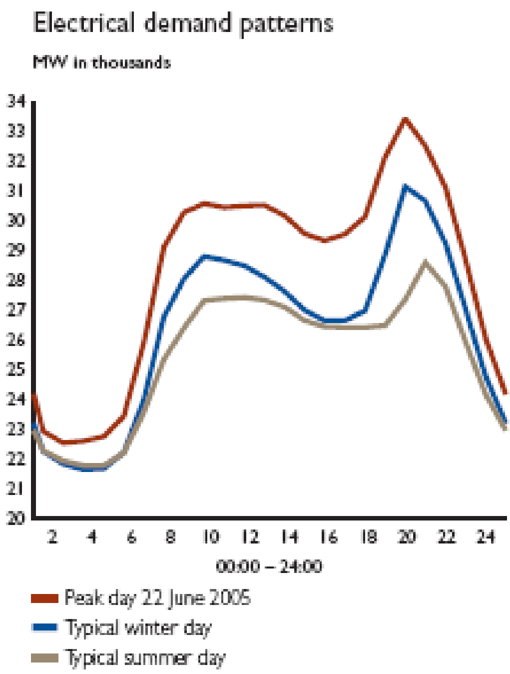


Figure 14 Electricity demand in South Africa (Eskom 2006, p.37)



2.3.2.4 Government Policies Relevant to Renewable Energy[30]

Access to modern energy sources, especially electricity, is considered to be one of the most basic of services that all people should have access to. In parallel to the RDP housing programme a National Electrification Programme (NEP) was implemented between 1994 and 1999 to ensure that all newly built government subsidised houses contained grid electricity connections. By 1999 Phase 1 of the programme had provided 2.5 million households with electricity bringing the total number of households with grid electricity to 5.5 million. By 2005 roughly 70% of households had access to electricity in their homes (Prasad & Visagie 2005, p.vi). Unfortunately it was found that many households with new electricity connections continued to burn paraffin and biomass to meet their energy needs because electricity was too expensive. To overcome this challenge Government introduced a Free Basic Electricity Policy which provided low-income homes with 50 kWh of free electricity per month (Prasad 2007, p.4; Prasad & Visagie 2005, p.vii). This amount was deemed sufficient for the operation of a black-and-white television, radio and occasional basic cooking[31] (Prasad 2007, p.4).

The NEP was based primarily on extending the existing electricity grid (and thus fossil fuel dependence) to incorporate previously excluded communities but on an institutional level government policy makers have begun to acknowledge the importance of renewable energy technologies. At the COP 15 negotiations the country committed itself to a reduction of greenhouse gas emissions by 42% from "business as usual" levels by 2025 (The Presidency 2009a). In his parliamentary Budget speech for 2008 Trevor Manuel (2008)[32], stated that South Africa has: *"an opportunity over the decade ahead to shift the structure of our economy towards greater energy efficiency, and more responsible use of our natural resources and relevant resource-based knowledge and expertise. Our economic growth over the next decade and beyond cannot be built on the same principles and technologies, the same energy systems and the same transport modes, that we are familiar with today."*

The 2003 *White Paper on Renewable Energy* stipulates that 10 000 GWh of electricity per year be sourced from renewable sources by 2013 (DME 2003). Of specific relevance to the SWH industry; the national government is currently developing a Strategic Framework & Implementation Plan for South African National SWH Development which hopes to achieve the rollout of 1 million SWHs across South Africa by 2014 (Afrane-Okese 2009). 50% of residential water heating needs (roughly 5 million SWHs) are to be supplied by solar water heaters by 2020 (Afrane-Okese 2009). The findings of this thesis could be of great use to the further development of this framework and the achievement of its targets by contributing valuable insights into the strategic leverage points for cost reduction in manufacturing SWH, quantifying the effect of SWHs for consumers in the Western Cape and the job creation potential of the industry.

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[30] For a slightly more detailed overview of the policy context please refer to the document entitled Policy Context on the CD attached to this document

[31] Note that households are unable to heat water within the free electricity subsidy

[32] South African Minister of Finance at the time

2.3.2.5 Different Levels of Government in South Africa

This thesis investigates how SWH can be made available for low income households. Sections 2.7 and 4.1 discuss the potential benefits of the technology for low-income households. Section 2.8.5 and 4.2 discuss the state of the local SWH industry. These two discussions are then integrated in section 4.3 to identify how government can become involved in the rollout of the technology. The discussion helps to identify which level of government is the appropriate level for effective intervention and how this intervention may be structured. In order to understand the role that different levels of government can play a brief overview of the responsibilities and mandates of national, provincial and local government is provided below.

<u>Powers and functions of National Government</u>

National government functions are fulfilled by the Parliament, Presidency and Cabinet of Ministers. Laws and policies are approved by Parliament, which is made up of the National Assembly and the National Council of Provinces (NCOP). The National Assembly is made up of elected members of Parliament (ETU 2010).

The President is elected by Parliament and appoints a Cabinet of Ministers. They act as the executive committee of government and each Minister is the political head of a government department. Each government department is responsible for implementing the laws and policies decided on by Parliament or the Cabinet (ETU 2010).

Every department prepares a budget for its work. The budgets are put into one national budget by the Treasury (Department of Finance), which has to be approved by Parliament (ETU 2010).

The departments with mandates relevant to this thesis, through their responsibilities in the energy sector or social/economic development sectors are:

- <u>The Department of Energy</u> with a vision to achieve a "transformed and sustainable energy sector with universal access to modern energy carriers for all by 2014." and "Improving our energy mix by having 30% of clean energy by 2025" (Department of Energy 2010).
- <u>The Department of Environmental Affairs</u> with a vision to create "A prosperous and equitable society living in harmony with our natural resources" (Department of Environmental Affairs 2010).
- <u>The Department of Human Settlements</u> with a vision to achieve a "nation housed in sustainable human settlements" (Department of Human Settlements 2010).
- <u>The Department of Labour</u> with a vision to achieve "...a labour market which is conducive to economic growth, investment and employment creation and which is characterised by rising skills, equity, sound labour relations, respect for employment standards and worker rights" (Department of Labour 2010).
- <u>The Department of Public Works</u> which is the administrator of the Expanded Public Works Programme (EPWP) with a mandate which includes the eradication of poverty, unemployment and underdevelopment (Department of Public Works 2010).
- <u>The Department of Trade and Industry</u> with a vision to: "By 2014, following the successful implementation of the microeconomic reform strategy and complemented by continued macroeconomic stability and a process of sustainable social development, South Africa will have a restructured and adaptive economy characterized by growth, employment and equity, built on the full potential of all

persons, communities and geographic areas" (The Department of Trade and Industry 2010).

Powers and Functions of Provincial Government

There are nine provincial governments. Every province has a Legislature made up of between 30 and 90 members of the Provincial Legislature (MPLs). The Provincial Legislature passes provincial laws and budgets and has to elect a provincial Premier. The Premier appoints Members of the Executive Council (MECs) to be the political heads of each provincial department. The MECs and the Premier form the Provincial Executive Council (Cabinet). Most of the public servants in the country fall under provincial government including teachers and nurses (ETU 2010).

In each of the nine provinces there are usually at least twelve departments. The names are slightly different, and in some provinces departments are combined, but they generally consist of Finance, Economic development, Tourism, Housing, Education, Health, Social Development, Transport, Public works, Planning and Environment, Sport, recreation, art and culture, Agriculture, Local government, and Safety and security (ETU 2010).

Each province has to develop a Provincial Growth and Development Strategy (PGDS) that spells out the overall framework and plan for developing the economy and improving services. Provinces also have a Spatial Development Framework (SDF) that says where and how residential and business development should take place and how the environment should be protected (ETU 2010). Legislation or programmes relative to renewable energies can form part of the SDF or PGDS. Provincial government can play a powerful role in this regard as the legislative authority of provinces, as vested in provincial Legislatures, gives them the power to "pass legislation for the province with regard to any matters within a functional area listed in Schedule 4 and Schedule 5 of the Constitution" (PMG 2010).

Powers and functions of Local Government

The whole of South Africa is divided into local municipalities that are responsible for the following functions: Electricity delivery, Water for household use, Sewage and sanitation, Storm water systems, Refuse removal, Fire fighting services, Municipal health services, Decisions around land use, Municipal roads, Municipal public transport, Street trading, Abattoirs and fresh food markets, Parks and recreational areas, Libraries and other facilities, Local tourism (ETU 2010).

Each municipality has a council where decisions are made and municipal officials and staff who implement the work of the municipality. The Council has to determine development plans and ensure service delivery for their municipal area (ETU 2010). SWH programmes may form part of such development plans as well as service delivery strategies. There are three different kinds of municipalities in South Africa.

1. Metropolitan municipalities: There are six of these consisting of the largest cities in South Africa. They have more than 500 000 voters and the metropolitan municipality co-ordinates the delivery of services to the whole area. There are metropolitan municipalities in Johannesburg, Cape Town, Ethekwini (Durban), Tshwane (Pretoria), Nelson Mandela (Port Elizabeth) and the Ekhuruleni (East Rand) (ETU 2010).

2. Local municipalities: Areas that fall outside of the six metropolitan municipal areas are divided into local municipalities. There are a total of 231 of these local municipalities (ETU 2010).

3. District municipalities: District municipalities are made up of a number of local municipalities that fall in one district. There are usually between 3 - 6 local municipalities that come together in a district council and there are 47 district municipalities in South Africa. The district municipality has to co-ordinate development and delivery in the whole district. While metropolitan municipalities are responsible for all local services development and delivery in the metropolitan area, local municipalities share these responsibilities with district municipalities. This is especially the case in very rural areas, where district municipalities will have more responsibility for development and service delivery (ETU 2010).

Interventions to increase the market penetration of SWH can be sucessfully implemented at every level of governement as is evident from section 2.9 below. The Strategic Framework & Implementation Plan for South African National SWH Development (Afrane-Okese 2009) illutrates that National Government can play a role. The Western Cape SWH project shows how provincial government can facilitate rollouts and the Kuyasa CDM project shows how a local government, in that case the city of Cape Town, can play a role.

2.3.2.6 Solar Radiation Levels in South Africa

The South African climate is extremely well suited for the use of SWHs with some of the highest levels of solar radiation worldwide, especially in the interior, though coastal conditions are still better than in most countries in Europe where SWHs have been successfully rolled out. The annual 24-hour solar radiation average for South Africa is 220 W/m^2 (ranging between 4.5 and 6.5 kWh/m^2 daily) while the average in large parts of the USA is only 150 W/m2 (3.6 kWh/m^2 daily) and around 100 W/m^2 (2.5 kWh/m2) for the United Kingdom and Europe (Prasad & Visagie 2005, p.10; Winkler 2006, p.50). Figure 16 presents a graphic representation of the mean annual level of solar radiation across Europe, the Middle East and Africa. Solar radiation is highest in the darkly shaded areas and lowest in the white areas. From the figure it is clear that South African weather conditions are much more suitable for SWH than European conditions are. The most widely used model of solar radiation in South Africa is the map shown in *Figure 15* produced by Eskom, the CSIR and the DME (DME 2002, p.3). It shows the level of *"solar radiation received on a level surface"* across South Africa.

Holm (2005, p.61) postulates that conventional estimates of solar radiation such as the figures provided here, tend to underestimate the energy that is available to SWH. The maps are typically based on direct surface radiation whereas SWH collectors are installed at an optimal angle (roughly equal to the latitudinal position plus 10°) to maximise radiation exposure. The installation angle can increase the energy that is available significantly. Cape Town, for example, receives 2198 kWh/m^2 (of radiation per year on an optimally tilted surface) at an average of 6.02 kwh/m^2 per day (Holm 2005, p.61). This figure is 15% higher than the value of 1915 kWh/m^2 per annum (5.25 kwh/m^2 per day) stated in the CSIR/Eskom/DME map.

Figure 15 Solar Radiation levels across South Africa (DME 2002, p.3)

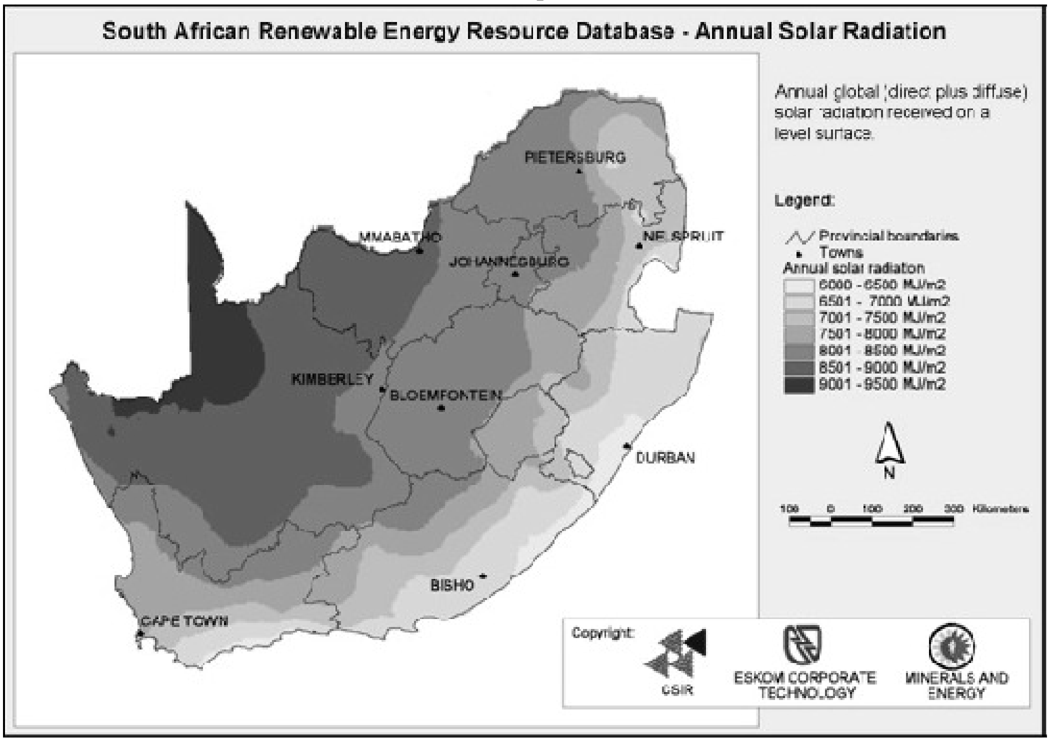

Figure 16 Solar Radiation levels across Europe, the Middle East and Africa (Holm 2005, p.19)

2.3.2.7 Potential Contribution of SWHs

If the challenges of poverty, greenhouse gas emission reduction and increased access to electricity are to be sustainably met, South Africa will need to reduce the energy and carbon intensity of its economy by developing strategies for poverty reduction that cause as little further environmental degradation as possible. Gallopin (2003, p.25) suggests a two pronged approach for achieving sustainability. He suggests that the rich minority, responsible for the lion's share of energy use and carbon emissions, drastically adjust their consumption patterns while currently disadvantaged communities are uplifted using strategies that do not bind them to the high ecological footprint consumption patterns. The focus of this thesis is on the latter half of the approach suggested by Gallopin.

Given that South Africa has such excellent levels of solar radiation this thesis argues that SWHs can and should be an integral part of the electrification and housing delivery processes as they can reduce the electricity usage of existing homes (Holm 2005, Winkler 2006). This will free up ecological space for new builds by reducing the electricity requirement and carbon intensity of new builds. By reducing dependency on grid electricity for water heating the technology can weaken the correlation between resource consumption and human development. Section 2.4.2 of the thesis will argue that, if the process of making SWH technology available for low-income households is considered to be as important as the final installations, the technology can also be used to create employment opportunities (Prasad & Visagie 2005). Such employment opportunities will be crucial for the fulfilment of a whole range of fundamental human needs (Max-Neef 1991). By delivering these, quality of life for low-income communities can be improved at a much lower cost in natural resources.

2.3.3 THE WESTERN CAPE PROVINCE

The specific focus of this thesis will be on the Western Cape Province and greater Stellenbosch in particular. This level of analysis was chosen as it allows for practical case studies of hot water demand and an overview of the potential of the solar water heating sector in terms of improving local economic development. Many of the challenges faced by the country are equally relevant in the Western Cape (DEADP 2007, Desanker 2002).

There are particularly strong incentives for the Western Cape Province to play its part in fighting environmental degradation and climate change. The area is one of the richest regions in the world in terms of diversity of ecosystems and species, enjoying international recognition as a top global 'biodiversity hotspot' (DEADP 2007). The provincial economy is more heavily reliant on tourism and agriculture than other provinces and as such climate change poses a larger than usual threat (Sustainability Institute & Probitas Real Estate Finance Education CC 2006). The Western Cape is South Africa's foremost tourism region (Winde 2009) and agriculture directly accounts for 4.8% of economic activity. Due to climate change the province is projected to experience increases in minimum and average annual temperatures, extreme weather events and rampant wildfires, whilst total rainfall, water resources and soil moisture content is set to fall. All these effects could drastically impact on the tourism and agricultural sectors (DEADP 2007). With an unemployment rate of 22.5% (Winde 2009) the province can ill-afford loss of employment opportunities due to environmental factors.

The electricity crisis is also acutely reflected in the Western Cape. More than 90% of the province's energy is extracted from imported non-renewable fossil fuels that cannot be sourced locally and the province imports most of its electricity from the provinces further north (DEADP 2007). The Koeberg nuclear power station generates roughly 36% of the province's electricity supply and failure of one of the reactors has a large impact on electricity availability (Sustainability Institute & Probitas Real Estate Finance Education CC 2006). Table 1 provides a breakdown of the electricity supply available to the Western Cape.

Table 1 Current Western Cape Electricity Supply Limitations[33]

Transmission Lines from Eskom Network	2400MW
Koeberg Unit 1	900MW
Koeberg Unit 2	900MW
Palmiet Pumped Storage (Peak)	400MW
Steenbras Pumped Storage (Peak)	168MW
Acacia Gas Turbine	171MW
Total Generation Capacity	**4939MW**

Demand for electricity in the residential sector remains extremely unequal, with average middle- to high-income households consuming on average 774KWh/month and low-income households using only 274KWh per month (Sustainability Institute & Probitas Real Estate Finance Education CC 2006). This indicates a large suppressed demand for energy services that would lead to a large increase in electricity demand if any significant gains in economic development are made. The existing electricity grid can ill afford such an increase.

Similar to the national context SWHs are proposed in this thesis as a potential synergic satisfier for the development challenges facing the Western Cape.

2.3.4 CONTEXT OF STELLENBOSCH MUNICIPAL AREA

Stellenbosch municipal area is confronted by all the challenges that the Western Cape as a province faces and serves as a reflection of the prevalent circumstances of wider South Africa. It includes communities from very different income groups and ethnic backgrounds. Social and economic inequality remains prevalent in the area and many households live in poverty. Despite strong economic growth of 4.4% per year between 2000 and 2004 the demand for unskilled and semi-skilled workers has been steadily decreased and income inequalities between rich and poor communities in the area are growing rather than decreasing with overall unemployment rising from 17% in 2001 to 26% in 2006[34] (Sustainability Institute & Probitas Real Estate Finance Education CC 2006).

The municipality faces the task of addressing poverty and inequalities amongst existing residents whilst also dealing with large population increases due to in-migration that has caused an acute housing shortage. The municipal area currently consists of roughly 34 000 households and will require an estimated additional 25 000 new formal houses by 2017, primarily due to the in-migration of people from surrounding areas and the Eastern Cape. At least 16 000 of the required houses will be for low-income households (Sustainability Institute & Probitas Real Estate Finance Education CC 2006).

[33] (Sustainability Institute & Probitas Real Estate Finance Education CC 2006 and DEADP 2007)

[34] For a more detailed overview please refer to the document entitled Income Inequality and Unemployment in Stellenbosch on the CD attached with the thesis.

Addressing this challenge is extremely difficult in light of the fact that Eskom has limited spare grid electricity capacity (Eskom 2008), which makes it difficult to provide additional electricity services for new housing developments. The municipal area thus reflects wider provincial and national circumstances through having to address the challenge of achieving poverty alleviation and reducing income inequality without increasing the carbon and ecological footprint of the area or placing further strain on the national electricity grid.

Alternative development opportunities that would uplift the disadvantaged portion of the population are urgently required to achieve greater socio-economic equity. A large scale rollout of SWHs on a provincial or local scale is one possible intervention that could play a role in achieving this objective. The technology not only offers an opportunity to improve quality of life through a once-off improvement in service availability and electricity expenditure reductions but it also offers an opportunity for employment creation. The creation of new employment opportunities could in turn drive further local economic growth by increasing economic activity.

2.3.5 CONCLUDING REMARKS

The primary purpose of this thesis is to illustrate the benefits of solar water heating and then to subsequently identify how the technology can be made accessible for low-income communities. By conducting a quick overview of the global, African, South African and, finally, the provincial and local context of Stellenbosch municipal area in the Western Cape province it has been shown that climate change is a real threat on all levels and that every facet of development, even in developing areas that are not historically to blame for the current state of affairs, needs to minimise its contribution to greenhouse gas emissions. At the same time interventions are also necessary to address the electricity capacity shortage crisis in South Africa to ensure that energy is available to power future economic growth. However, economic development cannot be halted as unemployment remains at around 23%. The government remains convinced that the South African economy will only be able to solve the unemployment challenge at GDP growth rates of 6% to 8% but growth *"...is not the ultimate aim. It is the means to the end – a better life for all"* (Western Cape Provincial Treasury 2006).

In the context of environmental concerns and electricity shortages solar water heaters can contribute to the ideal of a better life for all by:

- reducing the domestic demand for electricity.
- reducing greenhouse gas emissions, specifically carbon released during the generation of electricity in coal-fired power stations,
- providing the energy service of water heating to poor communities and,
- through the manufacturing and installation of systems, provide employment opportunities where they are needed most.

The discussion up to now has often alluded to the need to find alternative development perspective that will allow the disadvantaged portion of the world's population to improve their quality of life without placing further unnecessary strain on the earth's natural resources. The following part of the thesis will present such an alternative perspective and develop a conceptualisation of sustainable development to be used as the theoretical base for the discussions conducted in the thesis. This discussion is deemed valuable as it provides a solid epistemological basis for the research findings later in the thesis in terms of the contribution that solar water heating can make towards sustainable development in South Africa.

2.4 CONCEPTUAL FRAMEWORK: A SYSTEMS THEORY APPROACH TO SUSTAINABILITY

The previous paragraphs have shown how that South Africa has an interest and a responsibility in following an alternative development trajectory that would not lead to the destruction of the natural environment. At the same time developmental strategies have to address unemployment, poverty and the electricity crisis. The following section of the thesis will develop a conceptual approach that can be used to underpin solutions to the myriad of challenges faced by towns and provinces in South Africa. Subsequent discussions of the role that solar water heaters can play in helping to make energy consumption more sustainable will be based on the conceptual framework sketched here.

There are different concepts of what "sustainable development" means, with the most common definition being that of the World Commission on Environment and Development (WCED cited in Pezzoli 1997)[35] which reads that; *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*. Though widely accepted, this definition is open to interpretation and there are several different schools of thought on sustainable development. One possible categorisation divides these approaches into Conservative Political Ecology (Pezzoli 1997; Stiglitz 2002; Hattingh 2001), based on capitalist economic theory, Radical Political Ecology (McLaren 2003; Hartwick & Peet 2003), an element of which is based on socialist theory Deep Ecology and Environmental Ethics (Hattingh 2001; Macy & Young-Brown 1998), based on a belief that plants and animals have as much of a right to existence as human beings do, and Systems theory (Gallopin 2003; Clayton & Radcliffe 1996) [36].

Systems thinking (Gallopin 2003; Clayton & Radcliffe 1996) is an approach to sustainability that considers the various agents interacting in the world as systems. The approach acknowledges the complexity of these interactions and recognises that solutions to the problems confronting the world cannot be reduced to 'one dimensional mapping' (Clayton & Radcliffe 1996, p.12). The systems theory approach is selected for this thesis as it allows for an integrated investigation of the challenges facing the Western Cape and Stellenbosch. A point of departure that recognises the relationship between the challenges allows for SWH to be investigated as a partial solution to a complex systems problem with many elements. The systems approach, as developed by Gallopin (2003), is discussed below.

2.4.1 SYSTEMS THEORY ON SUSTAINABLE DEVELOPMENT AS DEVELOPED BY GALLOPIN

Systems theory emphasizes interrelationships between phenomena in the wider context wherein human civilization exists. It offers a holistic view of development in which the system as a whole amounts to more than just the sum of its parts. Gallopin (2003, pp.10, 11) argues that even supporters of a "weak" approach to sustainable development have to concede that the environment needs to be protected. He postulates that our lack of knowledge about the full value and possible future uses of natural resources makes it impossible to

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[35] Also known as the Brundtland Commission

[36] For an overview of the other approaches to sustainable development please refer to the document entitled Different approaches to Sustainable Development on the attached CD.

ensure that all substitution of different forms of capital with each other will be 100% efficient. Even conservative political ecologists have to concede that at the very least a precautionary approach[37] should be followed in sustainable development strategies.

A systems theory approach recognises that sustainable development strategies need to accept responsibility for the well-being of all life on earth but it remains particularly focussed on the improvement of human quality of life (Clayton & Radcliffe 1996) Based on this point of departure this thesis has a strong social focus. The conceptual approach is developed primarily based on the system theories of Gallopin (2003) and the social development theories of Max-Neef (1991). These authors are discussed sequentially and then their theories are integrated to inform the approach to sustainable development used for this thesis.

For Gallopin (2003), it seems inevitable that all thinking about sustainability and sustainable development should eventually reach the conclusion that sustainability can only be achieved by finding ways of maintaining and developing the entire socio-ecological system rather than just parts thereof. Implicit in such a conclusion is a realisation that all types of capital are not perfectly substitutable. Ecological elements are integral to the system and cannot be replaced by social or technological elements. It is necessary to find paths of development that will not eventually lead to the depletion of ecological systems. By the same criteria, social development cannot be completely sacrificed in favour of ecological sustainability. Integrated systems-based solutions that solve ecological and social challenges concurrently need to be found and implemented to ensure development that is sustainable on social, economic and environmental levels. According to systems theory challenges indifferent "spheres" can no longer be addressed separately (Gallopin 2003, Clayton & Radcliffe 1996) in the way that conservative political ecology suggests (Pezzoli 1997; Stiglitz 2002).

Systems theory disagrees with the vision of Deep Ecology and Environmental Ethics that the "perfect" society would exist in complete and constant harmony with nature. Instead a systems theory approach postulates that a sustainable system needs to be in continuous dynamic equilibrium with its environment, with enough internal variety, change and diversity to cope with varied external impulses and events[38]. Gallopin (2003, p.19) phrases this requirement as follows: "*All living systems are changing systems and the essential point is not to eliminate change, but to avoid the destruction of the sources of renewal, from which the system can recover from the unavoidable stresses and disturbances to which it is exposed because of its condition of being an open system.*" The word "development" implies change. It is, and will probably always be, part of human nature to dream of creating a better future. The task of sustainable development is to realise improved quality of life for human beings without destroying natural sources of energy flow. To achieve this, humankind needs to redefine "growth" as more than a quantitative increase in wealth. We need to redefine our goals and dreams in terms of qualitative increases in quality of life and not in terms of material wealth alone (Gallopin 2003, p.25).

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[37] The precautionary principle may be invoked where urgent measures are needed in the face of a possible danger to human, animal or plant health, or to protect the environment where scientific data do not permit a complete evaluation of the risk (Europa 2005).

[38] This concept is called requisite variety. A system in a complex environment should have a similar level of complexity internally to be able to cope with flux and change of the larger environment. This expression of requisite variety for this specific context is based on Ashby's (Ashby 1957, p.207) law of requisite variety which states that: "Only variety can destroy variety"

This changing system exists on a finite planet that can only support a certain maximum per capita level of resource consumption for every level of technology. Improved technology may increase the amount of utility available for human beings from the earth's resources but ultimately, no matter what level of technology is attained, there will always be stocks of natural capital that cannot be substituted for other forms of capital. There are limits to growth for every level of technology. These limits mean that for any given level of technology resource availability is finite. The only way to achieve an equitable quality of life for all people on earth is through the redistribution of wealth so that each person has access to a fair share of the earth's natural, renewable resources (Gallopin 2003, p.25).

The only way to achieve such redistribution in a widely acceptable way would be to foster two types of growth. The developed, rich "North" should strive to improve its citizens' quality of life through non-material growth while the poor countries of the "South" should be allowed controlled[39] material economic growth to catch up to "Northern" levels of development. Once global levels of per capita resource consumption have stabilised at equitable, sustainable levels (i.e. within the bio-capacity given the level of technology) all nations should strive to keep their level of natural resource use constant while quality of life is to be improved through non-material growth and development in cultural, psychological and spiritual spheres of existence (Gallopin 2003, p.27) (at least until technologies that allow non-resource based consumption increases to occur become available)[40].

The fundamental message of systems thinking for this thesis is that a certain minimum level of resource consumption is required to achieve a reasonable quality of life. It cannot be expected of poor countries and people to forego all increases in resource use. Solar water heating can play a central role in the achievement of further development amongst the rich and the poor of the world. It can reduce the energy intensity and ecological footprint of rich households that currently use electrical and gas water heaters and it can allow poor households without water heaters to improve their quality of life with only a marginal increase in their resource use levels and their ecological footprint. The technology presents a sustainable systems intervention that can reduce environmental degradation, create employment opportunities, reduce household energy consumption, and provide a valuable service to poor households.

2.4.2 THE FUNDAMENTAL HUMAN NEEDS APPROACH OF MAX-NEEF

Though the systems theory approach to sustainable development provides a suitable conceptual background for this thesis it is lacking in that it does not offer much scope for the analysis of what human beings need to achieve "development," i.e. criteria that need to be fulfilled to improve the quality of life of people. The work of Manfred Max-Neef (1991) speaks to this omission through a development approach called "Human Scale Development" that focuses on the development of "poor" communities based on a systems perspective. The theories of Max-Neef integrate well with the definition of "Quality of life" provided by Gallopin (2003, p.25) as *"...the satisfaction of material and nonmaterial human needs*

[39] This thesis is primarily concerned with ways of achieving sustainable, controlled economic growth in the developing world.

[40] This does not mean that the system should or will reach a constant state, dynamic change should and will always be part of human interaction with the natural world.

(resulting in the level of health reached) and the fulfilment of human desires and aspirations (resulting in the level of subjective satisfaction obtained).”

Though not explicitly a systems theorist, Max-Neef arrives at a systems approach through recognising the need for transdisciplinary[41] approaches, which recognise that relationships are key to understanding phenomena, and to solving development challenges. “Development” is recognised as more than just a specific problem but instead as a “*...web of complex issues that cannot be resolved through the application of conventional policies founded upon reductionist principles*” (Max-Neef 1991, p.15). His approach is based on a theory that discards hierarchical conceptions of human needs, and instead views human needs as a matrix of which people simultaneously[42] try to realise as many aspects as possible (Max-Neef 1991, pp.17, 49). The basic assertion of human scale development is that *“Development is about people and not about objects”* (Max-Neef 1991, p.16). From this point of departure Max-Neef argues that the best development processes are the ones that allow the greatest improvement in people’s quality of life. Quality of life in turn depends on the opportunities that people have to satisfy their fundamental human needs, hence the focus on human needs in this approach and the focus on quality of life improvements in this thesis[43].

For Max-Neef human needs have to be considered as a system – all needs are related and interdependent. The interrelationships mean that the process of satisfying human needs necessitates trade-offs but also that it enables people to fulfil many needs at once through a single intervention. Through his research Max-Neef has identified two categories of fundamental human needs; existential and axiological[44]. These needs can be fulfilled by different satisfiers, many of which fulfil more than one need at a time but always within three different contexts; with regard to oneself (*Eigenwelt)*, with regard to a larger social group (*Mitwelt)* and with regard to the environment (*Umwelt)* (Max-Neef 1991, pp.17, 18). For a model of how such a matrix of needs and satisfiers could look refer to Addendum C: Matrix of Needs and Satisfiers .

Many things we often conceive of as basic human needs such as food, shelter or education are classed rather as satisfiers that can help to fulfil fundamental needs such as that of subsistence or understanding. Fundamental needs remain consistent throughout human history and across different cultures. The satisfiers that are available and used to fulfil these needs change over time and between cultures (Max-Neef 1991, p.18). Economic goods, the final concept that contributes to the theoretical underpinning of Human Scale Development are the *“...means by which individuals will empower the satisfiers to meet their needs.”* These goods should never be seen as the ultimate end in themselves, otherwise life is placed at the service of artefacts rather than artefacts being used to improve life (Max-Neef 1991, p.24).

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[41] Transdisciplinarity according to Max-Neef (1991, p.15) is “...an approach that, in an attempt to gain greater understanding, reaches beyond the fields outlined by strict disciplines. While the language of one discipline may suffice to *describe* something...an interdisciplinary effort may be necessary to *explain* something (a relation between elements).” Italics were added by this author.

[42] Max-Neef concedes that there are situations wherein extreme circumstances lead to one need overpowering all others, such as the need for subsistence during famine but in general there is no clear hierarchical distinction between the importance of different needs (Max-Neef 1991, pp.17, 49).

[43] This does not mean that ecological concerns are abandoned, insights from DEEE still inform the thesis and the environmental benefits of SWH are deemed to be crucially important

[44] The study of the nature, types, and criteria of values and of value judgments (Merriam-Webster Dictionary 2010)

These conceptions allow one to develop an alternative definition of poverty as the inability to achieve basic levels of fundamental human need fulfilment in one or more category of needs. There are thus different forms of poverty in relation to each of the fundamental needs – conventional economic theory primarily accounts for only poverty of subsistence due to insufficient income (Max-Neef 1991, p.18). Conventional theories of development, such as those informed by conservative political ecology, attempt to stimulate the accumulation of economic goods whilst ignoring other aspects of human development. According to Max-Neef (1991, p.51) this approach results in a *"circular cumulative causation and thus the poor remain poor inasmuch as their dependence on exogenously generated satisfiers increases."* It is this circle of poverty that this thesis tries to address and that is the reason why systems theory and the theories of Max-Neef provide such an invaluable framework for the discussions that follow. The typology of human development offered by Max-Neef allows us to conceptualise and address the entire system of poverty and the inability to fulfil fundamental human needs. It is within this context that solar water heating can offer a systemic solution to many of the poverties experienced in low-income groups. It is what Max-Neef (Max-Neef 1991, p.34) defines as a synergic satisfier[45], a satisfier that satisfies a given need whilst simultaneously contributing to the fulfilment of other needs. In other words they are satisfiers with much strategic leverage in improving quality of life by fulfilling several fundamental needs at once.

In using synergic satisfiers to fulfil fundamental human needs and thus achieve "development" the process is as important as the final outcome. Human Scale Development does certainly not preclude the achievement of conventional economic goals, it simply sees them as part of a much larger process. The difference in the development paradigms lies largely in *"considering the aims of development not only as points of arrival, but as components of the process itself...the realization of needs becomes, instead of a goal, the motor of development itself. This is possible only if the development strategy proves to be capable of stimulating the permanent generation of synergic satisfiers"* (Max-Neef 1991, p.53). It is exactly this which the development of a solar water heating industry can achieve. If imported solar water heaters are simply provided to low-income communities their subsistence needs[46] might be slightly improved by freeing up additional income and Stellenbosch Municipality might receive the benefit of reduced electricity demand, but a golden opportunity to use the development of a solar water heating sector which could serve as a synergic satisfier would be lost. By developing such an industry that provides people with sustainable employment opportunities, their needs for subsistence could be much more sustainably fulfilled whilst needs for protection (in the form of job-security), affection (self-esteem and improved relationship with nature), understanding (exposure and participation in the roll-out of modern technologies), participation, creation, and identity could simultaneously be fulfilled. Through the *process* of providing SWHs to low-income households the circle of poverty could be broken. Though it might sound ambitious, the growth a local SWH industry could contribute to what Max-Neef (1991) identifies as true

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[45] For a discussion of other types of satisfiers that reduce the ability to fulfil fundamental needs or that specifically only addresses a single need refer to Max-Neef 1991.

[46] For a more detailed discussion of all the needs that I believe SWHs can fulfil refer to the section of this paper entitled *The Potential Benefits of Providing SWHs in Low-Income* Communities.

development; *"...healthy self-reliant*[47] *and participative development, capable of creating the foundations for a social order within which economic growth, solidarity and the growth of all men and women can be reconciled."*

Though the theories of Max-Neef are only coincidentally eco-centric in that the environment is only valued to the extent that it aids the fulfilment of fundamental human needs they allow sufficient space for the incorporation of environmental goals in development strategies. The fulfilment of human needs can only be accomplished on a healthy earth that remains ideally suited to support human development. The environmental context of human development, Max-Neef's (1991) *Umwelt,* remains the underlying context and enabling condition for the achievement of all other development goals.

2.4.3 SUMMARY

The systems theory of Gallopin creates an alternative lens through which one can understand interrelated development concerns but provides little beyond vague stipulations on how human quality of life can be improved. This breach is filled with the help of Max-Neef's fundamental human needs approach. Using a combination of the systems approach developed by Gallopin, informed by some insights from other schools of thought and deepened by the human development theories of Max-Neef, an approach to sustainable development for this thesis has now been conceptualised. In this approach it is recognised that there are finite limits to the extent of natural resources and that these need to be managed carefully. All levels of human existence are embedded in the natural environment and all attempts at improving quality of life should take environmental limitations as the point of departure. Simple reductionist trade-off calculations and capital substitutions cannot lead to sustainability. Development needs to be considered from a wider, integrated systems perspective that allows an understanding of the involved systems as more than just the sum of their parts. From such an understanding comes the realisation that development has to be measured in more than just a quantitative increase in wealth but rather in terms of qualitative improvements that also allow the decoupling of quality of life with natural resource use, especially at high levels of development.

For human beings such qualitative improvement can be achieved through the identification of integrated, synergic satisfiers that fulfil many different fundamental needs on an existential as well as axiological level. Quality of life cannot, however, be sustainably improved through the simple application of reductionist solutions for each human need. It needs to be done from an integrated systems theory approach wherein the process of delivering satisfiers is as important as the satisfiers themselves. To this end the process should itself fulfil other fundamental human needs. Exogenous reductionist satisfiers will only increase dependency relationships in the long-term and thus lead to larger unfulfilled human needs, especially on the axiological level as people become stuck in dependency relationships and feel powerless to improve their own lives.

A definition of sustainable development for this thesis could thus read; *Sustainable development is a process wherein people are empowered to fulfil their own fundamental*

[47] Defined as the *"regeneration or revitalization emanating from one's own efforts, capabilities and resources*." According to this principle anything that can be produced or solved at local levels should be produced or solved at local levels (Max-Neef 1991, p.64) as this will allow a focus on ongoing process rather than the singular provision of goods.

human needs in order to improve their quality of life. The process itself should be conducted with an understanding that human development does not stand separate from environmental, cultural or institutional systems and that development processes should ensure the long-term dynamic development of each of these spheres rather than instituting the gradual destruction of the one in favour of the other.

Given that there are many different conceptions of sustainable development this definition is formulated in order to have a single approach to sustainable development that can be used to evaluate and eventually justify the rollout of SWHs in low-income communities in Stellenbosch and the Western Cape Province.

2.5 RENEWABLE ENERGY

The previous parts of the literature review have shown how imperative it is that alternative, more sustainable, development strategies be developed and instituted. This is necessary in order to avoid disastrous environmental degradation and a concurrent reduction in the ability of the earth to sustain human life. After the challenge was identified, an alternative approach to development that would be environmentally sustainable, whilst allowing for poverty relief and continued improvement in quality of life, was conceptualised. This approach will now be used to evaluate the contribution that SWH can make to achieving sustainable development in Stellenbosch and the Western Cape Province and thus start testing the research hypothesis.

In the discussion of the need for sustainable development in paragraph 2.3.1 it became apparent that CO_2 produced during the combustion of fossil fuels was the primary cause of the increased ecological footprint of the human species. In order to achieve development that does not lead to further degradation of the natural environment, addressing the CO_2 issue should be one of the primary concerns. Increasing the use of carbon neutral renewable energies to replace fossil fuels is one way of reducing CO_2 emissions and achieving development decoupled from resource use. The use of renewable energy technologies offer systemic solutions to the challenges confronting the world, but the focus in this thesis is on the role that they can play in developing countries. In these countries the environmental benefits of renewable energies are complemented by the creation of entrepreneurial and employment opportunities and the provision of energy to disadvantaged communities. Development of renewable energy economic sectors can thus contribute to marked increases in quality of life through reducing unemployment (and thus poverty), energy poverty and environmental protection.

The particular focus of this thesis is on SWH as a renewable and sustainable energy technology based on solar energy. For an overview of conventional energy sources and the renewable energy alternatives refer to the documents *The Problems of Conventional Energy* and *Alternative Energy Sources* on the supplementary CD where the work of the WEC (2007) the IEA (2009; 2005), the GWEC (2006), Prasad and Visagie (2005), Teske et al (2007), Lindsay (2002), Lyman (2008), Lynas (2008), Mian and Glaser (2008), and Romm (2008) are summarised. A brief discussion of solar energy will follow below to explain the basic science behind solar energy systems.

2.5.1 SOLAR ENERGY

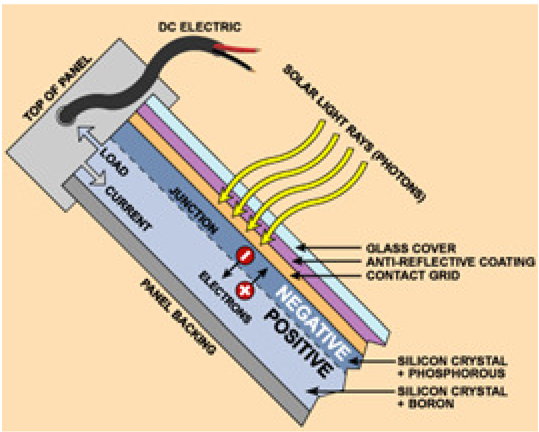
3 400 000 EJ of solar radiation reaches the surface of the earth every year. The sum total of the demand for energy worldwide is 450 EJ per year (WEC 2007b: 380), only 0.01% of the energy that the sun provides. The highest annual irradiance, roughly 300 W/m^2, is experienced in the Red Sea area, but a less sunny region like the United Kingdom still attains annual mean irradiance levels of approximately 105 W/m^2. Global annual average horizontal surface irradiance is around 170 W/m^2 (WEC 2007b: 383).

Two different types of technology are used to convert solar energy into more usable forms of energy. The first is based on photo-voltaic cells and the second on heat transfer processes in solar thermal collectors.

Photo-voltaic cells (PV) use semiconductor-based technology to convert light energy into electricity that can be used immediately or stored in a battery for later use (see Figure 17) (Conservation Technologies 2004). Electricity generated through PV panels can be used as a partial supplement for electricity generated from fossil fuels, serving as a renewable energy alternative that is not detrimental to the environment. The PV collector panels are modular in design and can be mounted on buildings very easily, making them suited for use in even the remotest of locations. PV energy conversion also has the advantage that it does not need direct solar radiation. Because the cells utilise light as an energy source they will produce electricity even on overcast days[48] (Florad 2010).

Unfortunately, PV panels are still far too expensive for low cost applications due to the high cost of the photo-voltaic cells as well as the relatively low energy conversion rate of 13-15% which leads to high costs per unit of electricity produced. At present, photovoltaic solar panels supply at most about 100W/m2 (Spiessens 2008, p.2) at a cost of roughly $8/Watt output (Blackburn & Cunningham 2010, p.6)[49]. The high costs make the technology impractical for South African low-income communities due to the high level of electrification in the country and the relatively low costs of electricity. In South Africa PV technology is currently used primarily in telecommunications networks, small-scale remote stand alone power supplies for domestic use, game farms and household and community water pumping schemes. The installed PV capacity was estimated at 12 MW in 2005 (Prasad & Visagie 2005, p.i).

Figure 17 Side View of a Typical Photovoltaic Solar Cell (Conservation Technologies 2004)



Thermal solar energy devices can be utilised directly, and thus more efficiently, due to less energy conversion losses. Efficiency levels for energy generation from solar thermal devices are 4-5 times higher than that of PV systems. Large solar thermal power stations can be constructed to generate electricity by superheating steam to run an electricity generator. Although this technology has been tested in Spain and the USA it is still relatively costly and not yet price-competitive with conventional coal-based electricity due to the high initial capital cost outlays (WEC 2007, Desertec 2010). According to Eskom cost comparisons show that concentrating solar thermal is about 168% more expensive than 'new' coal on a rand-per-megawatt-installed basis for capital cost (the difference in long term levelised-cost comparisons is likely to be much smaller) (Van der Merwe 2010).

[48] Depending on how thick the cloud cover is efficiency can be reduced by between 50-95% (Florad 2010)

[49] Prices for solar PV systems have shown a significant downward trend (as shown in Annexure F) and it is likely that they have continued to fall since the collection of this data.

The other option for using the thermal component of solar radiation is solar water heating. For domestic use it is the most cost effective renewable energy technology available at present (Conningarth Economists 2004 cited in Holm 2005) because it allows for the use of relatively cheap materials to attain high thermal conversion efficiency. The WEC (2007, p.385) finds that *"solar water heating is the most developed solar technology and [it] is very cost-effective when lifecycle costs are considered."* Though solar water heaters do not generate electricity they present a massive opportunity for the reduction of electricity demand by removing the requirement for grid electricity to heat water[50]. SWH is a tried and tested technology that has been widely and successfully applied in many regions of the world including Australia, Germany, China, Israel, Greece and the USA[51].

To date the high initial capital investment costs have placed solar water heaters at a disadvantage to electric water heaters (Holm 2005), but as grid electricity becomes more expensive due to rising fossil fuel prices and the construction of new power plants by Eskom (Van der Merwe 2010) increases in the application of solar water heaters can be expected (McCallum 2010). The large electricity price hikes that have been experienced and that are still expected in South Africa (Pringle 2009, Creamer 2010) are already making SWHs a more attractive investment in the middle and high income groups (Hallet 2010) but the high initial costs of the systems keep them beyond the reach of low-income households (Hertzog 2009), which is the focus research area of this thesis.

The following paragraphs will provide an overview of the existing SWH technology. This is necessary in order to inform further discussions about which systems are installed in the low-income context[52].

2.5.2 SOLAR WATER HEATING TECHNOLOGY

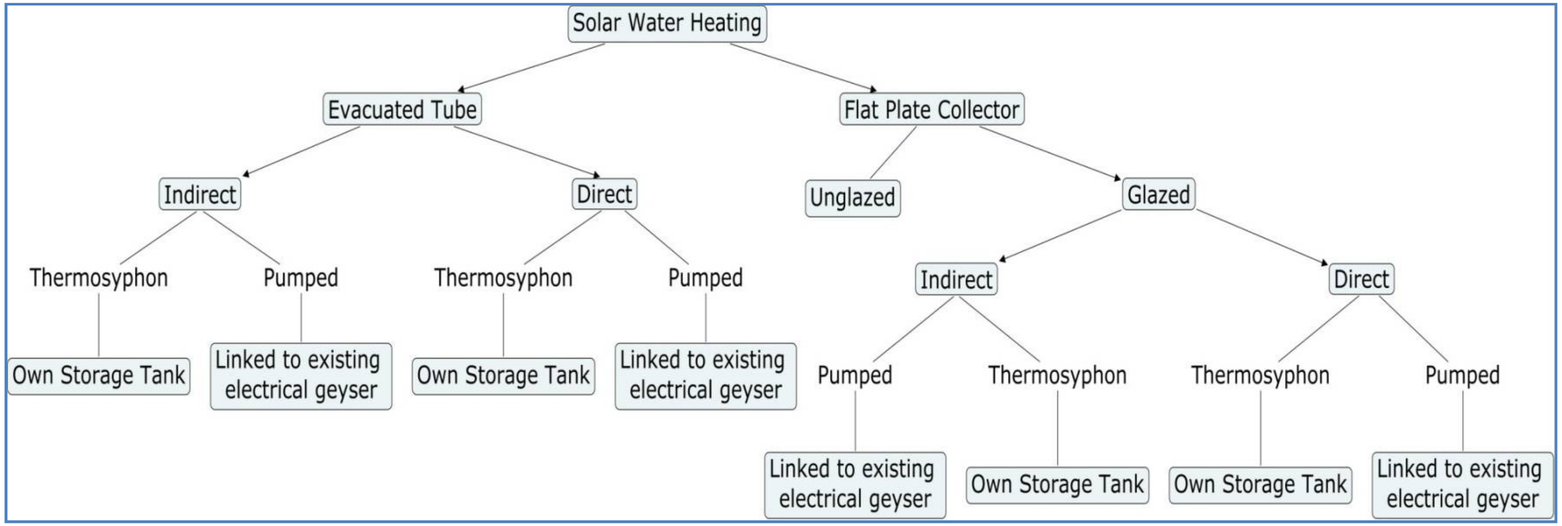
Figure 18 presents a typology of the solar water heating systems that have become market standards. The discussion thereafter will provide a brief explanation of the available systems.

[50] Which accounts for 30-50% of electricity usage in homes (refer to Table 3)

[51] For a short discussion of SWH rollout programmes in other countries please refer to the document entitled *SWH rollouts in selected countries* on the attached CD (Sterman 2009; Sunbelt Solar 2009; C. Meyer 2008, Langniss & Ince 2004).

[52] For an overview of all available water heating technologies please refer to the document *Water heating technologies* on the attached CD.

Figure 18 Typology of Solar Water Heating Systems



A solar water heater heats water by using energy from the sun. Solar radiation reaches the surface of the collector and passes through a glass cover. Inside the glass cover there is a black heat absorbing surface which transfers the heat from the solar radiation to a liquid, either water or another heat transfer fluid that indirectly heats water through a manifold at the top of the collector in indirect systems. The radiation that is not immediately absorbed by the absorbing surface is radiated outwards as long wave radiation which cannot escape through the glass covering. The glass then reflects the long wave radiation back onto the absorbing surface where more of the heat is captured and transferred to the liquid in the solar water heating system. The liquid that has been heated is conducted to the top of the system due to the thermosyphon effect, or through a pump system, allowing new cold liquid to enter into the bottom of the collector to be heated. A continuous cycle develops that allows water to be heated to ever higher temperatures until it reaches a saturation point. At this point the heat entering the system will be equivalent to heat lost due to natural temperature convection (SEA 2009, p.7; Langniss & Ince 2004; Level 2009; Sunbelt Solar 2009). The two overarching, basic types of Solar Water Heater used for domestic water heating are determined by the types of collector used. They are called evacuated tube collectors and flat-plate collectors.

2.5.2.1 Evacuated Tube Collectors

The original concept for evacuated tube collectors was developed by the Qing Hua University in Beijing in the early 1980s. The first commercial units were manufactured in 1985 and the patent was held by Qing Hua Solar company until 1998 (Van den Heever 2008, pp.8-9). Today most evacuated-tube collectors are still manufactured in China (SEA 2009, p.8).

The collectors consist of parallel rows of transparent glass tubes, which look very similar to fluorescent lights. Each individual tube consists of two glass tubes separated by a vacuum. In low-cost direct systems the inner tube is coated with a special black selective coating which increases solar radiation absorption and reduces reflection even further. An alternative design for higher cost indirect systems has a metal absorber sheet containing a heat pipe in the inner glass tube. The heat transfer fluid is contained in the heat pipe. Between the glass tube and the metal absorber sheet a vacuum is contained which serves to insulate the heat pipe by eliminating convection losses through radiation and conduction from the collector to the environment. (RETscreen International Clean Energy Decision Support Centre 2004, p.4; SEA 2009, p.8; Ramlow 2007, p.32; Budihardjo & Morrison 2009, pp.51-52). Figure 19 and Figure 20 illustrate the basic working principles of different types of evacuated tube SWHs. Figure 21 shows the different components of an EV system.

Figure 19 Schematic of Direct Evacuated Tube System (Budihardjo & Morrison 2009, p.51)

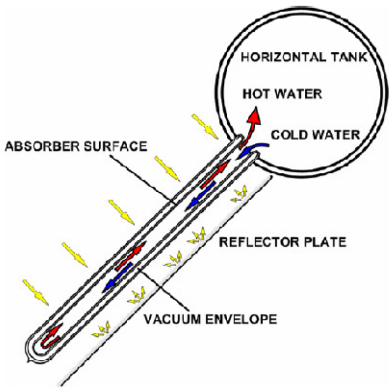


Figure 20 Schematic of Indirect Evacuated Tube System (Greenterrafirma 2007)

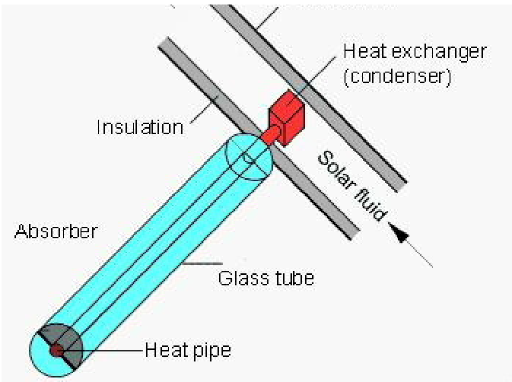
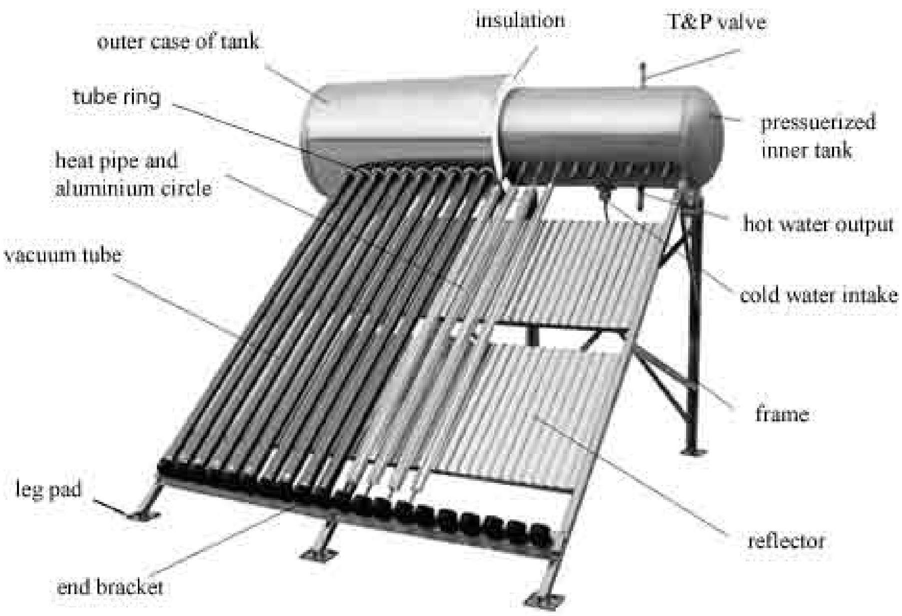


Figure 21 Components of a Direct Evacuated Tube system (Greenterrafirma 2007)



A brief[53] overview of the strengths and weaknesses of evacuated tubes based on literature reviewed is provided below. Note that there are widely disparate claims about the characteristics of flat-plate collectors compared to evacuated tube collectors.

Sustainable Energy Africa (SEA) (2009, p.8) argue that evacuated tubes generally have "...exceptional performance but have not yet had time to establish a track record of reliability." Van den Heever (2008) and the RETscreen International Clean Energy Decision Support Centre (2004, p.4) also add that evacuated tubes have:

- High energy conversion efficiencies, even when there are large temperature differences between the collector and its surrounding environment (due to the excellent insulation provided by the vacuum space between the glass and the collector)[54].
- High conversion efficiencies achieved even when radiation levels are low such as on partly cloudy days
- The ability to achieve high temperatures in excess of 70˚C.
- Easy transportation due to low weight and modular assembly.
- Spaces between the parallel evacuated tubes that encourage the shedding of snow and ice and make the collectors less susceptible to wind damage than the large closed surfaces of flat-plate collectors are.

The disadvantages according to Van den Heever (2008) and Ramlow (2007, pp.32-33) are that evacuated tubes:

- Are more expensive than glazed flat plate collectors (Research conducted for this thesis found that low-cost evacuated tube collectors are in fact significantly cheaper than low-cost flat-plate collectors (Van Zyl 2009, Bester 2010). For examples of low cost evacuated tubes refer to http://www.tasolsolar.co.za/ and http://www.its-solar.com/its-low-cost-low-pressure-systems/.).
- Tend to overheat more readily than flat-plate collectors and care must be taken never to oversize the collector array or undersize the storage tank.
- Are more fragile than flat-plate collectors and more susceptible to breakage

Unfortunately, many differing interpretations of the efficiency of evacuated tubes are offered in the literature. Ramlow and Nutsz (2006) assert that "*The truth of the matter, as the data shows, is that for most conditions, flat plate collectors will outperform evacuated tubes. Now if you needed really high temperatures, say over 160°F (71°C), then evacuated tubes might be the right collector for the job, but until that point, they simply won't perform as well.*"

Solaserver (2008) provide the figure (Figure 22) below which compares the efficiency of different types of solar water heaters. They assert that evacuated tubes perform better than flat-plate collectors whenever the air temperature exceeds 18ºC. The difference in efficiency however only becomes significant when the temperature difference between the liquid being

[53] As this is not a technical study these issues will not be discussed to any great depth.

[54] In hot climates like that of South Africa this can be a disadvantage as the saturation point of evacuated tube systems would be very high. As a result the water in the collector system could be heated beyond boiling point. This poses a scalding risk for people that use the water and it puts great strain on system components due to pressure build-up and unnecessarily high temperatures (Epp 2009, Anthony 2009a)

heated and the ambient temperature is much larger, e.g. in excess of 40ºC. At such high temperatures high efficiency levels become problematic for domestic water heating as it poses scalding dangers and reduces the longevity of the collector system.

Figure 22 Efficiency and temperature ranges of various types of collectors (Solaserver 2008)

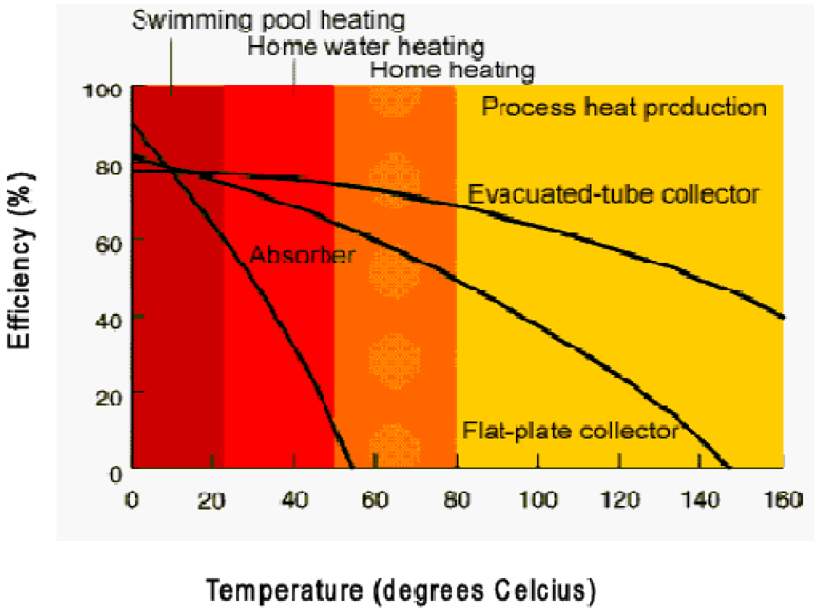


Figure 23 Top Collectors in Comparison (Ebb 2010, 46)

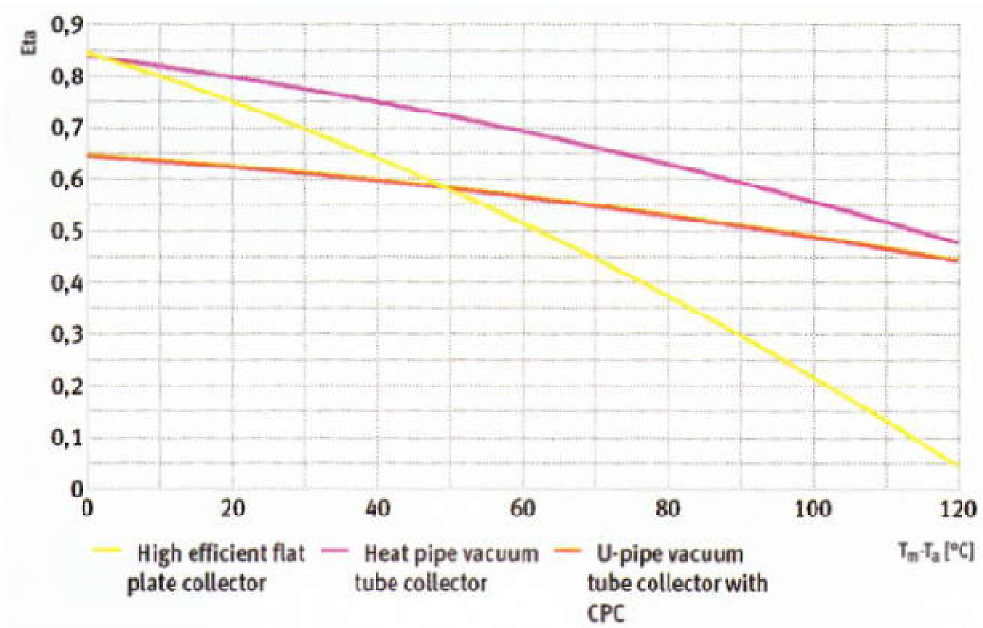


Figure 22 provided by Ebb (2010) in the journal *Sun and Wind Energy* shows that heat pipe vacuum tube collectors have higher conversion efficiency levels when the temperature difference between the fluid to be heated and the ambient temperature is more than 3 or 4ºC but also that the difference only becomes significant when the temperature difference exceeds 40 or 45ºC. For home water heating, where you do not want to heat water beyond 60ºC at most the difference in efficiency levels is thus not that significant. Improved efficiency at high temperatures poses threats to the longevity of system components as well as to users of the heated water.

RETscreen International's Clean Energy Decision Support Centre (2004, p.4) states that *"Evacuated tube collectors are the most expensive of the solar collector types, but they are the collectors that work best when outside temperatures are low and very hot water is required. They operate year-round in cold climates... They are not necessarily the most efficient collectors; however, when outside air temperatures are high and only low water temperatures are required, there is little heat loss to be eliminated. Under these conditions, unglazed collectors and glazed flat plate collectors can be more efficient[55]."*

In order to investigate which system best fulfilled low-income household requirements for hot water an evacuated tube and a flat-plate collector system were installed on two low-income households in Stellenbosch for in-field testing. The results of these tests are discussed under Section 4.1.1. During interviews solar water heater suppliers were also asked for their opinion on the advantages and disadvantages of evacuated tubes compared to flat-plate collectors. The findings are discussed in section 4.2.2.7.

2.5.2.2 Flat-plate/ Glazed collector

"Flat-plate" or "glazed" collectors are the solar water heating systems that have been commercially available longest. They have been on the market for more than 50 years (SEA 2009, p.8; Ramlow 2007, p.32), and have a proven track-record in domestic water heating. The main collector components are a transparent front cover (usually glass glazing), collector housing, and a dark absorber plate (Van Gass & Govender 2009; SEA 2009, p.8). Solar radiation passes through the outer layer of glazing and is absorbed by the dark absorber plate (usually aluminium or steel painted with black absorber paint). The absorber plate contains a network of heat pipes (usually made of copper) which transmit the absorbed heat to the water in the heat pipes (Ramlow 2007, p.32). The backs and sides of the collector box is insulated to reduce heat loss (Ramlow 2007, p.32; RETscreen International Clean Energy Decision Support Centre 2004, p.4)

According to Ramlow (2007, p.32) the primary advantages of flat-plate collectors are that:

- They have a proven track-record of reliability and efficiency,
- They are competitively priced[56] and
- They naturally operate within the comfortable and safe temperature range needed for domestic water

[55] These are typically the conditions under which solar water heaters in South Africa are used.

[56] Research for this thesis indicates that Evacuated tubes are now available at cheaper prices than flat-plate collectors

Figure 24 Flat-Plate Collector (All American Heating 2009)

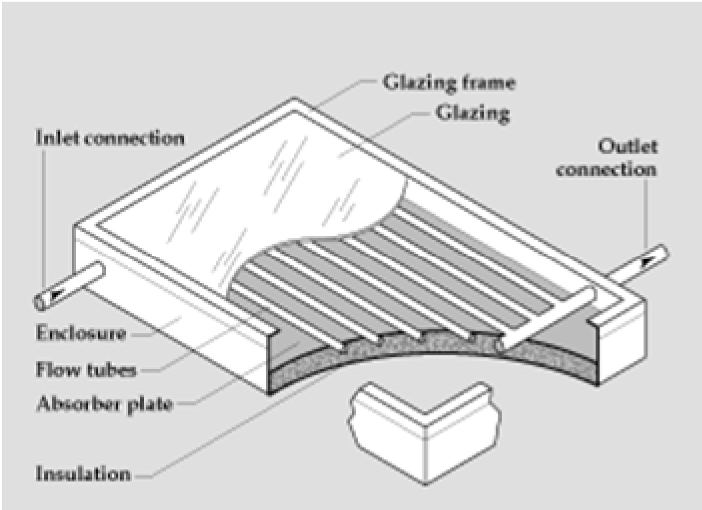
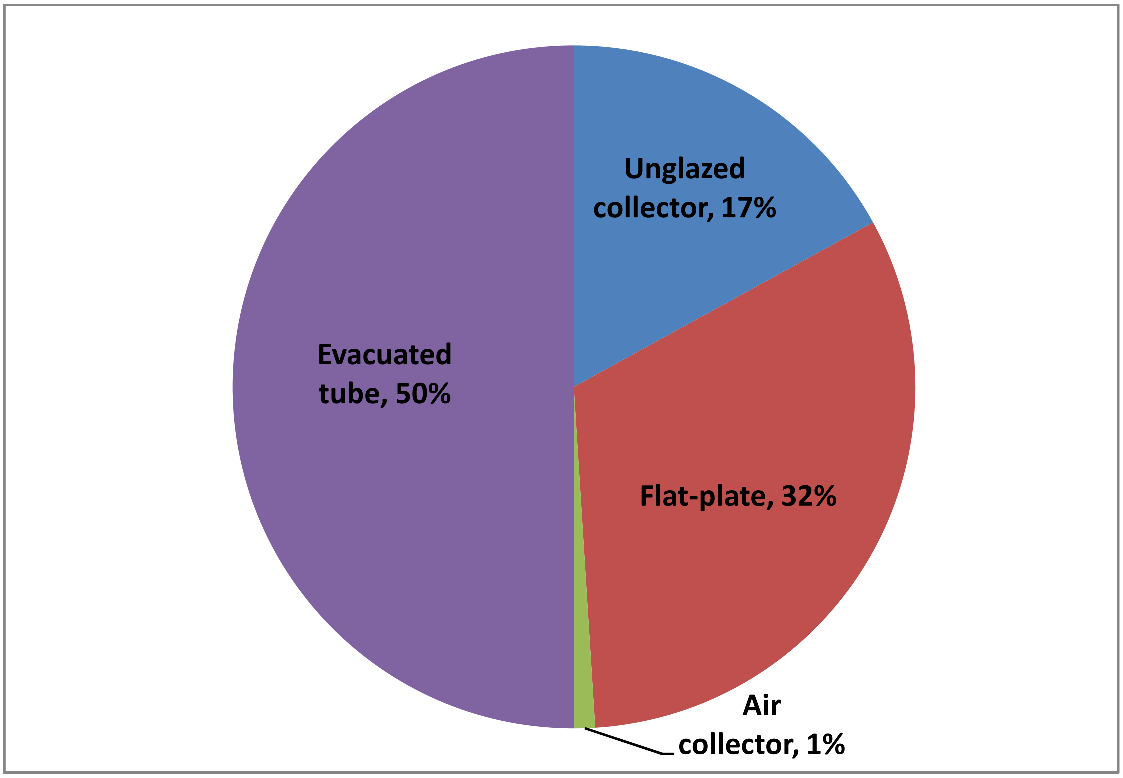


Figure 25 provides a breakdown of the types of solar thermal collectors installed globally. Evacuated tubes dominate the market with 50% of the total while flat-plate collectors account for 32%. This unequal distribution is largely due to the fact that the massive Chinese market is dominated by evacuated tubes. The rest of the world predominantly utilises flat-plate collectors (Weiss et al 2007). Unglazed collectors are used primarily for swimming pool heating (Weiss et al 2007).

Figure 25 Distribution by collector type of the worldwide solar thermal systems capacity (Weiss et al 2007)



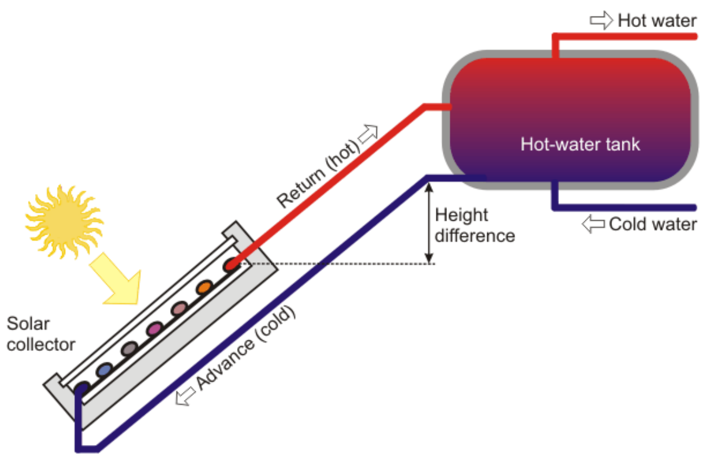
2.5.2.3 *Possible adaptations of basic systems*

There are several possible adaptations that can be made to solar water heating systems based on the price that the end-user is willing to pay for the system as well as on whether or not the systems should be linked to the existing water heating system. The available adaptations are discussed briefly below.

Pumped/active and thermosyphon/passive systems

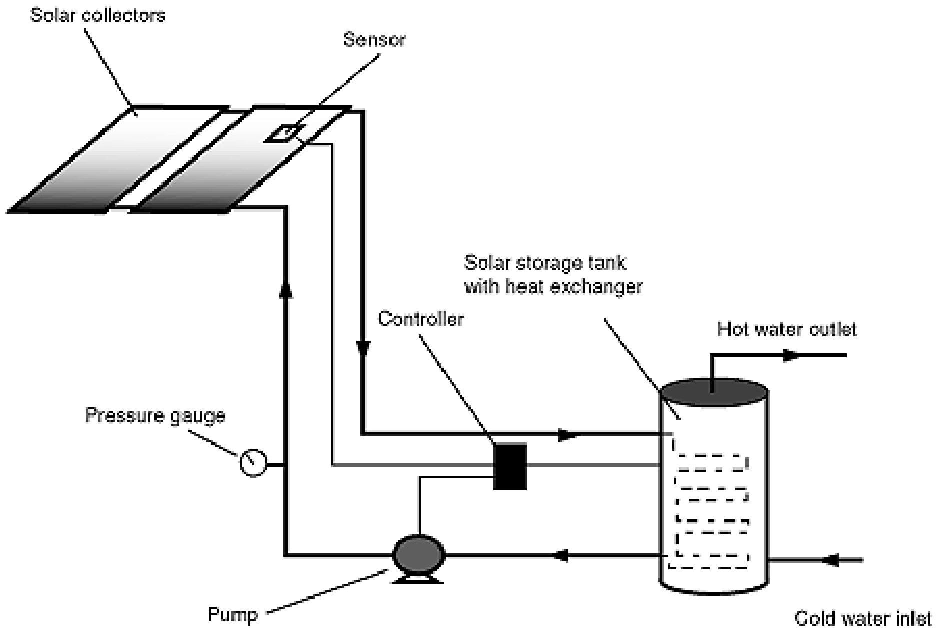
Passive systems are the normal thermosyphon/convection systems which work on the natural circulation of the water/heating fluid between the collector and the storage tank. They can only work in close-coupled systems where the storage tank is located above the collector area. This height difference makes natural thermosyphoning possible. In homes with large roof areas that allow for the installation of an in-roof storage tank above the collector plate it is possible to install passive systems that are not close-coupled, but these installations are not feasible in small, low-cost houses[57]. Active systems use a pump to circulate the water/heating fluid between the collector and the storage tank. Pumps are used when the solar collector is used in conjunction with a storage tank that is located lower than the collector inside the roof of a house, such as when the collector is linked to a conventional electrical water heater (SEA 2009, pp.7-9). Figure 26 shows the basic configuration of a typical passive close-coupled system. Figure 27 shows a typical active SWH system.

Figure 26 Close-coupled Thermosyphon System (Hagens 2009)



[57] As such these installations are not shown in the typology of systems given in Figure 18.

Figure 27 Schematic of a Typical Active SWH System (DeLaune et al. 1995)



Direct and indirect systems

In direct systems the fluid flowing through the collector area is the water that is eventually used in the house. Water flows into the storage tank from the inlet through the collector area and back into the top of the storage tank where it is then tapped off for use in the house. Direct systems (see Figure 19) can only be safely used in areas where frost does not occur and where the water is lime free, otherwise the system will be damaged when water freezes in the pipes overnight or if lime clogs up the circulation system (SEA 2009, pp.7-8).

In indirect systems (see Figure 20) water flows into the storage tank and manifold where it is indirectly heated through conduction by a heat exchanger pipe through which a heating fluid circulates after passing through the collector area. Indirect systems are more durable and can be used in all weather conditions and for all water types (SEA 2009, pp.7-8) but they are more expensive due to the requirement for extra piping, a manifold and heat exchangers.

High and low pressure systems

Solar water heating systems can be designed to operate as high or low pressure systems. High pressure systems are more suitable for domestic use in middle- to high income homes as water from the system can be more easily mixed with high pressure cold water supplied by municipal lines. High pressure systems are however more expensive than low pressure systems as they need to be constructed from more expensive materials that are able to withstand high pressures. In low pressure systems water pressure at the outlet tap is determined by the height of the storage tank. The higher the storage tank is above the tap where the water is used, the higher the water pressure will be (SEA 2009, p.8). Due to the relatively low heights of roofs, high water pressure is never attained. This can create problems when water from the SWH has to be mixed with pressurised municipal water.

Electrical backup for solar water heating systems

On completely overcast days solar water heaters are unable to heat water to sufficiently high temperatures (Florad 2010). Electrical or gas backup systems can be installed to ensure that hot water is always available. Conventional electrical heating elements can be installed in the storage tank and activated when back-up heating power is required. The electrical heating element can be installed in the storage tank of a close-coupled system or, if the SWH is linked to an existing conventional geyser, the old element can be retained. In order to ensure that the backup system activates only when required, a timer can be installed but this increases installation costs (Van Gass & Govender 2009). Alternatively demand water heaters can be installed above the hot water taps and switched on when the SWH is unable to heat water.

Solar Water Heaters for Low-Income Contexts

SWHs are probably the least expensive water heating technology on a life cycle cost basis as the source of energy, sunlight, is free (SEA 2009, p.3) but the systems are relatively expensive to buy and install. Additional adaptations that are made to systems lead to further increased costs. The cheapest systems available are close-coupled, direct, low pressure systems (Van Zyl 2009, Bester 2010, Hallet 2010) without electrical backup and these are the focus of the rest of this study as they are the systems which would be most affordable in a low-income housing context. Though an initial reaction to this statement might be that this will lead to the installation of ineffective systems for poor people this is not the case. There is no need for an active system as the target population for this project do not have electrical geysers installed in their homes and there is thus no need to install an active system. Stellenbosch and most of the coastal areas of the Western Cape, the primary focus area of this research, are frost-free so there is no need for indirect systems[58] (Wesselink 2009, Hertzog 2009).

The only real compromise is with regard to high vs. low pressure systems. In this case the water usage patterns in the target population, where very few homes have installed showers, somewhat mitigates the negatives of low pressure systems. However, the rationale for this thesis is in part that there is a suppressed demand for hot water in low-income households and one can expect that more of these homes will install showers if they have freely available hot water. At present the cost of pressurised systems (Hallet 2010) outweighs this concern – the approach is taken that low pressure SWHs are already a major improvement on electrical kettles for water heating and that prevailing economic conditions make the installation of more expensive systems impractical. Homes also have the option of adding water mixing valves at a later stage to mitigate this problem (Ndamane 2010). Similarly it is suggested that, if possible, systems should be installed allowing for the future addition of electrical backup. Incorporating electrical backup from the outset will lead to smaller electricity demand reductions and an opportunity might be missed to encourage behavioural changes to maximise solar energy used for water heating.

[58] In areas where the municipal water is prone to causing calcification or corrosion indirect systems may be required but calcification has not been an issue in the Kuyasa or Kwanokuthula rollouts.

The following section will provide an overview of the development of the global solar water heating market in order to illustrate the maturity of the technology and the impact that it has already had in several countries.

2.6 INTERNATIONAL EXPERIENCE OF SWH

By 2007 SWHs for domestic water heating accounted for 120.5 GW_{th} of energy capacity worldwide (Weiss et al. 2009). Based on 2007 estimates by Weiss et al (2009, p.25) this translates into energy savings of 10.6 mtoe and avoided CO_2 emissions of 35 million tonnes per annum. Figure 28 and Figure 29 provide a breakdown of the distribution of SWH installations globally. China, Turkey, Germany, Japan and Israel are the leading countries in terms of total installed capacity whilst Cyprus, Israel, Austria, Greece and the Barbados are the countries who have achieved the highest level of installations per capita. The largest markets for SWHs are China, Europe, Australia and New Zealand. Before the onset of the global recession in 2008, these markets were all experiencing strong annual growth rates in SWH instalments; China of 23.6%, Europe of 20% and Australia and New Zealand of 16%. Other, smaller, markets have experienced tremendous growth rates[59] with Hungary at 700%, Ireland at 293%, the Slovak Republic at 200%, United Kingdom at 93%, Namibia at 74.5% and Mexico at 60% (Weiss et al. 2009, p.5).

By 2002 there were an estimated 10 million SWHs installed in developing countries. As is apparent from the discussions above, China accounts for the largest share but by 2000 India had more than 500 000 m^2 of solar collector area installed and countries like Thailand have made significant reductions to energy usage by replacing 15% of water heaters with solar water heating devices. Though penetration in African countries has been slower, there are emerging markets in Kenya, Lesotho, Mauritius, Namibia, South Africa, Botswana and Zimbabwe (Langniss & Ince 2004, p.19).

South Africa, despite climatic conditions ideally suited to the use of SWH languish behind countries like Sweden and the Netherlands in terms of per capita and total installed capacity and has not achieved the spectacular growth rates that many other countries have. Judging by the sustained growth in countries with well established SWH markets, the technology is successful and South Africa is missing a strategic opportunity to develop a potential export industry.

[59] Growth figures are for the year between 2006 and 2007.

Figure 28 Total capacity of glazed and evacuated tube collectors in 2007 (Weiss et al. 2009, p.10)

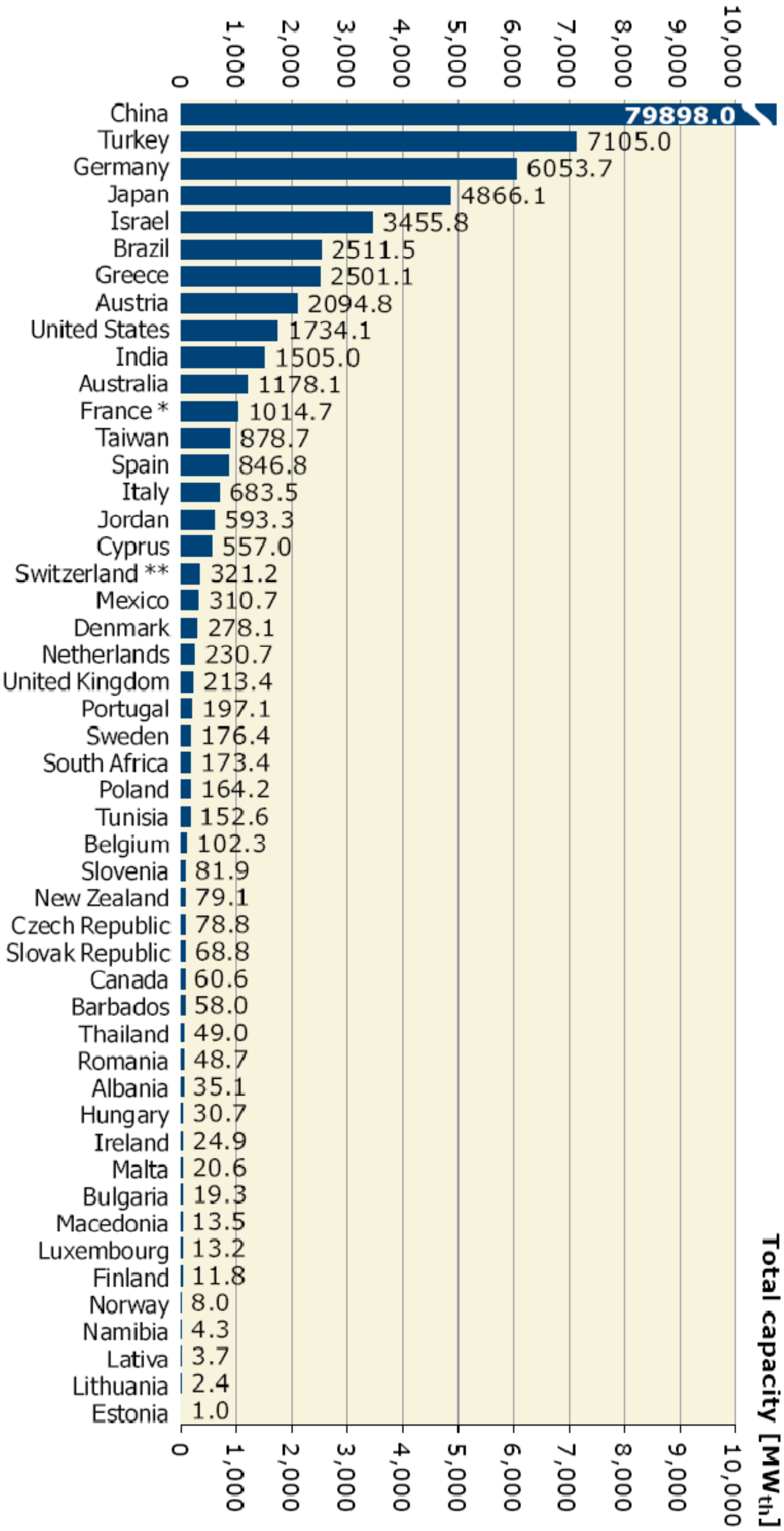
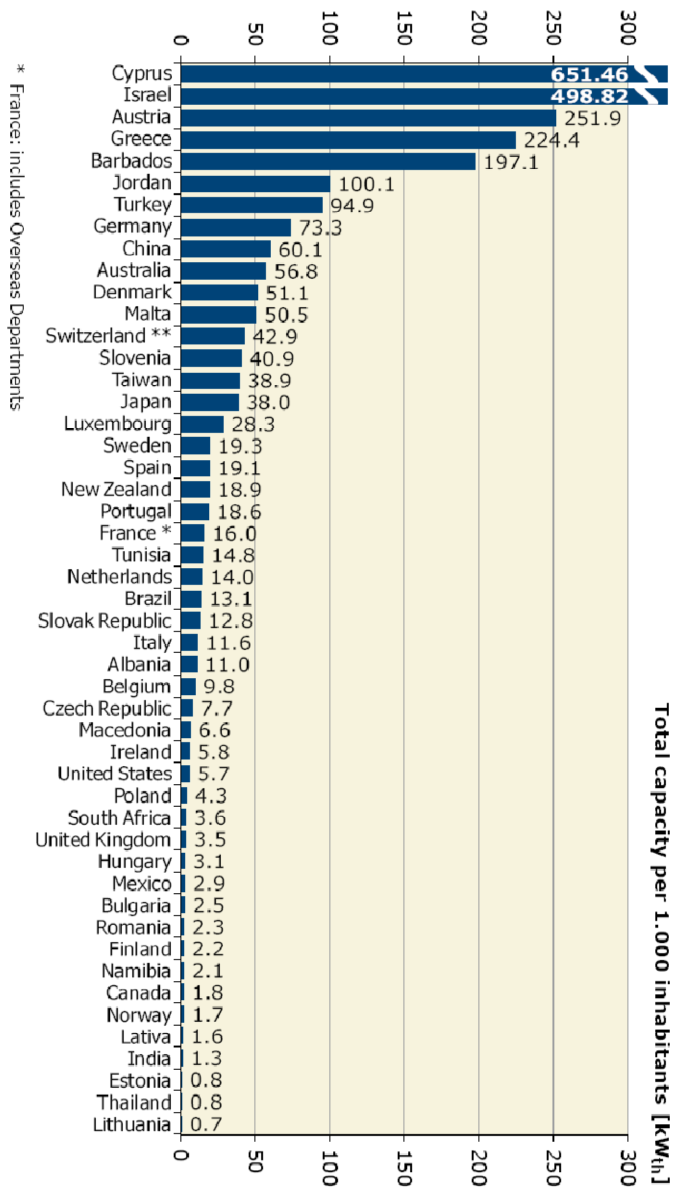


Figure 29 Total capacity per capita of glazed and evacuated tube collectors (2007) (Weiss et al. 2009, p.10)



The countries where markets for SWHs have grown most are the ones wherein governments actively intervened to reduce the two largest barriers to mass rollout, namely the initial, high capital costs of solar water heating systems and the lack of public awareness about the benefits of SWH (Holm 2005, p.19). Note that several of the top 10 countries in terms of installed capacity per capita are not particularly renowned for their hot weather. Effective government policies rather than outstanding environmental conditions seem to be a stronger requirement for sustained growth of a SWH market. From his research Holm (2005, p.20) concludes that; *"The global use of SWHs is driven by the socio-economic need for job creation, environmental concerns, energy security, national economy and peak demand reduction. Good solar conditions on their own do not necessarily lead to a SWH market penetration or lower prices. The main barriers of lacking awareness and higher initial costs are more readily overcome where national governments legislate supportive policies."*

Government policies that have proven to be largely ineffectual include tax rebates paid to manufacturers (particularly in the USA during the 1980s) and short-term government subsidies. Australia has achieved some success by introducing output related Renewable Energy Certificates but the most successful rollouts have been achieved through regulations making SWH installation on all buildings below a certain height mandatory (Holm 2005, p.19). Israel is a prime example of the success that can be achieved through government legislation leading to the development of large local markets and a strong export sector (Sterman 2009; Sunbelt Solar 2009; C. Meyer 2008).

Though the focus of this thesis is not on developing a policy regime for South Africa, it is hoped that it will identify areas in the local SWH market where policy support can contribute to the development of the local market and eventually an export sector. According to Holm (2005, p.44) the best quality SWH systems currently available are manufactured in countries where governments have created intelligent supportive policies for the growth of national solar water heating industries. This thesis can inform the development of such policies in South Africa.

By advocating a systems theory approach to the development of SWH in South Africa this thesis hopes to ensure that government policies to support the SWH industry do not disregard wider developmental goals. The argument is that, if the industry is developed from a systems perspective, it can play a strategic role in improving quality of life for lower income communities through the satisfaction of fundamental human needs. It is important that SWH rollout programs should not only be seen as a way to reduce environmental footprints or decrease pressure on the national electricity grid. If the process leading to large rollouts is followed from a systems perspective it can address many other developmental challenges in addition to environmental protection and energy security. This can be achieved if the empowerment of people to fulfil their own fundamental needs and improve their quality of life is seen as an overarching principle in planning rollouts. The industry analysis that is conducted is designed to inform government support for SWHs in a way that can ensure that the South African SWH industry becomes a source of job creation. By creating employment opportunities the SWH industry can further improve the quality of life of low-income households by reducing the unemployment burden. The following paragraphs will investigate the full range of potential benefits of providing SWHs in low-income communities.

2.7 THE POTENTIAL BENEFITS OF PROVIDING SWHS IN LOW-INCOME COMMUNITIES

The following section will provide an in depth overview of the potential benefits of providing SWHs in low-income communities. This discussion is important as it informs the objectives that need to be considered when evaluating the costs and benefits of rolling out SWHs in these communities. By identifying and evaluating these benefits, this thesis can inform government policy design and thus ensure that policies are maximally effective.

In his 2005 study, Professor Holm finds that "*solar and environmental conditions in SA are ideal for SWHs.*" While most energy specialists agree that South Africa has ideal environmental conditions for the development of solar energy technology, there is some debate about whether SWHs for low-income communities would be the best use of the available solar energy. Langniss and Ince (2004, p.20) argue that SWHs *"...are not the ideal technology to enhance the living conditions of the poor in developing countries. They also have limited capacity to contribute to income generating activities run by this section of* *society."* They go on to say that SWHs have, however, been successfully applied in domestic and commercial use in higher income communities and that they can easily be constructed locally for this income group. The primary barrier to the rollout of SWHs in low-income communities is the high initial capital cost (Prasad & Visagie 2005; Prasad 2007; Holm 2005; Winkler 2006; DME 2002) – an issue that this thesis hopes to contribute in addressing. Despite the doubts of Langniss and Ince, there are other authors who agree that a rollout of SWHs would contribute to the relief of poverty (of different kinds) in society. Prasad (2007, p.4) and the DME (2002, p.15) for instance, contend that SWHs[60]:

- save money for all households, irrespective of income levels, over the long term as it is the "least expensive means of heating water for domestic use on a life cycle cost basis",
- can improve the general welfare of households through reductions in air pollution from coal, wood or paraffin burning stoves,
- are a means whereby RE could significantly contribute towards poverty alleviation through the manufacture, sale, installation and maintenance of SWHs,
- reduce household expenditure on energy, thereby increasing disposable income.

These benefits are further discussed and analysed according to the systems approach to sustainable development and the Human Scale Development theories of Max-Neef to emphasise the potential solar water heating[61] as a synergic satisfier for many of the development challenges facing the Western Cape and Stellenbosch and to incorporate the effects in an analysis of the efficacy of SWH programs.

SWH systems themselves offer poverty relieving services and large environmental benefits whilst the process of supplying the systems, through the establishment of a large local industry that employs labourers from local communities, contributes to the relief of other development pathologies. The benefits of SWH systems for low-income households as well as those of job creation through the provision of the systems are shown below in Table 2[62] according to the matrix of needs and satisfiers developed by Max-Neef. The services that SWHs and the establishment of a large industry offer are described as satisfiers in the appropriate needs categories. The areas where solar water heaters and the production value chain contribute most to the relief of poverty are discussed in more detail thereafter.

[60] Of course the additional benefits of reducing peak electricity and greenhouse gas emissions are applicable to the rollout of SWHs in all income groups.

[61] The entire process from manufacturing, to installing and finally using solar water heating systems.

[62] The classifications in this table are based on the theories of Max Neef but reflect the researcher's own interpretation of his (Max Neef's) concepts, based on discussions with two homes wherein solar water heaters had been installed. The potential benefits of jobs created through the solar water heating value chain are based on the researcher's own interpretation of the theories of Max Neef in the context of the Western Cape Province.

Table 2 Matrix of Fundamental Needs and Satisfiers offered through a large, local SWH industry

Axiological needs		Existential Needs: Being	Having	Doing	Interacting
	Subsistence	Physical health improvement, through improved personal hygiene (Curtis et al 2002) due to the ready and cheap availability of hot water The sharp decline in deaths from infectious diseases observed in wealthy countries over the last century could not have been achieved without vastly improved public hygiene (Curtis et al 2000). The Kuyasa CDM project (2009) found that 80% of SWH recipients experienced improved health due to the interventions of the project. Though most households thought that the ceilings installed as part of the project there is some indication that the SWHs also contributed).	Improved housing through the availability of hot water (Wilkie 1986). Stable income through employment (Prasad and Visagie 2007). More disposable income due to savings on electricity expenditure (Arendse & Arendse 2009).	More time to rest due to less time spent heating water for bathing, cooking, cleaning (Arendse & Arendse 2009).	Improved living environment through hot water availability (Wilkie 1986). Improved social environment through better hygiene leading to higher general health levels (Curtis et al 2000, Wilkie 1986).
	Protection	Increased autonomy for households and communities as	Added protection against electricity blackouts as hot water remains	Better personal hygiene leading to health	Improved social

		they become less dependent on grid electricity (Arendse & Arendse 2009). People experience improved autonomy through having more disposable income due to higher employment levels (Theodossiou 1998) and less expenditure on electricity.	available (Arendse & Arendse 2009). Increased savings as electricity bills are reduced (Arendse & Arendse 2009). Perception of better protection of rights as access to energy services becomes more equitable. When inequality reduces levels of depression and anxiety decrease (Mellor & Milyo 2001) Stable employment opportunities (Prasad and Visagie 2005).	improvements (Curtis et al 2000). Parents feel that they can take care of their children better through having steady income, hot water to bathe young kids in and more disposable income due to lower electricity bills (Arendse & Arendse 2009). Childhood skin problems can be partially alleviated through daily bathing (Deborah 1998). By improving the health of their children mothers fulfil their need to care for their families.	environment as community as a whole sense improvement through increased economic activity as well as the visual impact of installed SWHs[63] (Ndamane 2009). As people experience relative improvements in their communities, levels of depression and anxiety decrease (Mellor & Milyo 2001) Improved aggregate health levels due to improved hygiene (Curtis et al 2000).
	Affection	Higher levels of self-esteem (Wilkie 1986) and mutual respect in community as people enjoy stable employment and high levels of personal hygiene	Relationships with nature improved as rollout of SWHs lead to increased environmental awareness (Wesselink 2009).		Personal intimacy becomes more enjoyable as hygiene levels improve due to ready availability of hot water.

[63] Refer to Figure 36 Kuyasa SWH project and Figure 35 KwaNokuthula SWH project for examples of the visual impact that SWHs can have in a community. They create a sense of progress and improvement.

Understanding	Previously excluded communities feel part of technological progress as they become the forefront of renewable energy technology applications in South Africa (Wesselink 2009). Pride in the environment increases as SWH projects increase understanding of environmental systems (Wesselink 2009).	Through the rollout of SWHs people have an opportunity to learn about energy and the environment (Wesselink 2009). Through becoming involved in the SWH value chain labourers are exposed to training workshops (Wesselink 2009, Hertzog 2009).	Through working with renewable technology workers in the industry as well as households who have SWHs installed have opportunities to investigate and enrich their knowledge of energy technologies (Hertzog 2009).	Workers in the SWH value chain become part of a community wherein they share their understanding and experiences of the new technology. Communities that feel that inequality levels relative to others are improving are less subjected to depression and anxiety (Mellor & Milyo 2001)
Participation	Communities and workers in the SWH industry experience solidarity as they all go through the same experiences during the SWH rollout project (Ndamane 2009). Communities who were previously largely excluded from general town improvement initiatives feel that they are now an integral part of development initiatives – not just as coincidental beneficiaries but as essential participants (Ndamane 2009).	Through the instalment of SWHs households feel that their basic rights are better fulfilled through access to modern energy services, they share in the responsibilities of maintaining the SWH systems and they experience what was previously a privilege of only the "rich;" readily available hot water (Ndamane 2009). Wilkie (1986) finds that the availability of running hot water and improved bathing facilities is associated with improved social standing in the United States. Those who work in the SWH value chain have the duties and responsibilities that accompany steady employment (Ndamane 2009).	Households have to cooperate in the installation of the SWH on their homes for the project to work (Ndamane 2009). Opportunities can be created where recipients and workers can express opinions about the improvement of projects (Ndamane 2009). People can feel part of global efforts to curb environmental degradation (Wesselink 2009).	Workers in the SWH industry become part of labour associations (Therion 2010, Ndamane 2009) This can lead to a sense of participation and interaction.
Idleness	Hot water availability offers new opportunities to experience tranquillity (Turner 2002). Bathing	A hot bath improves sleeping patterns. When a person emerges from a bath their core body temperature drops,	Hot water baths offer increased opportunities to relax and daydream (Turner	Improved personal hygiene can increase the pleasure of intimacy by improving skin

	can become a sensual activity (Wilkie 1986) instead of a tedious chore.	causing heart rate and breathing to slow which induces fatigue that promotes deeper sleep (Mandile 2002). The relaxation of a hot bath can improve a person's emotional "peace of mind."(Wilkie 1986). The heat of a warm bath increases circulation, boosting the blood flow to tight muscles, which loosens them (Mandile 2002)]. Persons with steady employment will be much less prone to depression and anxiety (Theodossiou 1998).	2002).	health (Mandile 2002). Through having access to readily heated water people have more free time as they do not have to heat water themselves (Arendse & Arendse 2009). Large SWH projects create a perception of a positively changing landscape (In regions near to coal power stations they will also help to reduce air pollution).
Creation	Productive involvement in the SWH value chain can stimulate rationality and curiosity amongst workers whilst increasing their autonomy by providing stable employment (Ndamane 2009).	Stable employment in the SWH value chain will offer workers the opportunity to improve their abilities and skills (Hertzog 2009, Hallet 2010, Ndamane 2009).	The creation of a large local SWH industry could offer local people opportunities to invent, build and design new systems and sub-systems.	Employment opportunities provide productive and feedback settings.
Identity	By being part of a community that has experienced a large SWH rollout the communal sense of identity and belonging will increase leading to concurrent increases in self-esteem (Ndamane 2009). The ready availability of hot water leads to increased personal care which in turn leads to increased self-esteem (Wilkie 1986).	The SWHs on the roofs can become symbols of improving communities. The entire community will share the experience of the SWH rollout project leading to greater community cohesion (Ndamane 2009)	Communities could take ownership of their local environment and become part of global movements that try to live more sustainable (Wesselink 2009). Through involvement in the SWH value chain workers can grow and actualize themselves in their work.	Communities with SWHs generate social rhythms as many daily activities become tied to the availability of sunlight. Entire communities are influenced by their everyday settings in neighbourhoods where everyone owns a SWH, this raises awareness of environmental concerns as

		Workers' in the SWH value chain can also experience feelings of belonging and increased self-esteem. Theodossiou (1998) finds that unemployment is associated with a marked rise in anxiety, depression and loss of confidence and a reduction in self-esteem and the level of general happiness.			well as creating a sense of being part of something larger (Wesselink 2009). Community cohesion can reduce the incidence of depression and anxiety (Mellor & Milyo 2001)
	Freedom	The availability of employment in the SWH value chain increases general levels of autonomy and self-esteem (Theodossiou 1998).	As more people gain access to hot water they perceive that rights are distributed more equally. Wilkie (1986) finds that improved bathing facilities led to a perception of improved quality of life and progress in the USA in the early 1900s. Mellor & Milyo (2001) find that the reduction of perceived inequality reduces levels of depression.		Through reduced time requirements for everyday tasks such as dishwashing, bathing and cleaning as less time is spent heating water (Arendse & Arendse 2009) households experience more temporal freedom.

2.7.1 QUALITY OF LIFE IMPROVEMENT

Table 2 illustrates the potential of SWHs to alleviate poverty through the fulfilment of a range of fundamental human needs. The table is an attempt to integrate the theories of Max-Neef into the developmental context of low-income communities in South Africa and the role that SWHs can play therein. The matrix is completed through a survey of a wide range of literature. None of the sources cited refer directly to SWH but they discuss elements that are of relevance to the availability of running hot water in households (Turner 2002, Deborah 1998, Mandile 2002, Wilkie 1998), or the benefits of steady employment (Mellor & Milyo 2001, Theodossiou 1998). Where the specific effects of SWH rollout programmes in terms of environmental awareness and time savings in households are discussed interviews with Wesselink (2009), Ndamane (2009) and Arendse and Arendse (2009) are used. It is not intended to present a comprehensive and final overview of the potential benefits that the provision of SWHs would hold but rather as a framework for further discussions of the potential of SWH as a synergic satisfier for fundamental human needs. The author recognises that SWHs cannot satisfy all fundamental human needs but by adapting a process based approach, as developed by Max-Neef, many more needs can be fulfilled. If rollout strategies are focussed simply on the eventual goal of installing SWHs on every roof an opportunity will be lost to create community participation and employment opportunities. If these opportunities are ignored SWH rollout programs will have far less developmental impact than if they were exploited as is shown in Table 2. In the table some categories indicating the contribution of SWHs are more indirectly fulfilled. They are filled in here to show how SWH offers a potential synergic satisfier that can relieve a range of poverties caused by unfulfilled human needs. Only the direct satisfier services that SWHs offer are discussed further below.

Hot water is a basic requirement for households and poor people would greatly benefit from having affordable running hot water (Prasad & Visagie 2005, p.30). The value of the service is illustrated through the initial development of the solar water heating industry in China. The original manufacturer, Huang Ming built a prototype SWH to provide his mother with a source of hot water so that she could avoid having her rheumatism flare up by washing the dishes and floor with cold water. The “invention” was an immediate success with instant health benefits for his struggling mother and soon, as the news spread, everyone in his neighbourhood wanted a solar water heater. Based on this initial success Huang built what is today the largest solar water heater manufacturing company in China (Sunbelt Solar 2009). The basic reason for water heating remains the provision of an energy service that simplifies activities like cooking, washing and personal hygiene care, increasing the pleasure derived from these activities (Turner 2002, Deborah 1998) and reducing the time required to complete household chores (Holm 2005, p.44). This remains the precept upon which any rollout of SWHs has to be based. Deborah (1998) and Curtis et al (2000) discuss the health benefits of frequent bathing and hand washing with warm water. Turner (2002), Mandile (2002) and Wilkie (1986) find that bathing provides psychological benefits by reducing stress, relaxing muscles and providing a relaxation opportunity. The instalment of SWHs unlocks this potential by making hot water readily available.

The process benefits of a locally based SWH rollout program lie mainly in its employment creation potential. Steady employment greatly reduces the incidence of anxiety and depression amongst individuals and households (Theodossiou 1998) whilst the feeling of reduced inequality has benefits for social cohesion and community building (Mellor and Milyo. 2001). Through the Kuyasa CDM project the SWH recipients also felt part of a process that had positive environmental implications and became aware of wider social movements (Wesselink 2009). Such feelings of participation and interaction fulfil fundamental human needs (Max-Neef 1991).

On a national level SWHs contribute to improved air quality and human health by reducing the amount of harmful emissions released to generate electricity. Local air pollutants released during the combustion of fossil fuels, such as coal, cause respiratory ailments whilst airborne particulate matter has been linked to increased risk of cancer in individuals. The negative health effects of air pollution are estimated to cost South Africa in excess of R4 billion annually (SEA 2009, pp.1-2).

2.7.1 REDUCED DEMAND FOR ELECTRICITY – SAVINGS FOR POOR HOUSEHOLDS

Water heating, through electrical geysers, accounts for a large portion of the residential demand for electricity (up to 46% as is shown by Table 3). There is however a significant disparity in electricity used for water heating between suburban high-income households and low-income households in townships. This disparity indicates a large suppressed demand for energy services in low-income communities whilst it also speaks of expensive, inadequate, unsafe and inconvenient energy sources in these communities (SEA 2009, pp.2-3). Successful attempts at poverty alleviation will almost certainly lead to increased usage of hot water in these communities. Given the environmental concerns and South Africa's electricity shortage it is absolutely essential that increases in water heating and electricity usage should be decoupled. Solar water heating can achieve this objective.

In their study on the implementation of renewable energy in South Africa Sustainable Energy Africa (SEA) (SEA 2009, p.11) found that if SWHs are installed "*Improved quality of life and a reduction in electricity costs can be expected in a low income household, where energy costs are often a large component of household expenditure and the SWH may replace the use of "dirtier" fuels, such as paraffin, for water heating*". If one considers that water heating accounts for 30-40% of household energy consumption and that at least 70% of this figure can be saved through the installation of a SWH the savings potential for households is significant, between 15 and 30% on their monthly electricity bill (Holm 2005, p.21; Van Gass & Govender 2009; SEA 2009, p.10)[64]. As electricity prices continue to increase in the coming years due to Eskom's expansion programmes (Pringle 2009; PMG 2009; Creamer 2010) the savings will become more significant, increasing the indirect benefits of SWH for households. Refer to *Table 2* for a comprehensive overview of the impact additional disposable income can have on fulfilling fundamental human needs.

By allowing energy usage in low-income communities to rise to a level similar to that of higher income communities SWH also plays a valuable part in reducing inequality levels in South African societies.

[64] As part of this research paper a survey of hot water usage was conducted in two communities in Stellenbosch to determine the exact extent of the costs of water heating in low-income communities. The findings of this sample are discussed under section 4 Research Findings.

Table 3 Residential Electricity Consumption in South Africa (DME 2002)

	ELECTRICITY CONSUMPTION					
	SUBURBAN		TOWNSHIP		INFORMAL SETTLE-MENT	
APPLICATION	kWh/ year	(%)	kWh/ year	(%)	kWh/ year	(%)
Water Heating	2722	**45.9**	**1164**	**30.2**	**373**	**18.0**
Clothes Washing	145	2.4	181	4.8	0	0
Cooking	897	15.1	1260	33.2	290	14.0
Space Heating	240	4.1	73	1.9	91	4.4
Refrig/Freezer	895	15.1	429	1.3	505	24.4
Lights	677	11.4	504	13.3	585	28.3
Other Appliances	358	6.0	183	4.8	225	10.8
Total	**5934**	**100**	**3794**	**100**	**2069**	**100**

2.7.2 REDUCED DEMAND FOR ELECTRICITY – ENERGY SECURITY

The impact that solar water heating can have on improving the energy situation in South Africa is not reflected in the matrix of needs and satisfiers completed in Table 2 as it does not fulfil a fundamental human need directly. It does so indirectly by ensuring that the national utility remains capable of meeting the demand for electricity in South Africa, which in turn fulfils a number of fundamental needs. The direct benefit of reduced electricity usage in Stellenbosch is much clearer in that it would free up existing grid capacity, enabling the municipality to concentrate on providing the additional serviced housing that is required in the municipal area.

On a national scale, residential consumption of electricity amounted to 32 846 GWh in 2000. Considering that more than 30% of total domestic electricity consumption is accounted for by water heating and that upwards of 60% of this figure can be replaced by SWHs the potential electricity savings amount to 5912.28 GWh per annum. This figure is more than the equivalent output of a large (900 MW) coal-fired power station (DME 2003, p.22) and more than 18% of the total residential consumption figure. Prasad (2007, p.17) and Sustainable Energy Africa (SEA 2009, p.10) do the same calculations based on the assumption that water heating accounts for 40-50% of residential energy consumption and finds that SWH could reduce electricity demand by 9000 GWh/annum, a large portion of which will be in peak demand times.

The implication is that Stellenbosch Municipality could also cut its residential electricity demand by around 40% if it mandates the installation of SWHs on all existing households, thus freeing up a significant portion of the available electricity capacity for the construction of new housing developments.

2.7.3 REDUCED DEMAND FOR ELECTRICITY – ENVIRONMENTAL BENEFITS

By reducing the demand for electricity, SWHs will not only benefit the electricity utility, consumers and municipalities looking to expand, they would also lead to significant environmental benefits. SWHs don't emit any greenhouse gasses themselves and replace grid electricity, generated in coal-fired power stations that are responsible for South Africa's relatively high carbon emissions (Prasad & Visagie 2005, p.30; Winkler 2006, p.40).

Coal is probably the cheapest source of energy presently available in the world but its use causes a range of social and environmental problems that are not calculated and included in the cost of the commodity[65]. Coal is one of the primary sources of carbon released into the atmosphere as well as many other harmful emissions such as sulphur compounds, nitrogen compounds and particulate matter (PM) pollution particles (Von Blottnitz 2006). For a breakdown of the emission of each of these per kWh of electricity generated in South Africa refer to Table 4. South African carbon emissions from coal power stations equal roughly 161 200 kilo tonnes per annum, whilst sulphur-related emissions equal 1.5 million tonnes per year (Von Blottnitz 2006). On average, for every 1MWh of energy produced by a coal power station, 1.02 tonnes of CO_{2e} is released into the atmosphere (Van Gass & Govender 2009; City of Johannesburg 2009; Pegels 2009, p.17). By reducing the requirement electricity generated in coal power stations, SWHs would also reduce the pressure on water supplies in regions where wet cooling towers are used as part of the coal power stations[66].

Table 4 Pollution generated in SA from coal-fired power plants (Von Blottnitz 2006, p.76)

	NOx	SOx	PM10	CO_2
mg/kWh of electricity generated	4020	8970	390	960000

2.7.4 EMPLOYMENT CREATION

As is clear from the matrix of human needs and satisfiers, reproduced in Table 2 having stable employment fulfils many of the fundamental human needs identified by Max-Neef. Employment in itself is a synergic satisfier which fulfils the needs for subsistence by providing (Max Neef 1991;

- Money for food and shelter,
- Protection by providing security about the future,
- Understanding through practical learning experiences,
- Participation by providing opportunities for collaboration and increasing self-esteem,
- Creation through involvement in the production of a product or service,
- Identity through improving self-esteem and feelings of worth as well as through work-based relationship forming and
- Freedom by giving people a sense of autonomy.

[65] Coal prices have also become much more volatile raising long-term concerns about the strategic availability of the resource, for a description of coal market volatility please refer to the document entitled *South African Dependence on Coal and Coal Market Volatility on the attached CD*

[66] For calculations on the energy saving effects of SWHs in low-income communities please refer to section 4.3

Given that employment holds so many benefits on so many different levels it is not surprising that unemployment becomes a pathology leading to a range of social ills. Manfred Max-Neef (1991, p.19) finds that in most cases long-term unemployment almost inevitably leads to pessimism and eventually fatalism. In communities with high levels of unemployment these feelings of pessimism and fatalism become a collective pathology of frustration (Max-Neef 1991, Theodossiou 1998), leading to worsening social ills (Mellor & Milyo 2001) until eventually unemployment becomes a systemic problem that cannot be solved through simple economic means but that in itself needs a systems approach to resolve (Max-Neef 1991).

SWH can feed into this context by offering improvements in quality of life and savings that will immediately start breaking down community pessimism and frustration by showing that progress is possible and that life can get better [The Kuyasa CDM project has seen this happening with some of the people that it employs (Ndamane 2009)]. Improved domestic conditions and the concurrent rise in self-esteem (Wesselink 2009) could contribute to renewed optimism about the future. Higher levels of optimism can then create an enabling environment from which people would be more employable (Max-Neef 1991, Mellor & Milyo 2001) – if the very technology that starts this positive cycle can then provide employment to the same communities the pathology of unemployment can be broken down.

This potential of SWH has been recognised in the literature with the DME (DME 2003, p.22) asserting that *"An increasing market for solar water heating would result in a growth in the relevant manufacturing industry and increased employment opportunities.*" and by Prasad (2007, p.17) who asserts that "*When the SWH market is expanded new SWHs have to be built. The manufacturing, installing and servicing [of] SWHs creates additional jobs."* and *"SWH can contribute to poverty alleviation in so far as jobs are created in manufacturing, installation and maintenance."* AGAMA (2003) provides a quantification of the employment generation potential in Table 6.

For the benefits of SWH to have the largest possible poverty reduction effect the challenge is to utilise as much of the strategic leverage that the SWH value chain provides. In terms of employment generation that would entail importing as few of the components as possible. This thesis identifies strategic opportunities for employment creation by quantifying the services that SWHs provide in terms of job creation and hot water provision. By quantifying the cost drivers in the Western Cape SWH industry the barriers to cost-reductions are identified. Understanding these barriers is a first step towards developing interventions that can assist in reducing costs. As systems become cheaper large scale rollouts in low-income communities can become more feasible and export markets in greater Southern Africa can be accessed.

The key challenge facing the SWH industry is the relatively high cost of the technology (Prasad 2007, p.4), especially that of flat-plate systems, which can be locally manufactured, compared to evacuated tubes, which have to be imported. Increasing electricity prices shorten the payback period to recoup the initial capital investment of buying a SWH. This may eventually stimulate increased market uptake in high-income consumer markets but large initial capital investment that is required will keep SWHs beyond the reach of the low-income households (Hertzog 2009). Some level of market intervention is required to realise the potential benefits of SWH in low-income communities.

If a provincial, national or local government decides to support the rollout of SWHs it will be faced with a choice between cheaper imported evacuated tube collectors and more expensive locally made flat-plate collectors. The characteristics of the different systems have been discussed and are further elaborated under the section entitled *Testing of Solar Water Heaters.* There is however more than just a technical component to the decision. Whether the technology is sourced locally or on international markets has vast development implications. It is argued here that systems should be sourced locally to ensure that development benefits of the entire value chain accrue in South Africa rather than in China, where evacuated tube collectors are manufactured.

> ***"Thus, the key policy issue is not whether to participate in global markets, but how to do so in a way which provides for sustainable income growth. This, as we have seen is a particular problem for poor producers and poor countries who seem to have experienced more of the downside than the upside of globalisation over the past two decades."***
>
> (Kaplinsky & Morris 2003, p.21)

As part of a synergic approach to needs fulfilment Max-Neef (1991, pp.64-65) argues that "*A commitment to Human Scale Development makes it necessary to encourage individuals to assume responsibility for a development alternative based on self-reliance. In this respect, the central question for Human Scale Development is: What resources are to be generated, and how should they be used in order to nurture self-reliance in individuals in micro-spaces? Self-reliance involves a kind of regeneration or revitalization emanating from one's own efforts, capabilities and resources. Strategically, it means that what can be produced (or worked out) at local levels is what should be produced (or worked out) at local levels*[67]*."* As is clear from the needs/satisfier table drawn up in *Table 2* many of the poverty alleviation opportunities offered by SWH depends on the ability of the value chain to create employment opportunities that will increase the self-reliance of low-income communities. Increasing self-reliance is central to development because it changes the way that people perceive their own potential and capabilities which often leads to an improved sense of value and self-worth (Theodossiou 1998, Max-Neef 1991). The development of the SWH industry in the Western Cape can become a catalyst in this process by creating employment opportunities locally. These employment opportunities can reduce the economic dependence and vulnerability of low-income communities (Theodossiou 1998). These changes can break the cycle of poverty, increasing self-esteem and leading to increased participation and creativity amongst low-income households and communities. As the pathologies of poverty are broken people from poorer communities can become a valuable and valued part of socio-economic structures (Max-Neef 1991).

This opportunity will be missed if a rollout of SWHs in South Africa is simply based on imported technologies. Providing people with hot water would make an improvement in their quality of life, but if someone in that household or in their community could be employed somewhere in the value chain that gets the water heater onto their roof the *process* would lead to the achievement of a range of development goals and a much greater improvement in quality of life. If the very communities that receive the SWHs could be included in the production of the SWHs, the capital that is spent on installing the SWHs would remain in South Africa and some of it would go into circulation in the low-income communities where the SWHs are installed. As capital becomes available in these communities due to higher employment levels economic activity in the community would increase and the inhabitants would be taking the first steps to further economic development and self-reliance. What's

[67] Emphasis added by this author

more is that, as that capital is put to work, it will create more local job opportunities as well as tax revenue for the authorities, allowing them to reclaim part of the investment that they made in the first place. One could also reasonably expect that the local SWH industry will increase in efficiency and grow to benefit from large economies of scale and eventually South Africa could become a major exporter of SWHs which would lead to even further economic growth and an improved balance of trade on the current account of the state.

Alternatively, if the millions of SWHs were to be imported from China the capital would immediately flow out of the country, the local SWH industry would be smothered in its infancy and the national balance of trade would deteriorate as foreign exchange flows out of the country. People living in low-cost housing would have hot water but still struggle to find employment and the capital that would enable them to pursue opportunities for personal and community development.

The SWH industry is particularly strategic in terms of job creation as the manufacturing of systems does not require highly skilled labour (Hertzog 2009, Hallet 2010, AGAMA 2003). It thus provides an opportunity for unskilled workers from low-income communities to secure permanent jobs and become part of the formal economy. In a country where government and municipalities are besieged by a poverty crisis, and have limited resources, it is essential that industry development initiatives should be targeted at strategic leverage points that can contribute most to sustainable development. This thesis investigates the potential impact of a mass solar water heating rollout to understand whether it would be worth the support and to identify key areas where support is required to realise maximum benefit.

Before the research is conducted, an overview of the available literature on solar water heating in South Africa is provided below to identify where the gaps in the research are or where Western Cape and Stellenbosch specific research is required to test the local applicability of general findings.

2.8 EXISTING LITERATURE ON THE SOLAR WATER HEATING INDUSTRY

The following sections of the thesis will overview the relevant literature that is available about the SWH industry in South Africa. Based on preliminary discussions with SWH industry players and academic staff at the University of Stellenbosch, Value chain Analysis (VCA) was selected as a method to investigate the SWH industry but no previous VCAs of the South African (or any other country's) SWH industry could be found. Several other studies on SWH and renewable energies in South Africa have however, been conducted and these are reviewed and summarised here to ensure that the analysis completed for this thesis adds to existing knowledge rather than replicating what has already been found.

2.8.1 HISTORY OF THE SOUTH AFRICAN SWH INDUSTRY

Though there has been a renewed interest in solar water heating technologies over the last decade due to concerns about energy prices, energy security and anthropogenically induced climate change, solar water heating is by no means a new technology. The industry is well established with many years of manufacturing and installation experience worldwide as well in South Africa (Weiss et al 2009, Holm 2005).

Figure 30 Historical statistics on SWH shipments in South Africa (Holm 2005, p.26)

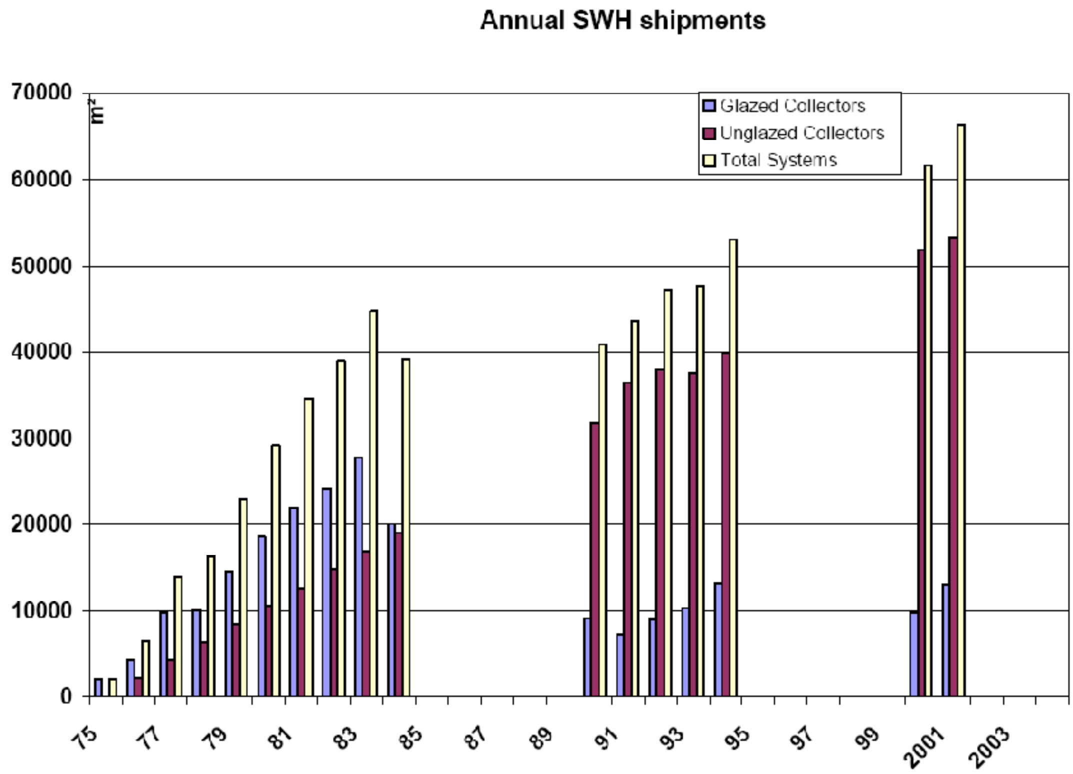


Figure 30 presents a graphical illustration[68] of the development of the SWH industry in South Africa. Unglazed systems are almost exclusively used for swimming pool heating in the high income market whilst glazed systems are used for domestic water heating (Holm 2005, p.27).

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[68] Data is not available for the omitted years

From the figure it is clear that SWHs have been installed and manufactured in South Africa since at least 1975 and that initial market uptake, in all likelihood due to the oil crises of the 70s and 80s, was very high. Peak installation for glazed collector systems was attained in 1983 and even with renewed interest installations have not yet recovered to the same levels.

Prasad (2007) divides the development of the SWH industry in South Africa into three historical phases.

- Phase 1 between 1978 and 1983 when there was widespread acceptance of SWH technology and many installations
- Phase 2 between 1984 and 2003 during which there was a large-scale collapse of the SWH market
- Phase 3 commencing after 2003 with increased government support for SWHs as well as renewed interest by middle to high income consumers.

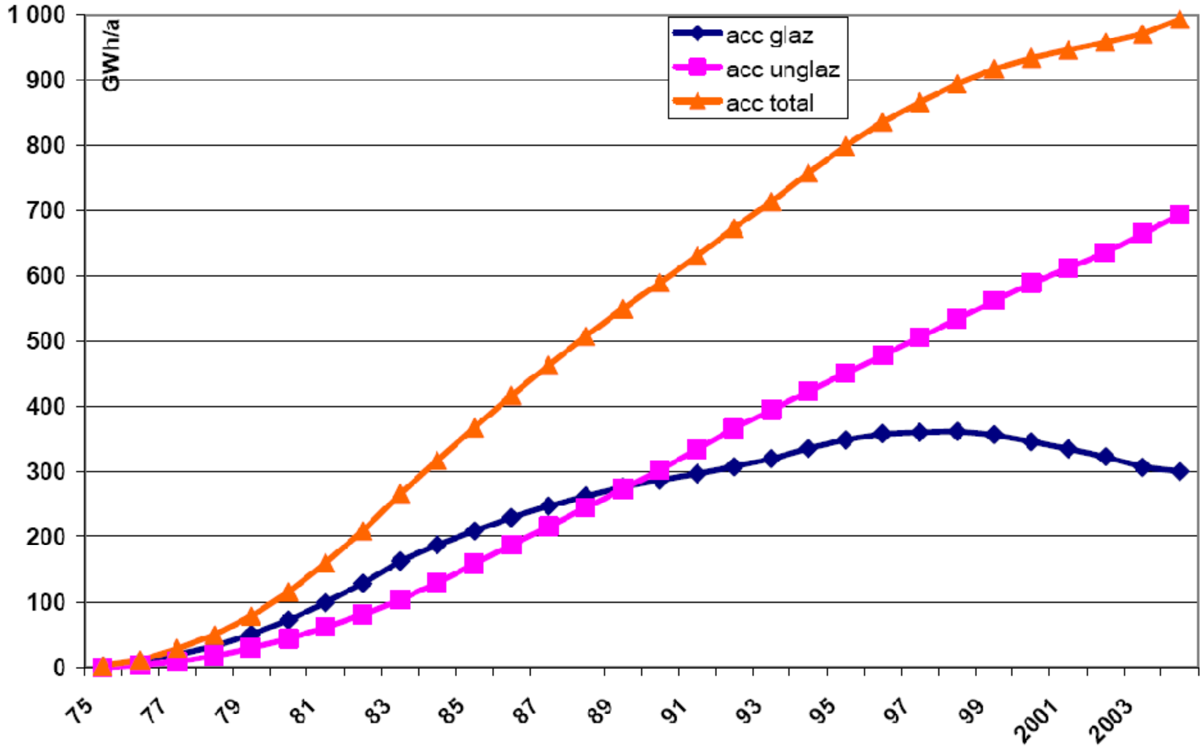
According to Prasad (2007, p.5) and Holm (Holm 2005, p.31) the interest in SWHs from the late 1970s into the early 1980s was largely due to the promotion of solar water heating technology by government through the CSIR due to the energy crisis experienced during that time. The SWH industry grew rapidly in this time and eventually there were six companies that manufactured and installed SWHs for middle to high-income consumers. Peak production was attained in 1983 with 27,000 m^2 of solar collector area installed during that year. Unfortunately that was also the year during which government supported awareness raising of SWH was stopped and the market collapsed soon thereafter. By 2004 it had still not regained its former levels[69]. Holm (2005, p.31) also attributes some of the slump in market demand to an exceptionally cold spate in the Northern parts of South Africa during 1982 which destroyed several thermosyphon SWH systems through frosting. This reduced customer trust in the technology and emphasised the importance of using the appropriate combination of technology for each application. The slump in demand after government support waned indicates that the industry needs some level of market intervention to achieve initial success. External, government intervention was also necessary to encourage the development of SWH markets in other countries such as Israel, Austria, the Barbados, China and Cyprus (Sterman 2009; Sunbelt Solar 2009; C. Meyer 2008, Langniss & Ince 2004). For the low-income market awareness raising alone is unlikely to be enough. The successes of the awareness raising campaign in the 1970s and 1980s were largely in middle - to high income markets (Holm 2005) but it is clear that intervention of some nature is required.

Between 1984 and 2003 the SWH industry remained depressed with little interest from government or mainstream private consumer markets. By 2001 the output of glazed SWHs was still only at 46.8% of the 1983 level (Holm 2005, p.26). Figure 31 shows the estimated cumulative capacity of SWH in South Africa in 2004 based on an estimated average system lifetime of 20 years (Holm 2005, p.22). From the figure it is clear that the total available SWH capacity has actually declined as the systems installed during the boom phase in the 1980s have expired without being replaced by new installations. By 2004 glazed collectors

[69] From recent interviews with SWH suppliers it seems that the industry had finally started recovering to its 1980s levels during 2007 and 2008, the recession of 2008/2009 dampened demand somewhat but increased Eskom subsidies and electricity price increases in 2010 have led to increased demand again.

produced an estimate of 300GWh of energy per year at 172 MW capacity, down from a peak production level of more than 350 GWh per year, at a capacity of more than 200MW, in 1997[70].

Figure 31 Annual energy produced by cumulative active SWH systems in South Africa (Holm 2005, p.30)



2004 heralded a new phase in the development of the SWH industry. There has been renewed support from public authorities, exemplified by the White Paper on Renewable Energy of 2002, identifying solar water heating as a critical part of national government's renewable energy strategies, and the Eskom SWH rebate scheme. Several local authorities such as the City of Cape Town and Nelson Mandela Bay have also taken the initiative in developing policies to support the rollout of SWHs, mostly in the middle to high income residential market[71]. It remains to be seen how sustainable and effective the renewed support for the SWH industry will be in the middle to high income residential market but it seems unlikely that current initiatives will be sufficient to achieve the large-scale rollout of SWHs in low-income communities as they are targeted at middle - to high income consumers. The technology remains too expensive for low-income markets (Hertzog 2009). To make such a rollout a reality more specific government support will be required.

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70 Drawn up with a nominal capacity of 0,7kW/m² of installed capacity, based on international standards developed by the International Energy Agency's Solar Heating and Cooling Programme (Holm 2005, p.30)

71 For more detailed descriptions of these projects please refer to the document entitled *Existing Solar Water Heating Programmes in South Africa* on the attached CD

2.8.2 INDUSTRY COSTS

Though it was not the primary purpose of his research Holm (2005) completed a rudimentary overview of the domestic SWH value chain in South Africa. He professes that businesses were reluctant to share cost information and that some of them did not have detailed cost breakdown records but he was able to generate the estimated returns to parts of the value chain based on costs. His findings are reproduced in Table 5 below.

Table 5 Estimated breakdown of returns across the value chain (Holm 2005, p.32)

Manufacturer material	Manufacturer labour	Cost of premises	Overheads	Promotion	Return (profit)	Distributor	Install /maintain	Total installed cost (100%)
31,2%	16%	2%	4,2%	2,4	17%	9,2%	18%	= 100%

According to this data, manufacturing accounts for 53.4% of the total costs with distribution, installation and maintenance only accounting for 27.2% of the costs. Profit margins at 17% are not exorbitant for a commercial industry operating at the scale that SWH in South Africa does. High profit taking is thus not the primary driver of high costs. Manufacturing material is the single largest driver of cost.

Winkler (2006, p.127) found that flat-plate SWHs cost between R8 000 to R12 000 to install and that evacuated tube SWHs could be installed for between R4 000 and R6000. If these evacuated tube systems were to be installed with electric backup the total cost would be between R6 500 to R7500 (EDRC 2003 and DME 2004b cited in Winkler 2006)[72]. Interestingly Winkler (2006, p.127) found that most local distributors of SWHs felt that evacuated tube SWHs would supplant flat-plate collectors as the dominant technology by 2010 and that it will eventually be the only type of system that is available[73]. Based on these figures it is clear that in order to identify the cost drivers of the SWH industry one has to look at the manufacturing activities in the value chain as they are the primary drivers of costs. This gap in the literature is filled in section 4.2.2.1 of this thesis, at least for the Western Cape SWH industry.

2.8.3 LEARNING CURVES FOR THE SWH INDUSTRY

Since South Africa has never had a solar water heating industry wherein the market grew steadily over a significant period of time there is little data available from which a learning curve can be extrapolated. Holm (2005) tried to fill this gap by combining the local data that is available with international experience of the learning curve for SWH producers. Based on these input variables the learning curve that Holm developed is a function of market growth. Holm (2005) finds that prices fall between 20-30% each time the accumulated output of SWH doubles. Italy is provided as an example, SWH manufacturing output doubled between 1998 and 2002 and prices fell between 20 and 25% (Holm 2005).

[72] These prices are given in 2006 Rand but were very much in line with the costs of low-cost systems during 2009

[73] Research completed for this thesis indicated that many SWH suppliers were still somewhat dubious about "new" evacuated tube technology and that flat-plate collectors were still the only systems locally produced.

Government institutions looking to encourage the expansion of the SWH industry in the hope of lowering prices through the creation of economies of scale need to be careful of a potential adverse price effect arising through supply shortages. A sudden increase in demand could lead to large price increases if supply capacity was unable to expand at a similar pace (Mankiw 2007). Government intervention programmes have to take cognisance of this possibility and ensure that demand grows at a steady pace to allow suppliers to expand their capacity accordingly.

Holm (2005, p.57) warns against the same threat and indicates that government policy needs to be in place to ensure that learning does in fact take place and that the gains thereof are transferred to final consumers. Most importantly a stable policy environment which guarantees SWH manufacturers long term institutional support is necessary to encourage innovation and learning.

2.8.4 EMPLOYMENT CREATION POTENTIAL

Several authors such as Holm (2005, p.54) and Prasad and Visagie (2005) have recognised the employment creation potential of the SWH industry. Prasad and Visagie (2005, p.12) postulate that *"SWH could make a major contribution in respect of reducing household expenditure and increasing job creation through the manufacture, sale, installation and maintenance of SWH, especially in disadvantaged communities."*

Holm (2005, p.54) is more specific in finding that significant amounts of low-risk, low initial investment cost jobs can be created for SMMEs in the distribution, installation and maintenance sector of the SWH industry in South Africa whilst the manufacturing sector is more capital and risk intensive. Both sets of authors mention that the SWH industry offers good BEE and gender parity opportunities. They however offer little quantitative data on the employment creation potential of the industry. AGAMA Energy consulting company (2003) have conducted research into the employment potential that various renewable energy technologies hold for South Africa which includes some data on the labour statistics of the SWH industry. When they started their research they too found that *"...employment data for the solar water heating industry is surprisingly difficult to find"* but their own research went some way towards filling this gap in the literature in South Africa.

Based on research completed by the Energy Information Administration of the Department of Energy in the USA they found that SWH in the USA contributed 6.1 jobs/MWp in 2000. Manufacturing, installation and retailing/distributing comprised 47.5%, 22.5% and 30% respectively of the total SWH workforce (AGAMA 2003, p.22). By 2002 AGAMA (2003, p.22) found that the South African Solar Water Heating industry employed 300 people in the nineteen manufacturing and 73 distribution organisations that then existed. Based on data from the 10 largest manufacturers AGAMA estimated that total sales in 2003 reached 15 000 m^2, equivalent to roughly 10 MWp per annum of electrical grid power supply. These figures indicate that the South African SWH industry creates at least 30 jobs/MWp or 0.0133 jobs per m^2 of systems that are produced and installed. Given the distribution of the workforce (based on American figures) mentioned earlier the manufacturing sector accounts for 14.3 jobs/MWp, while the installation sector accounts for 6.8 jobs/MWp and retail and distribution accounts for 9.0 jobs/MWp (AGAMA 2003, p.22).

Based on learning curve trends for energy generation technologies, which lead to declining labour requirements per unit of output, AGAMA developed a projection of the total direct job creation potential of SWHs in South Africa if all homes were to be equipped with locally manufactured SWH systems. Their projections are shown in Table 6 below.

Table 6 Direct Employment Creation Potential of the SWH Industry (AGAMA 2003, p.viii)

	Fuel		Mnfr		Inst		O&M		Other		Total	
	/MW	/GWh	/MW	/GWh	/MW	/GWh	/MW	/GWh	/MW	/GWh	/MW	/GWh
2002	0.0	0.0	14.3	30.0	6.8	14.2	0.0	0.0	9.0	18.9	30.0	63.1
2012	0.0	0.0	9.9	20.7	4.7	9.8	0.0	0.0	6.2	13.1	20.8	43.7
2020	0.0	0.0	7.1	15.0	3.4	7.1	0.0	0.0	4.5	9.5	15.0	31.5

If most of the systems installed were imported roughly 40% of these employment opportunities would not exist and 47 000 fewer jobs would be created countrywide. Indirect job opportunities and economic development benefits would also not be realised.

Furthermore, AGAMA (2003, p.xi) identified several reasons why the employment creation potential of renewable energy technologies, such as SWH, is advantageous over conventional energy sector jobs:

- Renewable energy generation is more decentralised than fossil or nuclear power generation, allowing for local economic development opportunities.
- Renewable energy technology industries can be located in disadvantaged rural areas.
- Renewable energy generation can be located closer to the final consumption points which would lead to improved regional service delivery, lower transmission losses and costs and greater reliability.

Though the research conducted by AGAMA energy is invaluable, this thesis will contribute to the knowledge available by providing data on the employment creation breakdown of SWH industries in the Western Cape as opposed to data based on American trends.

This data is necessary in order to inform government programmes to increase SWH market penetration. As has been argued, SWH interventions would achieve much more, from a developmental perspective, if employment creation is a key objective of intervention strategies. For employment creation benefits to be realised industry support policies and rollout programmes need to recognise and address the challenges faced by local industry. If market development strategies are designed to support local industry local employment creation can be maximised. The challenges faced by the local industry as identified in the existing literature, are discussed below. The research conducted in the Western Cape SWH industry for this thesis will be discussed in section 4.2.1.2.

2.8.5 CHALLENGES FACING THE SWH INDUSTRY IN SOUTH AFRICA

2.8.5.1 High Initial Costs

The initial installed price of an electric water heater is approximately half that of its corresponding SWH (DME 2002, p.17). Dieter Holm (2005), the DME (2002), and Prasad and Visagie (2005, p.v) identify this high capital cost, resulting from the relatively small market, as the main barrier to the widespread rollout of SWHs. The market may be failing to make the technology accessible due to a market failure. Conventionally determined prices may not take into account externalities such as environmental and social benefits. If these externalities could be included in the price determination higher amounts of a product or service may be produced and consumed. Such instances are called market failures that may be addressed through external market intervention form government institutions (Mankiw

2007). In the case of the SWH market the externality benefits that are not reflected in the price systems are the environmental benefits.

The high cost barrier may also be reduced through the creation of economies of scale that could be established through the creation of a larger market. These economies of scale may include reduced manufacturing costs and profit margins (Holm 2005). A DME (2002, p.17) study on SWH potential suggested that legislating for the installation of SWHs on all houses funded by the Reconstruction and Development Program (RDP) would provide the industry with a "base-load" demand that could contribute largely to the development of required economies of scale.

2.8.5.2 Low Electricity Prices

Tied to the challenge of high required capital expenditure, low electricity prices in South Africa have in the past been a significant barrier to the widespread uptake of SWH (Prasad & Visagie 2005, p.30; Prasad 2007, p.3) as there was little economic incentive for private consumers to invest in energy saving devices. As electricity prices have continued to rise from 2006 they have started to become a motivating factor for investment in alternative energy generation technologies. SWHs are becoming a much more attractive prospect for middle and high income consumers as the payback period for initial capital expenditure falls (SEA 2009, p.21). Increased electricity costs lead to more savings attributable to SWH and larger savings balance out the initial expenditure faster. Increased interest from higher income consumers illustrate that the cost-saving benefits of SWHs are valuable for households but the high initial capital costs makes the technology inaccessible for low-income households who do not have large sums of disposable cash. Without external intervention to overcome this capital cost barrier the cost-saving benefits of the technology will remain out of reach for poorer households who need it most. This thesis investigates the role that government can play in overcoming this barrier.

2.8.5.3 Imported Systems

SWH technology and production facilities in South Africa are relatively mature and locally manufactured systems compare well with what is available on the international market in terms of efficiency (AGAMA 2003, p.48) but the growing availability of cheap evacuated tube collectors from China pose a large threat to the local manufacturing industry, especially in the low-income sector (Hallet 2010).

2.8.5.4 SABS Testing Bottleneck

The SABS and its testing facilities are currently unable to cope with the large amount of SWH systems that are available in the market. They have a massive backlog in systems waiting to be tested. This has created a bottleneck in the testing of new systems that can serve as a barrier to price-reductions through growth in competition and innovation. It is difficult for manufacturers to test and develop new systems if they have to have each new system separately tested, especially if the process is costly and time-consuming (Hallet 2009, Hertzog 2010). The SABS attributes the problems to a lack of skills and sufficient testing equipment (Van Gass & Govender 2009, p.40; SEA 2009, p.22).

2.8.5.5 Awareness

When the SWH industry experienced its previous growth phase, it enjoyed public government support which greatly helped to increase awareness of the technology. Large marketing campaigns are needed to raise the profile of the technology (SEA 2009, p.22; Prasad & Visagie 2005, p.vi).

2.8.6 CURRENT MARKET CONDITIONS

Unfortunately, the favourable climatic conditions that South Africa enjoys have not led to the development of a burgeoning SWH industry and, largely due to lacking institutional support, the South African industry remains weak and fragmented (Winkler 2006, p.40). By 2003 less than 1.5% of homes in South Africa had solar water heaters installed (Holm 2005, p.21). The current SWH market in South Africa is dominated by private entrepreneurs selling systems to middle and high income households, primarily financed through mortgage funds or sometimes supplier finance (Winkler 2006, p.40). In the low-income context, market penetration has only happened in off-grid farm workers' homes and in government sponsored rollout programmes such as the Lwandle, Western Cape, Kuyasa, Zanemvula (Nelson Mandela Bay) and Cosmo City programmes[74].

If large scale rollouts of SWHs are to be achieved, with maximum local content, local production levels would have to increase quite drastically (Prasad & Visagie 2005, p.30) but the available literature suggests that the local SWH industry has significant excess capacity to fulfil increased demand. Holm (2005) found that South African SWH manufacturers have as much as 325% excess capacity and that they should be able to satisfy normal growth in demand for at least 6 years (from 2006) without even increasing labour. Thereafter, additional hours of labour and probably increased mechanisation would be required to keep up with normal market growth. AGAMA (2003, p.48) came to a similar conclusion in their report, finding that SWH manufacturers are operating at less than half of their total capacity. There are no restrictions on imports of SWH systems into South Africa and a significant portion of the systems made locally are exported to neighbouring countries. Manufacturers indicate that they would be willing and able to expand production capacity if it became clear that there would be long term, stable government policies to support the SWH industry (Holm 2005, pp.47-48)[75].

2.8.7 THE POTENTIAL OF DEVELOPING SWH AS AN EXPORT SECTOR

Holm (2005, p.47) found that, in 2004, exports to other African countries accounted for 51% of SWHs shipped in South Africa. There are no large firms manufacturing SWHs in any of the other SADC countries and the Southern African market presents a massive potential market for the export of SWHs from South Africa (Anthony 2009a), especially considering the ideal climatic conditions that prevail across the entire region (Holm 2005). The total population of the SADC countries is roughly 250 million (SADC 2008) and could exceed 400 million by 2025 (Kamara & Sally 2002). Most of these people fall into the low income group (SADC 2008) and if the prices of South African SWHs can be reduced to a point where they become attractive for mass rollout to other governments in the region, SADC could become a

[74] For more detail on these programmes please consult the document entitled *Existing Solar Water Heating Programmes in South Africa* on the attached CD

[75] In order to understand the wider context of the markets wherein SWH manufacturers compete it is necessary to understand the market for conventional electrical water heaters and other water heating technologies. For such an overview please refer to the document entitled *Water Heating Technologies* on the attached CD.

vast market for South African manufactured SWHs and the industry could become a major earner of foreign exchange.

2.9 EXISTING SOLAR WATER HEATING PROGRAMMES IN SOUTH AFRICA

A very brief overview of the existing SWH rollout programmes in the country is provided here to make the reader aware of the extent of current rollouts and to facilitate further investigation of the rollouts for those interested[76].

2.9.1 THE ESKOM SOLAR WATER HEATING PROGRAMME

With the advent of the electricity shortage crisis in South Africa Eskom announced a large scale solar water heating programme in 2008 as part of its demand-side management DSM initiatives. The Eskom national solar water heating programme is primarily targeted at middle to high income home owners as the utility found that these are the groups wherein the largest energy savings could be made with the installation of SWHs and that there was insufficient data and research[77] available on the use of energy for water heating in low-income communities. The programme entails the provision of subsidies for the installation of SWHs on private residential homes (Van Gass & Govender 2009; Prasad 2007, pp.6-7). The goal is to encourage the instalment of 925000 SWH systems between 2009-2015, but by the end of 2009 less than 800 subsidised systems had been installed (Copans 2009). The support provided as part of the programme is available as a partial subsidy for the cost of buying and installing a SWH paid as a rebate to the homeowner. Originally rebates totalled 15-20% of the cost of installing a SWH system but after a subsequent increase in the subsidy during 2010 they now range between 30-40% of the total cost.

In order to qualify for the Eskom rebate a system has to be certified by the SABS. The three primary South African Bureau of Standards Specifications related to SWHs in South Africa are SANS 1307, 6211 and 151 (Janjic 2008; DME 2002):

- SANS 1307 "Standard Specification Domestic Solar Water Heaters," sets out the various tests requirements and compliance criteria for domestic SWHs. SABS Methods 1210 and 1211 specifies which mechanical strength tests and thermal performance tests should be conducted for SANS 1307 accreditation.
- SANS 6211 specifically tests thermal performance to measure thermal performance in terms of a q-factor efficiency tests and heat loss characteristics of the system
- SANS 151 "Fixed electric storage water heaters" is used to measure the electrical back up requirements and components in SWHs.

[76] For a more comprehensive overview of the specific rollouts mentioned here please refer to the document entitled *Existing Solar Water Heating Programmes in South Africa* on the attached CD

[77] This thesis contributes to filling that gap

A list of systems that conform to these standards and that have received SABS certification can be found on the Eskom DSM (2010b) website[78].

2.9.2 LWANDLE SWH PROGRAMME

In 1995 the Lwandle hostels to homes project became the first large-scale SWH rollout project in a low income community in South Africa. The revitalisation project aimed to satisfy primary needs that were identified by the community itself: jobs, privacy, toilets and hot water (SEA 2009, p.30; SouthSouthNorth Africa 2008, p.2). A housing subsidy covered roughly 30% of the cost of installing more than 300[79] SWHs on the hostels with the remaining funding provided by the local municipality[80] as a loan that was reclaimed through incremental increases in the rental contribution for the hostels (The additional amount on the monthly rent was originally set at R17.50 and had risen to R23 per dwelling by 2003 (SEA 2009, p.30)). Despite a complete lack of maintenance, only about 5% of the originally installed systems had been damaged or removed by 2008 (SouthSouthNorth Africa 2008, p.3). Though the community was initially extremely satisfied with the project a survey conducted in 2003 found that there were some complaints that the heaters did not heat water sufficiently during the winter in the Cape (SEA 2009, p.30). This complaint could possibly have been avoided if the perception had not been created amongst residents that they would have systems with electrical back up installed.

Figure 32 shows the different types of hostels that are found at Lwandle with the installed SWH systems.

Figure 32 Lwandle Hostels (Prasad 2007, p.6; SEA 2009, p.30)

[78] <http://www.eskomdsm.co.za/?q=Industry_Supplier_Information>.

[79] For reasons which are unclear SouthSouthNorth Africa (2008, p.2) put the total at 341 units while SEA (2009, p.30)puts it at 305

[80] Which was the Helderberg municipality at that time

2.9.3 THE NELSON MANDELA CITY PROGRAMME

Figure 33 Zanemvula SWH project in NMBM (NMBM 2010, p.2)

As part of a "Go Green" policy the Nelson Mandela Bay Municipality (NMBM) has committed itself to support the rollout of 60 000 SWHs for middle to high income home owners by June 2012 and it is investigating the possibility of rolling out 100 000 low pressure systems in low-income communities. As part of the process the municipality is installing 1 000 low pressure, low cost systems at no cost for low income households in Zanemvula Township. At the time of writing the installation of the SWHs is set to be financed through low interest loans to home owners who will repay their loans through the municipal billing system (NMBM 2008; NMBM 2010; Afrane-Okese 2009).

2.9.4 CEF 500 SWH PROGRAMME

The Central Energy Fund (CEF), which is a Department of Minerals and Energy supported corporation mandated to manage the future energy needs of South Africa, subsidised the installation of 500 SWHs across the country with funding from the Global Environment Facility (GEF) and the United Nations Development Programme (UNDP) as part of a project entitled *Solar Water Heaters (SWHs) for Urban Housing in South Africa*. The project had a strong public relations component and managed to generate new interest in solar water heating through advertisements in newspapers (Prasad 2007, p.6; REEEP 2008).

2.9.5 COSMO CITY

Figure 34 Cosmo City SWH Project (McNamara & Vice 2009)

As part of the development process for an integrated urban environmental management plan for low-income urban housing development the city of Johannesburg launched a pilot project in Cosmo City Township to promote poverty-oriented climate change 'proofing.' The goal was the upliftment of communities while at the same time mitigating climate change. Energy and water poverty were to be reduced by lowering electricity and water costs. To achieve this aim 350 houses were "climate proofed" through the installation of ceiling insulation, rainwater harvesting tanks and gutters, CFL lighting and solar water heating systems during 2008/2009. These homes previously had no electric geysers and used two-plate stoves and electric kettles to heat water. A 150*l* solar water heater without electrical backup was installed on every house leading to an estimated annual carbon offset of 1.4 tonnes per annum per home (McNamara & Vice 2009).

2.9.1 WESTERN CAPE SOLAR WATER HEATING ROLLOUT PROGRAMME

Figure 35 KwaNokuthula SWH project

In 2008 The Western Cape Provincial Government launched a project to support the rollout of 1 000 SWHs in low-income communities in the Western Cape. The rollout forms part of strategies developed to reduce energy poverty in RDP housing developments, source 15% of all electricity consumption from renewable energy sources by 2014 and to reduce carbon emissions by 10% from 2000 levels (Roelofse 2009). The solar water heating project commenced with the installation of 184 SWH units in the KwaNokuthula RDP housing development near Riversdale. This initial rollout is now (during 2009) being extended with 360 additional units in the Cape metro area, in Elsiesriver, Nyanga and Atlantis, as well as 466 units in Mossel Bay, Oudtshoorn and Prince Albert (Roelofse 2009; DEADP 2008). The project created 60 jobs for local unemployed people in KwaNokuthula during the SWH rollout and a training academy was established in the province to train around 250 unemployed people over a 6 month period to assist with the further roll out of SWH's in the province.

Each installed unit comprised an 80L tank and a 1.5m² flat plate collector panel. The systems were installed without any electric backup, but owners have the option of adding an electric backup element at an additional cost of roughly R200. The total installed cost of the systems was R7 000 each (R. Meyer & Gariseb 2009, p.50).

2.9.1 CITY OF CAPE TOWN KUYASA PROJECT

Figure 36 Kuyasa SWH project

The Kuyasa CDM project installs low-pressure evacuated tube solar water heaters, compact fluorescent light bulbs and ceiling insulation in government subsidised homes in Kuyasa village in Khayelitsha near Cape Town. The original target for the project was to fit 2300 houses with a potential expansion if additional funding can be secured (SEA 2009, p.31).

The project was developed and implemented in a way that allowed it to qualify for Certified Emission Reduction certificates (CERs) as a Gold Standard[81], small-scale CDM project registered under the Kyoto Protocol's article 12 Clean Development Mechanism (CDM) project in August 2005 (SouthSouthNorth Africa 2005, p.3; SEA 2009, p.31).

The total cost of the project was originally estimated at R13.4 million, roughly R6 000 per house. R12.5 million is required for initial capital expenditure and R0.9 million over 10 years[82] for maintenance (Earthlife Africa 2009, p.42; SouthSouthNorth Africa 2005). These costs are covered through (SouthSouthNorth Africa 2005, p.4):

i. A research grant of R4 million from the provincial housing department,
ii. A Poverty Alleviation Grant of R3 million from DEAT
iii. A community repayment scheme providing R2million over 3 years[83] and
iv. The sale of Certified Emission Reductions (CERs), under the CDM to the total of roughly R3.2 million over 21 years[84].

In total 2.85 CO_2 tonnes/hh/year will be avoided as a result of the project. 1.288 CO_2 tonnes/hh/year due to the installation of the SWHs (SouthSouthNorth Africa 2005, p.4).

The project saves households an estimated R625/annum due to decreased electricity and paraffin usage. They will also enjoy reduced health costs and less lost days of work due to

[81] which means that the project has a high social upliftment value

[82] Calculated as a NPV with a 20% discount rate.

[83] Based on a contribution of R30/household/month calculated as a NPV at a 20% discount rate over 3 years.

[84] Based on a carbon price of €8 and calculated as a NPV at a 15% discount rate

improved thermal conditions, especially in winter months (SouthSouthNorth Africa 2005, p.4; SEA 2009, p.31; Winkler 2006, p.85).

In terms of wider poverty alleviation in the community the project offers tangible benefits through the use of local labour to install the SWHs, bulbs and ceilings and the provision of training to complete these activities (SEA 2009, p.31).

2.10 CONCLUSION

From the literature reviewed it is clear that SWHs are a potential synergic satisfier for the relief of poverty in South Africa and that they can play a significant role in achieving sustainable development in the Stellenbosch municipal area. They offer an energy service to low-income communities that will reduce their dependence on ever more expensive grid electricity whilst potentially also creating local job-opportunities that can lead to sustainable economic and social development in disadvantaged communities. By offering gainful employment the SWH industry can be used as a strategic lever to relieve various forms of poverty by fulfilling fundamental human needs. Within the global context of concern around climate change rolling out SWHs in low-income communities would contribute to the reduction of greenhouse gas emissions and lower the per-capita emissions of South Africa which currently has a very carbon intensive economy. In short SWHs offer a systemic solution to many of the challenges confronting South African towns and cities.

Unfortunately the achievement of a mass rollout of SWHs in low-income communities faces two significant obstacles; that of reducing cost to a level where they would become affordable in a low-income development context and that of awareness raising. The former challenge can only be addressed if information is available on the cost drivers within the SWH value chain. The SWH literature review has shown that manufacturing is the largest cost driver but not what the specific drivers in that sector are. Information that is available about the job creation potential of the SWH industry is based on American data and South African specific data could be useful in understanding and managing the jobs created through the SWH value chain. A value chain analysis method can be used to determine the specific cost drivers as well as the total job creation potential in order to identify where policy targets can play the largest role in reducing costs and creating jobs. Furthermore, beside the Kuyasa study little Western Cape specific research on hot water usage in low-income groups could be found. In order to develop a suggested model for the rollout of SWHs in Stellenbosch and/or the Western Cape more data is required on what the potential benefits of SWH are in low-income communities.

In China the SWH industry has already developed into a massive industrial sector that provides energy services to millions of homes. If the South African Government and SWH industry acts now it can fulfil the same service in South Africa. If it does not, a strategic opportunity to provide job-creation through the mass rollout of green technology would have been wasted. It is hoped that the research findings below will contribute to the realisation of this opportunity and thereby to poverty relief and more sustainable development in Stellenbosch, the Western Cape Province and wider South Africa.

3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

This thesis is completed hoping that it will ultimately contribute to the improvement of human lives. The overarching intent is thus *transformational*. It is however acknowledged that this work can only contribute in part to development strategies and therefore the methodology adopted is designed to *measure* and *understand* the SWH industry, the barriers that prevent widespread uptake of the technology and the potential benefits that the technology offers in order to enable future research and policies to eventually *change* lives for the better.

The research Methodology Chapter describes the research methodology, research design and research processes that were used to complete this thesis. Based on the systems theory perspective of sustainable development discussed in the literature review chapter, the research objective is achieved through a combination of quantitative and qualitative research strategies. This dual approach was selected to ensure that the research findings are based on quantitatively verifiable data that would be useful in modelling the future development and possible benefits of a large-scale low-cost SWH rollout programme. The qualitative research element allows the study to understand the less quantifiable psychological benefits of installing SWH systems in low-income households (as identified in *Table 2*) as well as what the barriers to cost reduction in the industry value chain are in the minds of business leaders.

Understanding the perceptions around low-cost SWH, from both the supply and demand side are vital to ensure that any suggested rollout initiatives do in fact fulfil fundamental human needs of the final recipients whilst enjoying the support of the supply industry. By following this dual approach the effect of research bias in assembling the quantitative data is balanced through qualitative interaction with the research subjects. This allows the researcher to re-evaluate his/her own preconceived perceptions that are brought into the research process. The approach thus mitigates the dangers of a one-dimensional singular approach as identified by Clayton and Radcliffe (1996, p.12).

The quantitative research consisted of:

- A survey conducted amongst low-income households in Stellenbosch to determine their current hot water usage and
- Data assembled during interviews with businesses in the SWH industry as part of the value chain analysis. This data was collected to identify the barriers to cost reduction and the job creation potential in the SWH industry

The qualitative research consisted of two case studies where SWHs were installed in low-income households as well as qualitative questions posed during the interviews with SWH suppliers. The specific approach followed, the motivation for the choices made and a critical evaluation of their advantages and limitations are discussed below. The literature on the value chain analysis method is also discussed as it informed the research approach and no similar analysis of SWH in South Africa or anywhere else could be located.

3.2 RESEARCH METHODOLOGY APPROACH

The methodological approach adopted by this thesis is discussed in terms of the Three Worlds Framework as developed by Mouton (2008). According to this approach three frames or "worlds" of knowledge can be used to conceptualise and discuss a research problem;

- World 1: The world of everyday life and lay knowledge. This frame contains the knowledge, experience and common-sense that we use to deal with problems in our everyday life.
- World 2: The world of science and scientific research. In this "world" scientists select phenomena from World 1 and make them into objects of inquiry. The aim of such enquiry is epistemic knowledge production which strives to generate truthful and reliable descriptions of phenomena. Though scientific enquiry accepts that no study can claim to find final and objective "truths", the motivation of scientific research remains the search for such ever-elusive "truth."
- World 3: The world of meta-science. In this frame the scientific findings from World 2 are evaluated in terms of meta-disciplines that reflect on the ethical and philosophical implications of the research conducted in World 2. Three possible meta-disciplines identified by Mouton (2008, pp.138-139) are realism (Positivism), interpretivism (phenomological) and critical theory. These are respectively linked to the quantitative, qualitative and participatory methodological approaches that are used for scientific inquiry in world 2.

The research problem of this thesis can be described according to the three worlds framework as follows.

The real world problem identified in World 1 consists of the poverty facing many households in the Stellenbosch Municipal area as well as the national energy shortage crisis that hampers the expansion of housing development in the area. Though the problems are seemingly unrelated the hypothesis of this research thesis is that SWH offers a potential integrated solution that could help address both challenges but that the high costs of the technology remains a barrier that prevents the full benefits of the technology from being realised. The development challenges facing Stellenbosch Municipality are thus viewed as a systems problem and are addressed from a systems perspective as discussed earlier under the literature review section.

These "real world" phenomena are brought into World 2 where they are made into objects of scientific inquiry. The aim of the inquiry is to determine what role SWHs can play in the reduction of poverty, both through local job creation as well as through providing bulk water heating to households that currently only have limited access to hot water. First the developmental potential of the technology is analysed quantitatively and qualitatively. Thereafter the SWH industry is evaluated according to a Value chain Analysis (VCA) method to identify the reasons for the prohibiting high costs of SWH systems. This is done in order to identify the disparity between the demand and supply for hot water services and to formulate provisional suggestions on how it can be overcome.

The quantitative and qualitative methodological approaches adopted in the World 2 framework place this thesis in the World 3 meta-sciences of positivism and phenomenology. The literature discussed earlier in the thesis, justifying the need for sustainable energy interventions and conceptualising the systems approach to sustainable development adopted for the research form the basis for critically evaluating the scientific research findings in terms of a coherent meta-science approach that justifies both the motivation for the research as well as the recommendations made.

Though the descriptions above create the perception that research paradigms are a clearly defined field there are numerous different perspectives and many debates in each approach.

Each methodological approach and/or its meta-science basis contains diverging perspectives and much literature is dedicated to the critical exploration of research methodology. Detailed discussion of the complexity of each approach would fall beyond the scope of this thesis and only summary explanations are provided of the conceptual foundations that are particularly relevant for the approach adopted for this research. It is important to include such a discussion as the ontological assumptions about the relationship between object and subject within each approach influences how being or reality is perceived and thus every observation made. The epistemological assumptions in turn influence how knowledge is generated to provide evidence for the research objective, thus influencing what is investigated and what is considered as important inputs in the research process.

According to Babbie and Mouton (2008, p.49) a quantitative methodological approach emphasises the quantification of constructs. A quantitative researcher believes that *"...the best, or only, way of measuring the properties of phenomena is through...assigning numbers to the perceived quantities of things.*" The positivist meta-science foundation of the quantitative approach is apparent through the use of surveys and statistical analyses in an attempt to study social phenomena in a similar way that natural phenomenon are studied. The approach strives to be value-neutral through the disciplining of subjectivity and prejudice by applying systematic statistical analysis techniques to gather data on social phenomena. Empirical evidence is used to statistically validate the knowledge generated to answer the research question (Holliday 2002, p.6). In this research thesis the quantitative approach is used to determine the measurable benefits of providing SWHs to low-income households, i.e. to answer research question 1.2. This data can then be used to calculate the energy savings that the local municipality can achieve through the mass rollout of SWHs.

The quantitative approach is also used to assemble and assess data on the cost drivers and employment creation potential in the SWH manufacturing value chain to answer research questions 1.4 and 2.1. An exclusive focus on quantifiable data is however considered to be inadequate to assess all the positive benefits of installing SWHs on low-income homes or to determine the relational barriers to innovation or expansion that might hamper the reduction of costs in the SWH value chain. It is for this reason that a qualitative approach has also been used in the research.

Being very aware of the potential distorting effects of personal bias in researching the potential benefits of Solar Water Heaters due to the wide disparity in social background between the background of the researcher and that of the low-income households that were studied a qualitative approach was included as part of the research. Qualitative research "attempts always to study human action from the insiders perspective" (Babbie and Mouton 2008, p.53) and though acknowledging that gaining a true "insiders" perspective for this study would be impossible in the timeframe of a year the qualitative approach allowed the researcher to develop a greater understanding for the issues confronting low-income communities in the Western Cape. The qualitative approach is ideal for this goal as it defines the goal of research as "*describing and understanding rather than the explanation and prediction of human behaviour"* (Babbie & Mouton 2008, p.53). The focus is on exploring the context and relationships to develop hypotheses as well as to allow for the emergence of new questions (Holliday 2002, p.6) that cannot be anticipated in a purely quantitative study.

A third possible approach would be the participatory action research (PAR) methodological approach which "...involves a much closer relationship than that which is usual between the researcher and the researched." Such an approach is necessary if the persons who are the earmarked beneficiaries of the research are to be part of the entire research process (Babbie &

Mouton 2008, p.58). PAR is valuable if the research is designed not only to increase the store of knowledge available but also to affect real change while it is being conducted. Though some elements of the research design for this thesis resemble a participatory action research approach, especially during the interaction with low-income households, the level of participation was not as consistently prominent as Participatory Action Research (PAR) advocates that it should be. The intention was never to follow such an approach as the aim of the research was not to affect direct change but rather to add to the store of knowledge which would eventually facilitate change. Therefore it was decided that the data and input required to answer the research question could best be gathered using qualitative and quantitative methods.

The combination of a quantitative and qualitative methodological approach is in line with the systems theory approach to sustainable development that forms part of the epistemological framework for this thesis. It would be inefficient and extremely difficult to address the challenges facing Stellenbosch and other similar towns singularly, but if they are viewed as an interrelated system of challenges, solutions may be found that offer improvements on a whole range of levels to several seemingly disparate problems. A quantitative research approach would reveal challenges and opportunities for solutions on a macro scale whilst the qualitative approach provides an opportunity to understand challenges from the perspective of the residents whose lives will be affected or from the perspective of businesses offering the technologies that are proposed as solutions. The combination of the approaches allows the research to make generalised statements in World 2 while remaining firmly grounded in the real experiences of people living in World 1.

The quantitative approach was employed during the distribution of surveys to determine the electricity used for water heating in existing low-income households in Stellenbosch, for the assembly of data on the employment creation potential of the SWH industry in the Western Cape as well as to investigate the barriers to cost-reduction across the value chain. For the industry value chain analysis, face-to-face interviews were conducted whilst a survey was used to determine aggregate figures for electricity used for water heating in low-income households. This data was analysed to identify the potential benefits that SWHs would offer as well as areas in the industry where institutional support is most necessary and where Stellenbosch Municipality could offer incentives that would attract SWH producers.

The qualitative approach was primarily adopted during a case study during which SWH systems were installed on two low-income homes in Stellenbosch, but also during interviews with businesses in the SWH value chain to ascertain what the primary concerns of industry players are. The case study of low-income households in Stellenbosch, where two particular households were the units of analysis, were insightful in that they offered an opportunity to observe first-hand the impact that SWHs have on the lives of people in real-world settings. These insights in turn served to inform the argument for the mass rollout of SWHs. The qualitative questions that were asked of SWH industry players enabled the research to identify perceived barriers to cost reductions held in the industry as well as relational barriers between different parties in the value chain. The perceived barriers are as important as quantitatively identified barriers as they play a large role in the investment decisions in the SWH value chain. The qualitative approach ensured that the research remain grounded in the context and reality of the SWH industry and the low-income communities targeted for mass rollout programs either in Stellenbosch or the wider Western Cape.

3.3 RESEARCH DESIGN

According to Babbie and Mouton (2008, p.74) research design is the blueprint according to which research is conducted. The research methodology approach selected ultimately has to fulfil objectives and goals of the research design blueprint. Babbie and Mouton offer three levels according to which research design can be classified:

- Empirical or non-empirical,
- Based on primary or secondary data,
- If based on secondary data, text data or numeric data.

This thesis is principally an empirical study based on primary data. The sources of primary data are surveys, interviews and data on electricity usage supplied sourced from the municipality of Stellenbosch. The purpose of the research is primarily descriptive and exploratory in nature. The empirical research question asked is descriptive in that it asks what the hot water usage levels are in low-income households and exploratory in that it investigates the job creation potential and barriers to cost reduction in the SWH industry. Elements of the questions asked could also be considered to be predictive in that the potential impacts of a mass SWH rollout program are investigated, both on a macro and micro level.

Babbie and Mouton (2008, p.80) identify the following reasons for conducting exploratory research;

1) To satisfy a researcher's curiosity and desire for better understanding
2) To test the feasibility of undertaking a more extensive study
3) To develop methods to be employed in any subsequent study
4) To explicate the central concepts and constructs of a study
5) To determine priorities for future research
6) To develop new hypotheses about an existing phenomenon.

In this case reasons one, two and five are applicable. By providing a better understanding of both the supply side and demand side of the SWH value chain this thesis could contribute to future, more extensive studies and ensure that they prioritise strategic leverage points to achieve maximum job creation and poverty reduction with minimal input. Stelltiz et al. [cited in Babbie and Mouton (2008, p.80)] emphasize three methods by which exploratory research can be conducted:

1. Through the review of the related social science and other pertinent literature. This method was used in the literature review section of this thesis as the available literature on renewable energies and specifically solar water heating was reviewed.
2. Through a survey of people who have had practical experience of the problem to be studied. In this case the businesses involved in the SWH value chain and low-income households.
3. An analysis of insight stimulating examples. The case study in this thesis was conducted to facilitate such an analysis.

Exploratory research typically involves the use of in-depth interviews, case studies, literature reviews and informants and usually leads to "insight and comprehension rather than the collection of detailed, accurate and replicable data." Though exploratory studies often fail to provide a definitive answer to their research question, they are essential as they break new ground and yield new insights into a topic for research (Babbie & Mouton 2008, pp.79-80). In the case of this thesis an exploratory research question was really the only available option as a survey of the available literature yielded no results for similar projects and new ground had to be broken. The recommendation of Babbie and Mouton (2008, p.80) that an open and flexible research strategy should be followed was adhered to throughout and the guidance of experts working in the field was employed whenever and wherever possible.

In trying to develop an understanding for the water heating requirements of low-income households there was also a descriptive element to the research question. Babbie and Mouton (2008, p.81) find that qualitative research approaches are often used to answer descriptive questions. This holds true for this thesis with the qualitative case studies and many of the survey questions providing data to be used in analysing the demand for hot water amongst low-income households.

To answer the exploratory parts of the research question the unit of analysis is the solar water heating value chain as a whole. The eventual aim is to create two models of the industry illustrating the job creation potential for different activities in the value chain as well as the largest barriers to cost reduction across the value chain. In order to arrive at these figures, the units of analysis are the individual companies that constitute the value chain. To assuage the fears of companies about the potential leak of sensitive information only percentage values of contributions to cost were collected to create the model for cost barriers in the value chain. The job creation potential is modelled in terms of the number of jobs created per 1000 systems installed.

The descriptive elements of the research question are answered in terms of kilo Watt hours (kWh) of electricity used to heat water and Rand savings on monthly electricity bills. The unit of analysis is the household.

All variables analysed are cross-sectional for 2009. In the value chain analysis of cost barriers in the SWH industry part of the reason for using a percentage breakdown is that the ratio of costs are the important factors, rather than the specific Rand values. Specific Rand values are difficult to obtain and the relative levels are important in understanding what the primary drivers of costs are.

The case study of SWH for low-income households in Stellenbosch based on the installation of SWHs on two is primarily-cross sectional as the principal comparison is between hot water and electricity usage before and after the installation of the SWHs. Changes are quantified as a comparison between the cross sectional studies before and after the installation rather than as a longitudinal study conducted over a long period of time. A true longitudinal study would consider the evolution of patterns over time (Huber & Van de Ven 1995), as opposed to the comparison of two different sates evaluated in this thesis.

The case study was included specifically to align with the systems approach taken for this thesis as they ensure that the research question and proposed solutions remain firmly based in a real world context. This is achieved because the case study approach allows for the evaluation of the "system"-wide effects of SWH in low-income communities by investigating the effects of the technology on households in their normal environment. The research methodology behind case study research is discussed extensively in Babbie and Mouton (2008, pp.280-283), Flyvberg (2001), Holliday (2002, p.18), and Mouton (2008, pp.149-150). According to Yin (2003, p.13) a case study is an *"empirical inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between the phenomenon and the context are not clearly evident"* usually arising from *"the desire to understand complex social phenomenon.... [which] allows investigators to retain* *the holistic and meaningful characteristics of real life events*" (Yin 2003, p.2). The case study approach has a distinct advantage when a set of variables are investigated over which the researcher has little or no control (Yin 2003, p.9). In this case the complex real world context of a household in a low-income community has many variables over which a researcher would have no control and a case-study approach was selected to facilitate the development of an understanding of the complex social phenomenon of the impact that the installation of a SWH might make in the lives of a low-income household in Stellenbosch. Flyvberg (2001) argues that case studies offer the power of real world examples through the delivery of contextual practical and intimate knowledge of the unit of analysis.

There is however some criticism of the case-study approach (Babbie & Mouton 2008, p.280; Flyvberg 2001, p.66; Mouton 2008, p.150; Yin 2003, pp.10-11) The most frequent of which is that case studies cannot be used to generate general theories and that they are thus irrelevant for the generation of scientific data. There are also concerns about the perceived lack of rigour in case study research as well as the potential for research bias due to the close relationship between the researcher and the unit of analysis in a case study. Sometimes case-studies are accepted as part of initial exploratory phases of research, but not when the research becomes more "serious." Much of this criticism is based on the assumption that general theories are more valuable than localised, specific knowledge (Smit 2009, p.68).

Flyvberg (2001, pp.71-81) refutes these challenges to the validity of case studies by highlighting that case studies do in fact have "generalising" value. According to him case studies have two factors counting in their favour as empirical sources of data.

- Firstly, they can contribute to general theory by subjecting a research hypothesis to Poppers' notion of falsification, possibly refuting the hypothesis.
- And secondly that generalisation is not the only credible form of knowledge production. Instead he argues that one can generalise on the basis of a single case study and that such a study could be central to the development of a scientific theory or hypothesis through generalisation as an alternative to other methods.

Flyvberg (2001, p.77) contends that "...the power of the good example is underestimated" and his defence of the validity of the case study research methodology inform the decision to use the approach for this thesis.

The discussions above reflect the research design and methodology approaches that were used in answering the research questions of this thesis. A combined qualitative and quantitative approach was used in conducting the value chain analysis to investigate the job creation potential as well as cost barriers in the South African solar water heating industry whilst a quantitative survey and two case studies combining quantitative and qualitative methodological approaches were used to determine the contribution that SWHs can make to poverty alleviation in the Western Cape in South Africa.

3.4 RESEARCH METHODS

The following paragraphs will describe how the research process took place as well as provide a justification for the research decisions that were made. This will include an identification of the data sources used and how they were selected. The literature reviewed to inform the value chain analysis, the interviews conducted as part of that analysis and the relationships built with the case study households influenced the research process to a large extent and the process was an emergent process which led to the emergence of several unexpected quantitative and qualitative questions. The details of the parts of the process are discussed below.

3.4.1 THE LITERATURE REVIEW

Completing a literature review for the research thesis was a challenging prospect. A search of journal databases on Ebscohost and Academic Search Premier, the University of Stellenbosch library catalogue and the World Wide Web for similar research on the solar water heating value chain, either in South Africa or abroad, yielded no results. It was thus decided that the research questions would be viewed primarily as exploratory questions that could feed into future, related research. The literature reviewed is used to construct an argument for the importance of changing development paradigms to explicitly focus on long-term sustainable development and renewable energy technologies. Once this had been completed an overview of the literature relevant to solar water heating and the South African context was completed. Primary sources consulted in this regard where Holm (2005), Van Gass and Govender (2009), Prasad and Visagie (2005) and Winkler (2006). The bibliographies provided in these documents as well as extended internet and journal database searches were used to track down other relevant sources. Interviews[85] with a range of persons involved in the renewable energy and/or solar water heating sector served to help me locate documents that were not readily available on search databases. The final compilation of literature reviewed is used to provide an overview of the state of the SWH market in South Africa and the contribution that SWH can make to the quality of life in low-income households.

The data sourced from these various sources is both quantitative and qualitative in nature and is used to justify the case for the mass rollout of SWHs and to build the argument that the barriers to cost reduction need to be overcome so that the maximum job creation potential can be realised through increasing the amount of systems being installed and manufactured.

As no previous literature on the SWH industry value chain could be located a fairly comprehensive overview of the literature on general value chain analysis (VCA) was conducted. The work of Kaplinsky and Morris (2003) was particularly helpful in this regard. A detailed discussion of the VCA literature falls beyond the scope of this thesis but the interested reader is asked to refer to the document entitled *Value chain Analysis* on the attached CD. Section 3.4.5.1 below provides a short discussion of the method as described in the literature.

3.4.2 THE CASE STUDY OF SWH IN LOW-INCOME HOUSEHOLDS IN STELLENBOSCH[86]

The original intention had been to have several different SWH systems tested by the Centre for Renewable and Sustainable Energy Studies (CRSES) at their testing facility on the roof of

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[85] Particularly useful interviews were those with Izak van Gass, a researcher working for Eskom, Helmut Hertzog of Atlantic Solar, Carl Wesselink, project manager of the City of Cape Town Kuyasa project, Professor Ben Sebitosi of the Department of Mechanical Engineering at Stellenbosch University and Riaan Meyer and Duncan Scott of the Centre for Renewable and Sustainable Energy Studies

[86] For a justification of why Stellenbosch Municipality was chosen as a focus area please refer to the document entitled Selecting Stellenbosch Municipality as a Focus Area on the attached CD

the Engineering Faculty. The idea was to do a technical analysis of which low-cost systems would provide the most reliable source of hot water in Stellenbosch's climatic conditions. Such a study would be valuable as there is some debate in the available literature about the different performance of flat-plate collectors vs. evacuated tube collectors. Unfortunately, after discussions with the CRSES and the funding partners for the research (Unilever and the Royal Society of Chemistry) it was decided that such a comparative technical test would be too expensive and not entirely relevant to the research question posed in this thesis. It was instead decided that the research could offer more valuable insights into the performance of SWH systems if they could be tested in real-life settings where the experience of residents with the technology could be monitored. The reduced financial costs of this approach also made it feasible within the budget of the study.

Tasol Solar donated a 100*l*, low-pressure, direct, evacuated tube SWH system. A 80*l* 200kPa direct flat-plate collector system was bought from Atlantic Solar and the Royal Society of Chemistry provided a third system, manufactured by Celsius Solar in Scotland, which was installed with the help of the inventor David Osborne. Tasol are the only providers of SABS certified low-pressure evacuated tube collectors in South Africa and have been involved in the Nelson Mandela Bay SWH rollout. Atlantic Solar was selected as a key partner for the research as they supplied and installed the SWHs for the Western Cape Solar Water Heating project in KwaNokuthula. The Celsius Solar system is an alternative new extremely low-cost design made of moulded plastic and an aluminium collector plate.

After securing the SWH systems the next step was to identify three suitable houses for the installation of the systems. Community leaders in both Kayamandi and Cloetesville were contacted to assist with the selection of households. They were Songo Fipaza, who had orchestrated the development of several youth development programmes in Kayamandi and Joanne Manuel, the local leader of the FEDUP NGO and a church outreach programme in Cloetesville. With the help of these individuals three households were identified for the study. Each, at the time of initiating the research, had five permanent residents, consisting of two adults and three children/young adults. The houses had to have North-facing roofs and the residents had to be willing to cooperate in a research project over a few months.

Both the flat plate and evacuated tube systems achieved excellent water heating results as shown in Figure 41 but the Celsius Solar system was deemed to be unsuitable for further study due to very low levels of efficiency. There were also some problems with the evacuated

Figure 39 Celsius Solar Alternative Low-Cost Installation

Figure 37 Atlantic Solar Flat-Plate Installation

Figure 38 Tasol Evacuated Tube Installation

tube collector system due to leakage from the feeder tank. A team came out from Tasol on three separate occasions to fix the problem. After the final call-back an extra tap was installed that would enable the residents to stop the inlet of water if the overflow became too great. This seems to be a satisfactory solution and the family have mentioned no further problems with the system. Tasol (Van Zyl 2010) believes that the leakages occurred due to slight damage to the feeder tank, possibly caused by rocks thrown at the system. After the modifications, which could be done very cheaply, the system did not experience any further problems. If the system was, damaged by vandalism, it illustrates the necessity that larger SWH rollout programmes should not be completed without encouraging community participation in the planning process. Because this installation consisted of a single isolated system it created the potential for envy and jealousy that could lead to vandalism. In the Kuyasa CDM project no incidents of vandalism have been reported as the rollout programme only commenced after much time was taken to include the local community in the planning process (Wesselink 2009).

The Celsius Solar system was tested as an example of alternative very low-cost technologies. Further testing of the systems was suspended after it failed to heat water during personal tests or during a trial installation on a low-income home in Cloetesville[87].The example served to

[87] Nothing could be found in the specific installation that would explain the poor performance as the system was installed North facing on a roof out of the shade. The installed system had been monitored for a few weeks during autumn and despite ideal climatic conditions with daytime temperatures reaching higher than 30°C the system produced water that was only lukewarm to the touch BB Commercial, a manufacturing plant in Johannesburg, were also interested in the

(footnote continued)

illustrate the dangers of installing sub-standard systems in low-income community rollouts. Poor technology will only be a waste of valuable resources and harm the perception of renewable energy technologies. The SWH industry in South Africa is well established and years of experience have shown that the existing commercially available systems are the most cost efficient configurations (Hertzog 2008, Bester 2010). Before alternative technologies are recommended for mass rollout they need to be thoroughly tested, not only in laboratory tests but also in case study projects such as was conducted as part of this thesis. It is likely that the Celsius Solar system failed due to a lack of sufficient insulation around the water storage tank and a collector area that is too small given the large amount of water in the tank that has to be heated. The area under the collector is even more poorly insulated and, despite having a Perspex cover, the collector plate remains in contact with air from the surrounding environment. These poor insulation properties mean that most of the heat collected is lost again to the atmosphere rather than transferred and retained in the water stored in the tank.

The initial objective had been to monitor the systems during the winter but due to delays in sourcing the systems monitoring could only start in spring. In retrospect this enforced delay was an advantage in that it allowed the systems' hot water output to be monitored during the variable weather of early spring rather than only during the cold, cloudy winter period. In order to assemble some quantifiable data on the performance of the installed SWH systems two Toptronic T500K Thermometers[88] with liquid temperature probes were purchased and used to measure the water temperatures delivered by the SWH systems at different times of the day between 17 September and 17 November. Before purchasing the thermometers their specifications were checked with the staff of the CRSES to verify that they were of sufficient quality to monitor the temperatures. The objective was not to develop an accurate, detailed model of the temperatures achieved by the SWH systems but rather to have quantifiable indication of the achieved water temperatures that is more descriptive than how the water felt to the touch. Data on solar radiation levels during the monitoring period were obtained from the Stellenbosch University's Department of Mechanical Engineering via the internet (Stellenbosch University 2009) and through direct consultation by e-mail with JP Meiers (2009) who works at the weather station.

Unfortunately the thermometers require that temperature measurements be taken manually. After visiting each case study household three times in one week to take temperature measurements it became clear that the research was becoming intrusive and that such frequent visits could influence water usage patterns and might affect the trustworthiness of information provided by the households. It was thus decided to train one person in each household in the use of the thermometers and to ask them to take regular temperature measurements at certain times of the day. This approach was feasible as the thermometers are extremely simple to operate. It was also explained that the water temperature had to be measured after it had been running for longer than 30 seconds in order to ensure that water from the storage tank and not from connecting pipes should be measured. The temperature measurements were recorded on a calendar and checked on a twice weekly basis by the author.

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technology and they conducted their own temperature tests in Johannesburg which failed to achieving significant water heating results (Beukes 2009).

[88] Rated to be accurate to within 0.3%rdg +/- 1ºC

Unfortunately, residents were not always able to measure the water temperatures three times per day as instructed and often only one reading per day was taken. This meant that during the research period the readings were often taken at different times of the day in the different households making them useless for comparative purposes. This led to a flaw in the research process due to the low numbers of comparable data assembled. A study with better equipment where a thermometer was installed on the outside of the house to measure the temperature within the hot water storage tank would have been a better approach but few other options were available under the budget constraints of the project. Though flawed, the data does provide a few valuable indications as discussed under 4.1.1.1.

The provision of hot water services combined with frequent visits enabled the researcher to build a strong collaborative relationship with the households and this allowed for the completion of in-depth qualitative research into the benefits that SWHs provide to low-income households. The primary output of the case-study is thus qualitative data on the poverty-alleviating potential of SWH technology with some quantifiable data used to provide an indication of the water temperatures achieved by the SWH systems. As with any case study research it is dangerous to inductively make assumptions about wider populations based on just one or two instances. The value of this study lies therein that it can be used to inform future wider research and that it allowed the researcher to develop a deeper understanding of the impacts of an the installation of a SWH in a low-income household. Such insights are particularly valuable in understanding the synergic benefits of SWH as many of the more indirect benefits such as improved senses of "freedom" or "pride" can only be observed through close interaction. In order to balance this case study with quantitative findings, a wider demand-side survey was conducted to determine what existing hot water usage patterns are in low-income communities in Stellenbosch.

3.4.3 THE DEMAND-SIDE SURVEY CONDUCTED

The ultimate objective of the survey was to establish how much hot water low-income households in Stellenbosch currently consume and which devices they use to heat water. This data could then be used to infer the amount of electricity that could be saved through a mass rollout of SWHs and also what the immediate poverty alleviation impacts would be in terms of savings on domestic energy expenditure. The first sources consulted to create the survey were previous surveys on energy consumption that had been conducted in the City of Cape Town Kuyasa project (Kuyasa CDM Project 2008 & 2009) as well as, as part of a small survey completed by Solek (Nel 2009), an energy consulting company, in Kayamandi. These studies were used to establish a baseline questionnaire which was then taken to Jan Foster[89] a lecturer in social research methods and poverty issues for further evaluation and advice. After incorporating his recommendations the survey was tested in two low-income homes after which it was modified and updated to compile a final version. The final surveys that were used (Afrikaans and English versions) are included in Addendum B: Questionnaire used for Hot Water Usage Survey in Stellenbosch. As an additional safeguard to assuage fears about

[89] Please see http://sun025.sun.ac.za/portal/page/portal/Arts/Departments/sociology/staff/jvorster for an overview of work he has completed

miscommunication two research assistants from the case study households[90] were appointed to assist in the administration of the surveys.

A cluster sample respondent selection method was selected for the surveys (Stattrek 2010). This decision was made because interest in the research had already been sparked in the neighbourhoods where the SWHs had been installed and that served as a good point of departure for conducting the survey. The drawback of this approach was that it had to be made very clear that participation in the survey would not result in the installation of a SWH for the participant households.

A two stage cluster sampling technique (Stattrek 2010) was applied by dividing low-income communities in Stellenbosch into neighbourhoods and then selecting two of these for further research. In the second stage of the sampling process a selection of homes were randomly selected to complete the surveys. It was possible to divide the population into clusters as each household could fall into only one cluster, a requirement for cluster sampling (Stattrek 2010).

Though a cluster sampling approach offers less precision than simple random sampling or stratified sampling, the approach was selected because a larger sample of households could be surveyed if they were selected in a single geographic area. Randomly selecting homes from the greater Stellenbosch municipal area would've resulted in greatly increased travelling time and cost as well as increased complexity in explaining the reason behind the survey. The decision is justified in that the population is concentrated in "natural" geographic clusters (Stattrek 2010). Using cluster sampling many interviews could be conducted over a few days. Simple random sampling, in contrast, would've required the interviewer to spend much time travelling and explaining the justification for the research (Stattrek 2010).

Whenever possible the survey was filled in with the person in the house who is generally responsible for house cleaning, bathing the children and purchasing electricity. Typically these are the older women. The standard measure of hot water usage was a typical electrical kettle (1.7*l* capacity). In some cases pots on electrical stoves are used for water heating. In these cases the questions asked were adapted to suit the containers used and volumes were converted back into the standard unit used in the rest of the survey.

3.4.4 CALCULATING THE ENVIRONMENTAL BENEFITS OF SWH

The results of the demand-side survey were used to calculate the CO_2 emission reductions that are possible through the installation of SWHs. The case study homes showed that SWHs could fulfil all hot water requirements for bathing and cleaning activities but in order not to over exaggerate the effects of the technology it was assumed that SWHs would replace 80% of water heated in electrical kettles for these activities in wider populations. The demand side survey was used to calculate the average amount of electricity used to heat water per annum (excluding cooking and hot beverages). Based on the literature reviewed (Van Gass & Govender 2009; City of Johannesburg 2009; Pegels 2009, p.17) a figure of 1.02 tonnes of CO_{2e} /MWh of electricity saved was used to determine what the averted CO_2 emissions would be from the installation of SWHs. The amount of CO_{2e} emissions averted was thus calculated as:

[90] These people were chosen due to their understanding of the project and the relationships that had already been created through the case study research.

$$Average\ electricity\ used\ per\ household\ per\ annum\ (in\ MWh)$$
$$*\ 1.02\ tonnes\ CO2e\ (emissions\ per\ MWH\ of\ electricity\ generated)$$
$$*\ 0.8\ (percentage\ of\ emissions\ averted\ through\ the\ installation\ of\ SWHs)$$

This calculation gives an estimate of the amount of CO_{2e} emissions that can be averted per SWH installed on a low-income household. This figure can then be used to project emission reductions for wider rollouts as is done in the models for rollouts in Stellenbosch and the Western Cape later in this thesis.

3.4.5 VCA INTERVIEWS WITH COMPANIES IN THE SWH INDUSTRY

3.4.5.1 The Value chain Analysis Approach

According to Shank and Govindarajan (1992, p.180) *"The value chain framework is a method for breaking down the chain of activities that runs from basic raw materials to end-use customers into strategically relevant segments in order to understand the behaviour of costs and the sources of differentiation."*

The primary purpose of a value chain analysis (VCA)[91] as originally conceptualised by Michael Porter was the analysis of a value chain to identify opportunities for strategic improvement (Dekker 2001, p.2; Porter 1985, p.139). In a similar vein another purpose of this thesis is to identify which parts of the value chain structure of the solar water heating industry in the Western Cape in South Africa limit industry development, where these can be improved and how the provision of solar water heaters can become a synergic satisfier for fundamental human needs through job creation.

A VCA presents a structured method for the analysis of the impact of strategically important activities and sectors of a value chain on the costs incurred by the chain in its totality (Dekker 2001, p.5). These aspects mean that VCAs are powerful tools to be used in strategic decisions of how and where in a value chain a company or government should focus its attention and resource expenditure. By providing an overview of the interrelationships between activities in the value chain, a VCA also allows industry players to realise the potential for innovation and efficiency increases in the links between activities, rather than just in the activities themselves (Shank & Govindarajan 1992; Shank 1989; Min & Zhou 2002). In a globalised world, where economies are highly integrated, such awareness is critical as most firms now compete in markets as part of an integrated value chain instead of as individual actors in a fragmented value chain (Cox 1999, p.168).

VCA enables the identification, utilisation and management of the interrelationships that are so fundamental to success in the modern business world.

Lambert et al [1998, cited in Min and Zhou (2002)] identify four primary types of links that can be developed between firms.

1. Managed business process links which connect multi-tier supply chain partners wherein the firms involved actively manage their relationships with other actors

[91] For a much more detailed overview of the literature on VCA please refer to the document entitled *Value chain Analysis* on the attached CD.

linked to it in the chain. In these links firms typically have the ability/power to allocate strategic resources to others near it in the chain. These links are typically found between powerful actors in a value chain and their partners.

2. Monitored business process links which are not fully controlled by a firm but which it nonetheless at least has the ability to monitor and audit.
3. Not-managed business process links which firms cannot manage, nor monitor and in which they are entirely dependent on their partners to manage the links.
4. Non-member business links exist between firms in a specific value chain and actors outside of that value chain. These links are not integral to that value chain but they can affect the performance of firms therein.

Through presenting an overview of the links that exist in the SWH value chain, this thesis can contribute to the development of stronger inter-firm linkages in the existing SWH industry in the Western Cape and identify areas where new firms could emerge and play a role in the value chain. This will be achieved through the provision of information that would help firms in the value chain to effectively understand, monitor and manage links as well as to identify opportunities to increase inter-firm efficiencies through innovation in the links between firms rather than just in activities within firms. (Cox 1999, p.169)

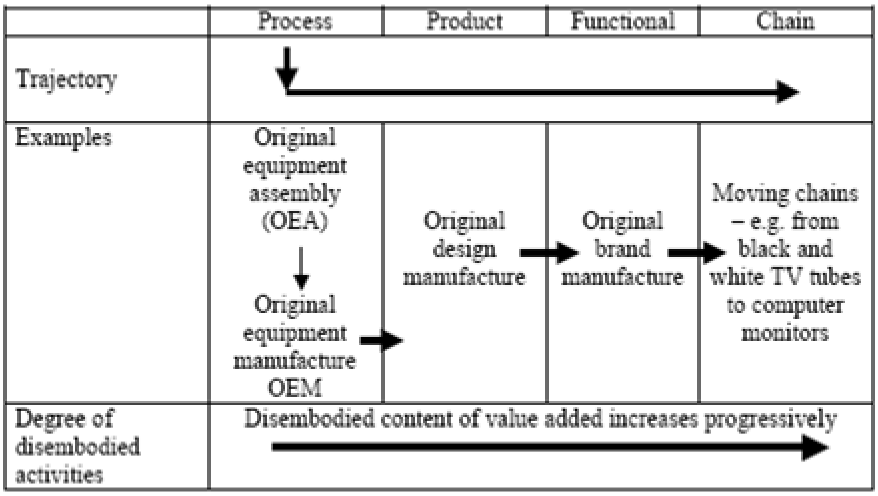
Inter-firm analysis also allows firms from all segments of the chain to gain insight into the interrelationships between the costs of suppliers and buyers (Kaplinsky & Morris 2003, p.2). When the knowledge becomes available the firms can then use it to better control cost drivers, to redesign the value chain for greater efficiency and to target attempts at upgrading and innovation.

According to Kaplinsky & Morris (2003, p.38) firms have four different options for upgrading:

i. **Process upgrading:** to increase the efficiency of internal processes as well as linking processes between different parties in a value chain.
ii. **Product upgrading** through the introduction of new products or improved old products.
iii. **Functional upgrading** by changing the functions in which they are involved through outsourcing or internalising different functions or shifting production to a different part of the value chain.
iv. **Chain upgrading** by shifting production into a new value chain.

International experience suggests that the typical path for upgrading starts with process upgrading, progresses to product upgrading, later to functional upgrading and finally to chain upgrading. Upgrading also tends to move towards activities with higher disembodied value added (Kaplinsky & Morris 2003, p.39). The process is illustrated by Figure 40 below. For this thesis the core focus is on opportunities for process upgrading and on identifying potential barriers to this form of innovation.

Figure 40 The prevalent process of upgrading (Kaplinsky & Morris 2003, p.40)



3.4.5.2 *Applying Value chain Analysis*

Different sets of data that can be generated through a VCA are data on benchmarking, barriers to entry and rent, power relationships, inter-firm relationships and income distribution.

Benchmarking

A VCA can be used to analyse the productive efficiency of different actors in a value chain. The measure of efficiency can be other companies fulfilling a more or less similar role in the value chain or the state that a specific actor has to be in to maximise its market penetration (Kaplinsky & Morris 2003, p.63). In the case of this thesis it is hoped that the research, by providing aggregated values for cost drivers across the Western Cape SWH industry, will help firms in the chain to benchmark themselves against the industry averages. This would then enable them to focus on appropriate cost reductions and increase competition that would eventually lead to cost reductions.

Barriers to entry and rent

A VCA is uniquely set up to build an understanding of the distribution of returns to productive activity within a value chain. It can be used to model the returns that accrue to the different activities within a value chain. The largest returns will inevitably be found in the segments of the value chain where firms are best able to protect themselves from competition (Kaplinsky & Morris 2003, pp.25-26). A central purpose of this thesis will be to investigate the existing barriers to entry in the SWH industry to identify where inordinate rents accumulate, but, more importantly where costs are concentrated in a similar way so that purposive action and policy-making can target the obstacles that prevent increased competition and cost reductions.

According to Kaplinsky and Morris (2003, p.42) the key to understanding distributional outcomes *"...is to be found in a focus on the incomes which are sustained in different parts of the chain, rather than on profits."* Different measures that can be used to determine "profitability" of firms in a value chain include return on equity, margins on sales, share of total value chain profit and returns on net assets (Kaplinsky & Morris 2003, pp.86-88). Kaplinsky and Morris identify returns on net assets to be the best indicator of profitability but in the SWH industry it was extremely difficult to gain access to data on company equity, loans and payment schedules. Cost structures had to serve as a substitute indicator as quantifications of returns to factors of production. Kaplinsky and Morris (2003, p.88) pave the way for such an adaptation by stating *"...instead of using profits, or perhaps in addition [to it]... it is perhaps more helpful to focus on the incomes which are sustained in different parts of the value chain and that accrue to different factors of production within the value chain."*

<u>Power relationships in Value chains</u>

Powerful actors in a value chain fulfil a governance function through the establishment of parameters that govern product specifications, processes and logistical qualifications across the value chain. In different value chains this governance function can be fulfilled either by producers or buyers, depending on power concentration in the specific value chain (Kaplinsky & Morris 2003, p.8). In modern economies it is becoming increasingly important that the governance function be purposefully fulfilled to ensure maximum efficiency across a value chain.

Avdasheva et al (2005, p.3) postulates that the governing link in a chain will normally be found in the part where there are the highest barriers to entry. In essence, power will accrue to the party which controls scarce resources in some form that provides it with leverage over other organisations. Generally speaking, larger firms tend to be more powerful than smaller firms (of course there are exceptions to this rule) but "size" can be a very relative concept. Cox (1999, p.173) identifies three essential insights that are required to successfully categorise value chains according to power-based typologies:

i. The physical resources that are required within the supply chain to create and deliver the finished output to the final customers.
ii. The nature of the exchange relationship between supply chain resources and the flow of revenue in the value chain.
iii. The nature of the ownership structure of strategic resources within the value chain. Essentially, who controls the strategic resources and how they manage to do so.

Based on similar typologies, Gereffi [cited in Kaplinsky and Morris (2003, p.32)] divides value chains into buyer and producer driven categories. Buyer driven chains are controlled by large buyers such as retailers and marketers, are typically labour intensive, and are mostly found in developing countries. Producer-driven chains are governed by producers that command vital technologies or other production inputs.

For organisations or policy makers trying to influence behaviour in a value chain, understanding the underlying power structures of the value chain is essential (Cox 1999, p.172). Through understanding power relationships, government regulators can reduce monopolistic outcomes by forcing producers to provide customers with increased portions of the total value created, rather than just the minimum required to satisfy them (Cox 1999). Such an understanding would also allow policy makers to identify areas where existing power relationships may be barriers to entry that prevents small entrepreneurial firms from becoming actively involved in the industry. If areas can be identified where people in low-income communities can create their own businesses in the value chain, it would enhance the development potential of the process of providing SWHs.

In the analysis of the SWH value chain, power relationships are investigated through qualitative interviews with SWH companies in which specific questions are asked about factors that determine output levels, expansion decisions, price structures and quality standards.

VCA and income distribution analysis

An income distribution analysis is considered an important part of the SWH VCA as the data would be a good indicator of the wider economic benefits offered by the SWH industry. The VCA theoretical framework, as discussed by Kaplinsky and Morris (2003, p.91), allows for such an analysis focusing on returns to factors of production. Though the focus here is not on income accruing to labour, but rather on employment opportunities created, the VCA framework still provides valuable guidance for the analysis. By investigating entrepreneurial and employment creation potential in the SWH industry it will be possible to determine to what extent the SWH industry could become a synergic satisfier for the development needs of the low-income communities in Stellenbosch municipal area. If most of the income in the chain accrues to skilled labour it would not make sense to invest in the industry to alleviate poverty. The investigation is conducted through the evaluation of secondary quantitative data provided by industries in the SWH value chain.

3.4.5.3 Identification of Sources for Information

The process of identifying SWH companies in the Western Cape to contact for interviews started with a list of SWH suppliers provided by the CRSES. They had compiled such a list as part of the consultancy project that they completed leading up to the KwaNokuthula rollout of SWHs. This list was used as a first entry point as they had used it to identify SWH suppliers that could provide systems for rollout in a low-income community. This list was then updated with information from the Eskom-DSM (2010b) website on SABS accredited SWH systems and their suppliers in the Western Cape as well as from the SESSA (2010) solar water heating website's list of member suppliers in the Western Cape. Finally an internet and telephone directory search was conducted for other firms involved in the value chain.

Companies with their head office outside of the Western Cape were excluded from the study. Every effort was made to contact organisations that manufacture SWHs but not all energy consulting companies or SWH retailers were contacted. There are dozens of firms involved in the industry at a service level but the primary focus of this research study is on production. The manufacturing firms all sell directly to the public and would work directly with municipalities looking to roll out SWHs in low-income communities. Service sector intermediaries only add additional margins to the price of SWH systems and the few that were interviewed were unable to provide data on the cost drivers or job creation potential of the industry beyond the installation and maintenance level. Service sector companies do offer a valuable service to higher income consumers where each installation is different and unique advice is required on which system configuration would work best, but for mass scale rollouts it is best to work directly with manufacturers.

3.4.5.4 *Calculating the Employment Creation Potential of the SWH value chain*

In order to estimate the job creation potential of the SWH industry, as shown in Table 15 and Table 16, several diverse sources had to be consulted. Employment creation figures for flat plate collector manufacturing were obtained by averaging figures provided by three collector manufacturing companies. Similarly figures for installation were obtained by averaging figures provided during interviews with eight SWH suppliers. The figures for geyser manufacturing labour were obtained by averaging the labour inputs required for manufacturing fibreglass storage tanks and copper storage tanks. Though the processes are vastly different, the amount of labour required varies by only 10% to 11% and an average figure is considered to be a useful figure to estimate total job creation potential. Interviews with companies in the SWH industry indicated that the number of office support personnel was relatively independent of production capacity, with most firms employing four to eight people in office support jobs. The larger firms had an office support compliment of seven to eight staff members and this is taken to be an indication of the amount of jobs that would be created in this sector. Firms involved in manufacturing geysers and/or panels use the office staff to provide retail services and as such no additional employment opportunities were calculated for retail activities. It is expected that large government rollout programmes in direct collaboration with system manufacturers will not lead to retail job creation. Maintenance is discussed later in the thesis under section 4.2.2.5. Figures provided by all industries were standardised to calculate labour to output ratios.

Calculating reliable estimates for job creation higher up in the value chain required some creative solutions as data was extremely difficult to come by. The firms providing raw materials in South Africa employ thousands of people and produce thousands of tonnes of said materials in highly competitive international environments and they are circumspect about how much information they make available.

The Copper Development Association (CDA) and Palabora mining and copper production company provided basic data on job creation in the copper industry and some figures for copper tubing manufacturing were obtained from Maksal copper tubing manufacturers. PFG building glass provided figures for the labour intensity of producing prismatic glass for SWHs. Unfortunately attempts to contact the aluminium supply industry players failed and employment creation figures had to be obtained from available publications. Previous studies for the employment generating capabilities of these industries in South Africa could not be found on the internet or in academic databases. The tables below indicate how the employment intensity figures were calculated.

Table 7 Sources of Data for the Employment Intensity of the South African Aluminium Industry

Source	(Sergeant 2008; Brendan 2008)	(Lochner 2006)	(Lochner 2006)	**Average job creation/tonne of aluminium produced/annum**

Total Production per annum: Amount of employees	Loss of 120000 tonnes of production/annum leads to loss of 900 jobs	Total jobs to be created through Coega = 1350, for production of 720000t of aluminium/year	Hillside aluminium smelters produced 680 000t of aluminium in 2004, creating 1200 jobs	**Average job creation/tonne of aluminium produced/annum**
Direct employment intensity/tonne produced/annum	0.0075	0.001875	0.001764706	**0.004659926**
Estimated Indirect employment opportunities created		9 000 to 15 000	16 000	
Indirect employment intensity/tonne produced/annum		0.0188	0.0235	**0.0211**

Table 8 Employment Intensity of Prismatic Glass Manufacturing

Total number of employees involved in Prismatic Glass manufacturing	Sheets produced per day (based on 4.5min needed to complete key elements of the process)	Sheets produced per month (7day workweek, 3 eight hour shifts, 30 days/month)	Sheets produced per year (11 1/2 months year)	Weight of sheets produced (ton) (calculated with the help of (MatWeb 2010) for standard pane sizes.	**Employment intensity /tonne/annum**
66	320	9600	110400	1639.26513	**0.040262**

Table 9 Employment Intensity of Copper Production

Tonnes of Copper produced by Palabora per year	Total direct Employment opportunities created in mining and initial production	Maksal tubing production per year (tonnes)	Total direct Employment opportunities created in tube manufacturing	**Employment intensity /tonne/annum**
85000	2100	18400	500	**0.051879795**

The weight of the material required per system for Table 16 was calculated based on dimensions provided by SWH collector manufacturers. Typical collector dimensions for an 80-100*l* capacity system are taken as 1.98m by 0.86m by 0.075m.

The baseline system contains seven risers (lengths of copper tubing running vertically in the system), 2 lengths of copper tubing across the top and bottom of the collector system and a 2m length of copper tubing to transport hot water from the storage tank to the hot water tap. These figures allow for the calculation of the total length of copper tubing required. Standard copper tubing diameters of 22mm are assumed. The weight of this amount of copper is calculated with the assistance of the MatWeb website (2010) based on standard copper density.

The volume of aluminium required is calculated by summing the total volume of aluminium required for the frame, collector fins and backing plate. The weight of this volume of material is then calculated with the assistance of the MatWeb website (2010) based on standard aluminium density.

The amount of prismatic glass required is calculated for 1.6m^2 panes. The weight is calculated with the assistance of the MatWeb website (2010) based on standard glass density[92].

Other key materials used during the manufacturing of a flat-plate collector are absorber paints and insulation materials such as polystyrene and rock wool, but the quantities of these materials used are comparatively small, both in terms of absolute quantities used as well as compared to the amounts used in applications such as refrigeration and thermal insulation in buildings, and as such they are not included in the figures as they are unlikely to contribute any significant additional employment creation opportunities.

Materials used for storage geyser manufacturing are also not included in the study as the geysers typically used for low-cost installation are constructed of imported fibre glass composites that don't contribute many direct employment opportunities in South Africa.

3.5 LIMITATIONS OF THE RESEARCH METHODS

3.5.1 TECHNICAL TEMPERATURE MEASUREMENTS

For a comprehensive technical analysis of the performance of SWHs in Stellenbosch an expensive study at a testing site such as is available at the CRSES would need to be conducted. If the focus of the study had been to complete a technical comparison of the performance of different SWH systems, the systems should have been installed for identical households as near to each other as possible. Since the thesis is not intended to provide quantitative technical comparisons of SWH systems, it was decided that the two case study households should rather be chosen from two different communities as they could thus serve as a gateway to reaching more households through awareness raising. This increased awareness of the technology and the ongoing research proved to be a powerful asset when the surveys were distributed, as it sparked wide interest amongst different communities. The installation of the systems in a coloured and African community also allowed for an investigation of how households from different communities reacted to the availability of bulk water heating. It is recognised that one should be careful to make general inductions for large populations based on such singular studies, but the findings in the two households can be used to inform future research using wider samples. What the research conducted does offer is an informative case study of how households experience SWHs and what difference they make in daily activities. Understanding the value of the technology for the intended

[92] It is possible that the highly ionised prismatic glass differs in density from standard glass but it is assumed, due to a lack of available information on the density of prismatic glass, that the difference is not significant enough to have a large impact on the job creation potential.

recipients is an important part of the knowledge required when policy trade-offs have to be made between different poverty alleviation strategies.

3.5.2 COST FIGURES FROM SWH FIRMS

The data assembled on cost figures for the Western Cape SWH industry had to be based on percentage contributions provided by commercial companies. This high level breakdown does not allow for the detailed investigations that Kaplinsky and Morris (2003) suggest for VCA, but they do provide real world indicators of what cost drivers are.

3.5.3 SIZE OF THE SAMPLES

The sample for the demand analysis consisted of 90 households. This is a relatively small sample but the results obtained had statistical variance and are thus deemed to be indicative of wider trends. The results also correlate well with the surveys completed for the Kuyasa CDM project (2008, 2009).

Similarly the number of SWH industry companies interviewed was relatively small but the three SWH collector plate manufacturing companies interviewed (Atlantic Solar, Solarmax and Solardome) are the only manufacturers that are based in the Western Cape. Similarly the interviews with four importers of SWHs (TASOL, ITS Solar, Solartech and Ecosmart Solar) and a geyser manufacturing company (Extreme) cover most of the larger players based in the Western Cape, even though there are dozens of small retailers of SWH systems in the Province. A more comprehensive national survey may provide more robust results, especially if it were able to include figures from Kwikot as the company is a large provider of SWH collectors and geysers.

3.6 CLOSING REMARKS

The research methodology and methods section has provided a theoretical justification for and description of the approach that was taken to investigate the research hypothesis and to answer the research questions.

The demand side analysis, through the case study and the survey, tests to what extent SWHs serve as a synergic satisfier for the demands of households while the supply-side value chain analysis evaluates the job creation potential of the solar water heating value chain. This information can then be used to calculate the total costs and benefits of solar water heating and to inform government regulation and industry support decisions. This thesis will contribute to the effective targeting of government intervention by providing an overview of what the barriers to cost reductions are in the solar water heating industry in the Western Cape. The investigation of the industry will also allow the identification of the appropriate level of government intervention.

The following chapters will show how the research methods were applied and present the findings of the analysis of solar water heating as a potential synergic satisfier for achieving sustainable development.

4 RESEARCH FINDINGS

The literature review identified potential advantages of SWHs and also some gaps in the existing literature. The research conducted for this thesis fills these gaps by investigating what the poverty alleviation potential of SWHs is, what the cost drivers and job creation potential of the industry is and how much harmful emissions can be avoided due to the systems, in order to quantify the potential synergic benefits of the SWH industry. These research findings are then used to develop a model for the rollout of SWHs in Stellenbosch and the Western Cape, which will hopefully inform policy development regarding SWH. Through the application of a survey in low-income households, case study research and interviews with SWH companies the research questions are answered and the research hypothesis evaluated. The demand analysis tests whether and to what extent *SWHs are a potential synergic satisfier for achieving sustainable development* in terms of fulfilling fundamental human needs through the provision of hot water. The supply side value chain analysis investigates the job creation aspect of synergic needs satisfying as well as what the barriers are to price reductions[93], how these barriers might be overcome and how government may be able to support the rollout of low-cost SWHs.

4.1 FINDINGS OF DEMAND ANALYSIS

Based on the systems approach to sustainable development adopted for this thesis, a study of SWHs in low-income communities needs to remain solidly grounded in the needs of the people it means to serve. In analysing the value chain it is vital to understand what contribution SWH technology can make to the lives of communities facing economic and/or energy poverty in order to be able to quantify the costs and benefits of mass rollout programmes.

An objective of the thesis is to contribute to processes that would lead to cost reductions across the value chain. For this objective to be achieved a clear picture needs to be drawn of the developmental service that SWHs offer. This information is not only valuable for government policy makers but also for businesses in the value chain. The largest segment of the South African population falls into the low-income category (Bhorat & Van der Westhuizen 2006) and the RDP housing sector is a potential market for more than a million SWH systems (Department of Housing 2009, Afrane-Okese 2009). The long term growth of the SWH sector will depend to a large extent on the ability of producers to understand and serve the low-income market segment.

On the policy side it is vital that government needs to have access to information on the poverty relieving potential of SWHs so that it can develop and invest in efficient programmes that maximise the development effect of invested resources. The demand analysis conducted here quantifies the benefits that SWH offers for low-income households in terms of potential electricity savings. This makes it possible to postulate what the impact of a mass rollout of SWHs in low-income communities in Stellenbosch and the Western Cape would be.

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[93] Which would make the benefits more easily realisable

The demand analysis consisted of two different processes. The first was a case study based on the installation of two SWHs on the homes of two low-income households in Stellenbosch and the second comprised a survey of 90 low-income households residing in state-subsidised houses to identify their hot water usage. Research questions 1, 1.1, 1.2, and 1.3 are answered through this investigation. Section 4.1.1 discusses the findings in the case study households and section 4.1.2 discusses the findings of the general household survey.

4.1.1 TESTING OF SOLAR WATER HEATERS IN CASE STUDY HOUSEHOLDS

As part of this research project three solar water heating systems were installed on the homes of three low-income households living in Stellenbosch. The objectives of the installations were to determine:

- Whether there is a significant difference in performance of a low-cost evacuated tube system and a low-cost flat-plate system[94].
- quantitatively how much electricity is saved in households through the use of a SWH system[95]
- qualitatively how large an improvement in quality of life the availability of large volumes of “free[96]” hot water makes

Fulfilling these objectives is a key step towards answering the primary research question

1. What are the potential benefits of solar water heaters for low-income communities?

And the secondary research questions;

1.1 What are the benefits of SWH for a low-income household?

1.2 What would be the extent of electricity savings if a mass rollout of SWHS is achieved on all low-income households in Stellenbosch or in the Western Cape?

1.3 What would the environmental benefits be of achieving a mass rollout of SWHs for all low-income households in Stellenbosch or in the Western Cape?

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[94] As discussed under the research methodology section this aim was not satisfactorily achieved and the quantitative water temperature measurements are only valuable as an indication of whether the technology consistently offers hot water at hot enough temperatures to substitute for the use of current water heating systems (mostly electrical kettles and stoves).

[95] The target population for this study was low-income households living in formal houses. RDP housing developments are a large section of this group and they provide ideal targets for SWH rollout programs. The uniformity of the houses make installations simpler and thus cheaper. Most of these households have access to grid electricity and use electrical kettles or stoves to heat water (Kuyasa CDM 2009, Hertzog 2009, DME 2001, Prasad and Visagie 2005, survey completed for this thesis). SWHs thus generally substitute electrical energy used with solar energy. In rural areas other sources of energy, such as biomass or paraffin may be used to heat water but these communities fall beyond the scope of this research.

[96] The hot water from a SWH is free in the sense that consumers do not pay per unit of hot water used. After the initial capital investment has been made there are thus no further costs for hot water used. In low income communities where personal care activities may be inhibited by the unit cost of heating water in electrical devices, SWHs thus have the potential of improving quality of life by removing the cost barrier to using sufficient qualities of hot water.

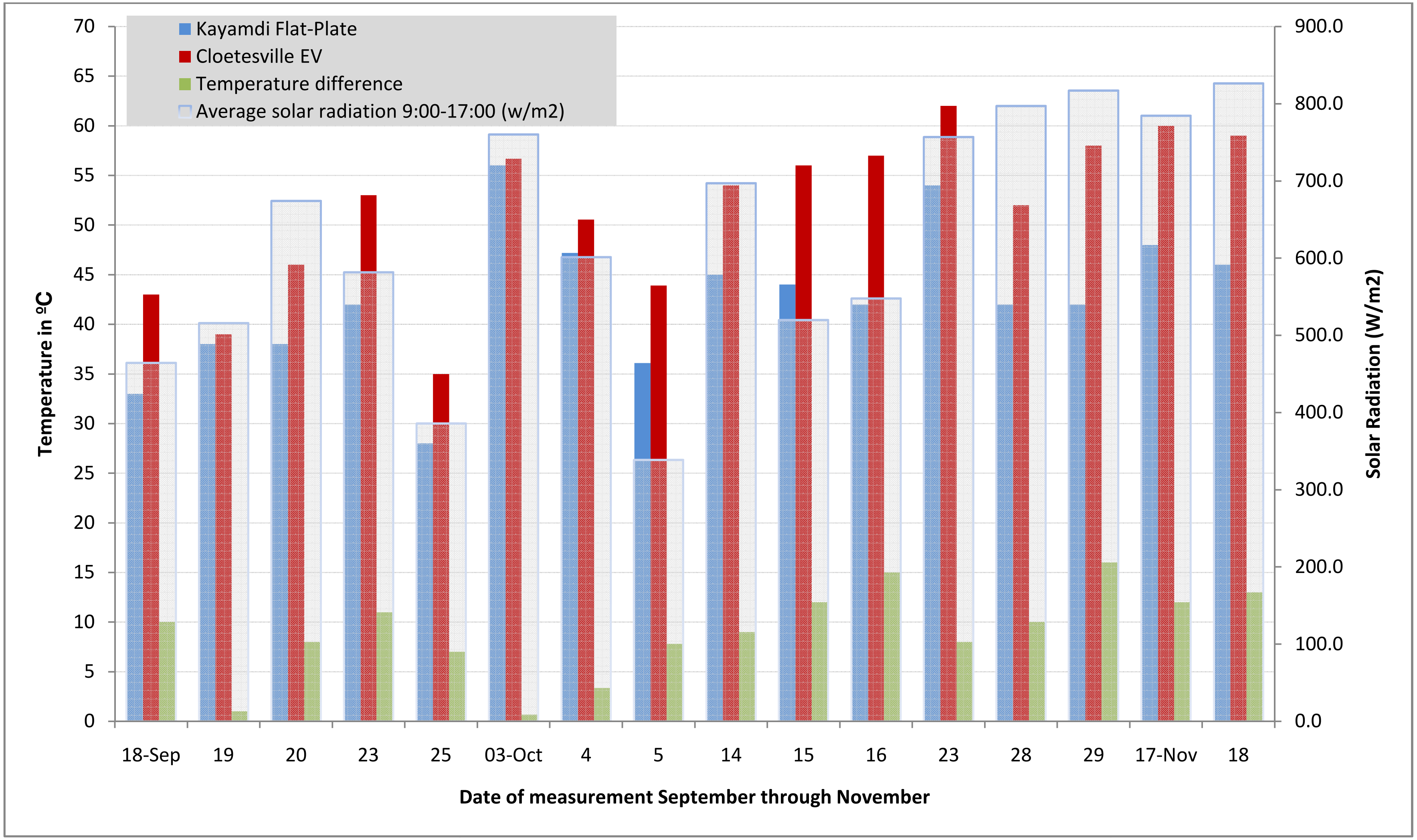
The temperature monitoring of the systems was conducted in order to develop an understanding of the different solar water heater collector systems that are available.

4.1.1.1 Quantitative Results of Temperature Monitoring

The testing of SWH systems in practical, real world settings rather than under laboratory conditions, though not ideal for a technical study, offers some valuable insights[97]. They enabled the researcher to experience firsthand the developmental service that SWH offers in a household whilst also allowing for an investigation of whether the differences between flat-plate technology and evacuated tube technology make a marked difference in low-income households. If the hot water temperatures generated consistently differed by only a few degrees centigrade, and both households expressed satisfaction with the system that they received, the technical efficiency differences between the systems should not be a paramount concern in deciding which systems to support in large SWH rollout programs. In that case other arguments about local economic development and job-creation potential could be the deciding factors in selecting systems for mass rollout programs. The temperature monitoring results are shown and discussed below.

[97] Originally the intention was to monitor the temperatures for a longer period but sourcing two systems and getting them installed proved to be a time-consuming process that shortened the time available for testing significantly.

Figure 41 Comparative Temperature Measurements from Both Households



Through the temperature monitoring the hope was to achieve several different goals. The sample of measurements shown above, were all taken at 5'o clock in the afternoon. The average solar radiation in Stellenbosch (Stellenbosch University 2009) in the subsequent 9hours is also shown on the graph. The correlation between water temperatures generated and solar radiation levels for the flat-plate collector and the evacuated tube collector is 0.7 and 0.75 respectively. This indicates a fairly strong positive correlation between the amount of sunshine available and the temperature achieved by both types of systems and is thus a fairly effective test. The positive relationship is weaker than expected because these measurements were taken from systems that were actively in use. This means that water was tapped from the storage tanks during the day and temperatures would thus drop suddenly, independent of changes in solar radiation. Heat retained in the water in the storage tanks overnight would also affect temperatures the following day. Solar radiation levels over the past day or two would thus affect the temperatures attained by the systems. As has been mentioned earlier, the intention was not to conduct a thorough technical comparative test between different types of SWH. Instead the goal was to develop an understanding of the order of magnitude of working temperatures that one can expect from a SWH installed on a state-subsidised house in Stellenbosch. The most important conclusion to be reached from the temperature measurements is that the water supplied by both the installed SWHs achieved temperatures in excess of 35ºC and mostly above 45 ºC on all but the most cloudy of days when average solar radiation was lower. This is shown in Figure 41. The evacuated tube collector achieved consistently higher temperatures, often in excess of 10ºC higher than the flat-plate system[98].

Despite these disparities in temperatures achieved both households expressed great satisfaction with the systems that have been installed. They indicated that the SWHs were able to fulfil all their water heating requirements and that it had brought a positive change in their lives (Arendse and Arendse 2009, Nomalizo 2009). The tests would therefore seem to indicate that on a purely technical basis evacuated tube systems might be better to install as they are more efficient for water heating but that both types of system can fulfil the hot water requirements of low-income households. According to SWH installers (Hertzog 2009, Hallet 2010) the high temperatures achieved by evacuated tubes could cause longevity problems as components are exposed to extreme heat. Flat-plate collector systems reach stagnation point earlier and are not subject to overheating while evacuated tube systems may heat water beyond boiling (Ramlow 2007).

These tests are by no means intended to serve as final technically dependable indications of system performance, but rather to serve as an indicator for future technical tests and to provide a preliminary understanding of the efficiency of SWH systems in general and in comparison to each other. The most important insight in terms of this thesis is that both households indicated that the systems installed were able to provide satisfactory water heating services. This finding means that SWHs, with either evacuated tube or flat-plate collectors, can satisfy most, if not all, of the fundamental human needs that are met through the availability of hot water. SWH is thus deemed to be a technology that can supplement other water heating devices in the low-income context and further investigation into the synergic benefits of the systems are warranted. Though the Evacuated Tube system achieved higher maximum temperatures both systems were adequate to fulfil the hot water

[98] In similar experiments conducted as part of the Kuyasa project evacuated tubes also produced higher water temperatures than flat-plate collectors (Wesselink 2010).

requirements of the households. In terms of efficacy in fulfilling their purpose both systems were adequate. This means that if a choice has to be made between the two types of collector other factors such as price, longevity and employment creation potential can be considered as deciding factors.

4.1.1.2 Qualitative Results

In parallel to the temperature monitoring of the SWHs the case study households were interviewed prior to the SWH installation and three months thereafter to evaluate how their expenditure on electricity for water heating changed due to the installation of SWHs.

Electricity savings in households with SWHs installed

Table 10 provides a breakdown of the key hot water usage patterns in the case study homes.

Table 10 Water consumption in SWH case study homes

Address	**7 Mdandana Street, Kayamandi, Stellenbosch**	
SWH system installed	80*l* capacity, direct low-pressure (200kpa) flat-plate collector system	
Males living in house	2	
Females living in house	3	
Total people living in house	5	
Comparison	**Before SWH installation**	**After SWH installation**
Electricity bill per month stated	R600[99]	R400
Litres of hot water heated in electrical kettle for bathing per month (small baths)	102*l*	0*l*
Litres of hot water heated in electrical kettle for bathing	0*l*	0*l*

[99] The stated electricity expenditure is compared with real electricity expenditure in Figure 42

per month (large baths)		
Litres of hot water heated in electrical kettle by all males each month for hair washing	0*l*	0*l*
Litres of hot water heated in electrical kettle by all females each month for hair washing	0*l*	0*l*
Litres of hot water heated in electrical kettle for dishwashing per month	51*l*	0*l*
Litres of hot water heated in electrical kettle for laundry per month	0*l*	0*l*
Litres of hot water heated in electrical kettle for general house cleaning activities per month	0*l*	0*l*
Volume of water heated in electrical kettle per month (hot beverages and cooking excluded)	153*l*	0*l*
Calculated expenditure on hot water per month (hot beverages and cooking excluded) [100]	R11.55	R0.00

Address	**56 Hoek Street, Cloetesville, Stellenbosch**	

[100] Calculated for a 1.7l 2000W electrical kettle that takes 5.5min to boil water. Total energy used per 1.7l of water boiled is 2000W*0.9166667h=183.333334 Wh= 0.183334 kWh. At electricity charges of 70c/kWh the cost per kettle boiled is R0.128.

SWH system installed	80*l* capacity, direct low-pressure (municipal water pressure) evacuated tube collector system	
Males living in house	4	
Females living in house	2	
Total people living in house	6	
Comparison	**Before SWH installation**	**After SWH installation**
Electricity bill per month stated	R560	R400
Litres of hot water heated in electrical kettle for bathing per month (small baths)	204*l*	0*l*
Litres of hot water heated in electrical kettle for bathing per month (large baths)	408*l*	0*l*
Litres of hot water heated in electrical kettle by all males each month for hair washing	2.55*l*	0*l*
Litres of hot water heated in electrical kettle by all females each month for hair washing	3.4*l*	0*l*
Litres of hot water heated in electrical kettle for dishwashing per month	153*l*	0*l*
Litres of hot water heated in electrical kettle for general house cleaning activities per month	0*l*	0*l*
Litres of hot water heated in electrical kettle for laundry per month	0*l*	0*l*

Total volume of water heated in electrical kettle per month (hot beverages and cooking excluded)	770.95*l*	
Calculated expenditure on hot water per month (hot beverages excluded) [101]	R58.19	R0.00

[101] Calculated for a 1.7l 2000W electrical kettle that takes 5.5min to boil water. Total energy used per 1.7l of water boiled is 2000W*0.9166667h=183.333334 Wh= 0.183334 kWh. At electricity charges of 70c/kWh the cost per kettle boiled is R0.128.

Deriving the exact amount of energy savings due to the availability of free hot water in the case study households proved to be more difficult than expected. In interviews they claimed to have saved between R40 and R50 per week on their electricity expenditure since having the SWHs installed. This figure is equivalent to roughly 30% of their total expenditure on electricity and is in line with the findings of other studies estimating electricity use for water heating in low-income households (Holm 2005, Van Gass and Govender 2009, SEA 2009, DME 2002). Quantitative interviews to identify the exact extent of hot water savings show a much lower saving. The findings from each household are discussed below.

7 Mdandana, Kayamandi. Flat-plate SWH Installation

7 Mdandana residence used very little hot water to begin with, with the largest use of hot water being for a personal bath in a small amount of hot water (half a kettle full of hot water) three times a week. The only other use of hot water is for dishwashing with half a kettle full being used once a day. It seems that circumspect hot water usage has become engrained behaviour in this household as they reported no increased use of hot water during the study period. Even after hot water became freely available with the installation of a SWH they continued to use a minimal amount of hot water for personal hygiene and other purposes. The expense of using additional water from the municipal water account is not a barrier to increased hot water usage as the family does not pay its municipal water account (Nomalizo 2009). However, if they were forced to pay their water bills the cost of water may have a limiting effect on their use of the SWH. What hot water usage they did have was completely replaced with hot water from the SWH and they expressed complete satisfaction with the technology, citing that it provided enough hot water to fulfil all their hot water requirements, even in the coldest periods of winter. According to Ethel (Nomalizo 2009), the mother of the household, *"Die ding werk baie goed. Net so paar ure se son op 'n dag is genoeg om vir ons warm water te gee en dit spaar baie electricity*[102]*."* They also found that the storage tank was well enough insulated to often provide them with hot water in the mornings as well.

It is likely that over time, as the household becomes more accustomed to having freely available hot water, hot water usage will increase and the SWH will make a larger impact on the lives of the residents. A subsequent interview in April 2010 indicated that the household members had in fact started to adapt their behaviour and use more hot water. It was particularly encouraging to note that they purchased two much larger buckets to be able to use more water from the geyser!

Though the residents claimed that they had seen electricity bills fall by roughly R50 a week since the installation of the SWH system. However, this figure may be highly inflated. Cost calculations of the hot water used, indicate that a SWH system can only save the household about R11 per month. This calculation is based on more objective data on hot water usage and probably more reliable than the amounts expressed. The presence of the researcher may have served as an incentive to inflate expenditure on electricity figures in interviews. A perception seemed to exist that the neighbourhood had a better chance of being awarded a wide rollout of SWHs if the savings that they brought were higher. Though efforts were made to dispel this perception by clearly explaining the research process, it seemed that it still had some effect on the answers given. The water usage data is probably a more accurate indicator

[102] "The thing [SWH] works very well. Only a few hours of sunshine is enough to give us hot water and it saves a lot of electricity."

as the correlation between rolling out SWHs and hot water usage was slightly more hidden in these questions. Bias from the households was expected and that is the reason why they were also asked to provide data on their use of hot water separately. This data allowed for a control calculation of possible savings as discussed above.

Based on the experience of the 7 Mdandana household the quality of life improvement brought by SWHs would not warrant the cost that need to be incurred to provide the technology to similar households. In this case SWH proved to be a synergic satisfier of several fundamental needs in only a few more ways than an electrical kettle is. The largest benefit cited was that it saved a lot of time and made hot water access a lot easier which freed up more time for other activities (Ndamane 2009). This free time has allowed the mother and children of the household to sleep a little later in the mornings since they no longer have to wake up early to start the electrical kettle. This has improved their lives because they are less tired in the evenings and they can stay up a little later to talk to each other and spend more time together (Ndamane 2009). Although it only takes slightly more than 5 minutes to boil an electrical kettle one should not underestimate the value of this time saving, especially for a mother that has to prepare separate baths for all her children and herself. The immediate availability of hot water makes it much easier for this household to enjoy the bathing experience. In the past they use to skip baths because it was too much effort to prepare them, but now, because it is a much more accessible activity, they enjoy bathing (Ndamane 2009). The electricity savings on their own are not massive and as such the local economic development role that the technology can play has to be an integral consideration for government policies designed to facilitate widespread application of SWH systems in low-income communities.

The SWH system attracted much attention from the local neighbourhood with some members even expressing intense jealousy and a certain amount of anger that only one household had received a SWH system. Such reactions create potential resistance to future projects of this nature and wider stakeholder engagement would be necessary if further interventions are made. Transdisciplinary case study research would need to be conducted in order to ensure that all aspects of such projects are investigated by experts with a wide range of expertise covering technical and social fields. Interest in the technology was immense with many people enquiring from the researcher residents of 7 Mdandana about the technology, its costs and efficiency. The widespread interest generated does indicate the value of pilot projects in awareness raising whilst the reaction of the neighbours shows that even though cost savings are minimal people believe that they can benefit from the technology.

56 Hoek Street, Cloetesville, Evacuated Tube Installation

The experience of 56 Hoek Street revealed more interesting data than that of 7 Mdandana. In this household more hot water was used before the installation of the SWH. All hot water was sourced from the SWH after the installation. Residents claimed to have seen a reduction in electricity expenditure from R560 to R400 per month since the installation of the SWH system. Similar to the case of 7 Mdandana, this figure is probably inflated. The costs of water heating calculated by summing the total hot water used is considered to be a more accurate reflection of water heating costs. According to this measure the household saved roughly R54 per month on their electricity expenditure after the installation of the SWH. This figure is more in line with the average of R63.79 potential saving through the installation of SWHs calculated in Table 12 as well as the savings found by the Kuyasa project (Kuyasa CDM 2009).

However, in this residence ready hot water availability did make a large difference in quality of life. Residents have started to use much larger quantities of hot water for various activities. They claim that the hot water made a large difference in their lives, saving them time, money and effort and that bathing has become an easier, more pleasurable exercise. As the female head of the home, Bet Arendse, put it *"Dit voel nou sommer lekker om te was![103]"* Bathing is no longer an uncomfortable chore but has become a "relaxing" daily experience, with especially the women in the household conveying much gratitude for the large benefits brought by the system. Similar to the 7 Mdandana household the residents of 56 Hoek Street expressed overall satisfaction with the system. They also found that the system supplied enough hot water to fulfil their requirements and that water temperatures were retained sufficiently overnight to enable household members to wash in the mornings as well. No changes in water usage behaviour were required to adapt to the variability of sunshine. The evacuated tube system does sometimes generate potentially hazardous high water temperatures (a maximum measurement of 67°C was recorded during the study and this figure will rise significantly during the much hotter summer months) but the risks are much reduced by installing taps beyond the reach of young. Residents indicated that they preferred such high temperatures as it increased the convenience of the system.

Based on the experience of 56 Hoek Street solar water heating does offer a real improvement in quality of life and it fulfils the requirements of a synergic satisfier as identified by Max-Neef through the satisfaction of a range of several fundamental human needs as identified in *Table 2*[104].

In the neighbourhood of this installation, the SWH system also sparked a great deal of interest and many neighbours came around asking where and how they could get a similar system. Unfortunately, finding out what the cost of an installation was, left many of these interested persons dismayed, illustrating the need to find ways of reducing the costs of SWH technology to make it accessible to people from these communities. Reaction from the neighbourhood was so positive that family members from across the street started to fulfil their own water heating requirements by fetching buckets of hot water from the SWH installation. Across the road from 56 Hoek Street, Jacoba Arendse, Bet Arendse's daughter, her partner and their child have also substituted all their hot water requirements by tapping two large buckets of hot water from the SWH. In their case the SWH offers an additional benefit of increased safety. The small family used to heat all their hot water on an open heating element that was made to balance on bricks. The device contained open electrical wiring and presented a massive danger of causing injury or even fires. After the installation of the SWH across the street this device was only used for cooking which greatly reduced the safety risks as well as the time spent heating water.

4.1.1.3 Municipal Data on Electricity Usage

At the end of the study period the electricity usage data for the two case study homes was drawn from the Stellenbosch Municipality Electricity Department. Table 11 shows the monthly statistics for electricity usage in these homes during 2008 and 2009 whilst Figure 42

[103] "It has now become a real pleasure to wash [oneself]"

[104] Of course excluding the local economic development benefits that are also identified there

provides graphical representations of the comparative electricity usage and cost[105] thereof for 2008 and 2009.

[105] All cost calculations are based on 2009 rates for electricity in Stellenbosch. These were a daily charge of R2.70 + R0.70 per unit of electricity used . For low income homes the basic electricity grant of 50 units was subtracted from the total cost and the daily charge was not brought into consideration as this is a fixed cost.

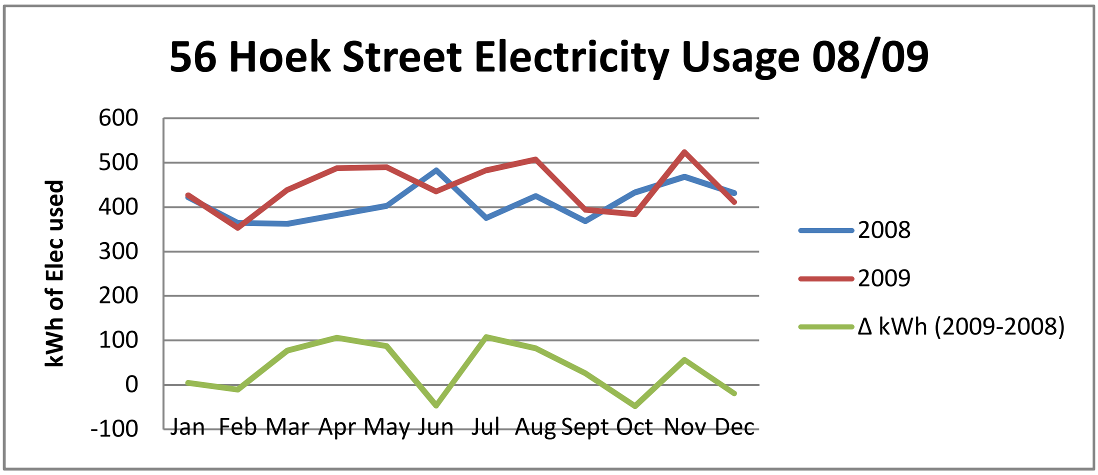
Table 11 Municipal Electricity Usage Data (Stellenbosch Municipality Electricity Department 2010)[106]

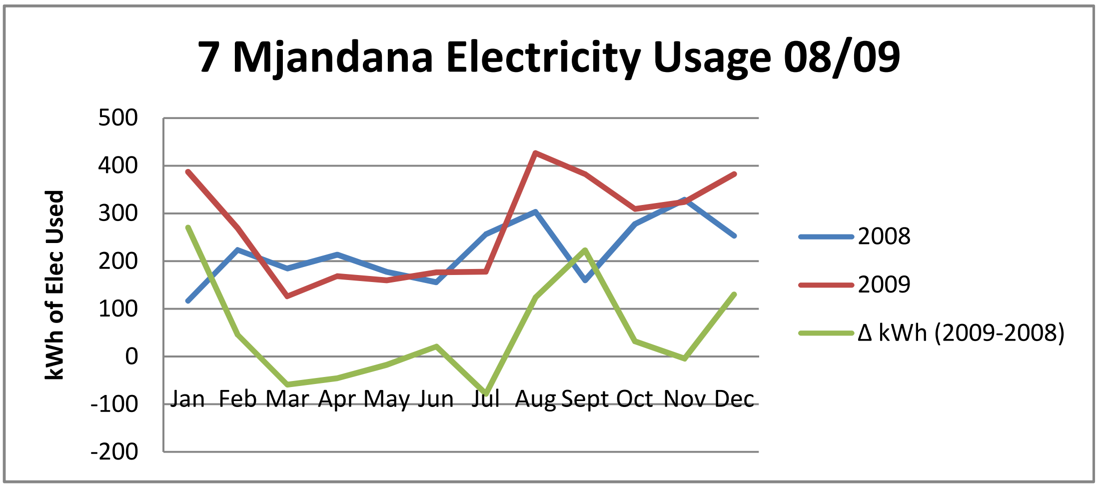
56 Hoek Street						
	2008		2009			
	kWh's	Cost	kWh's	Cost	Δ kWh (2009-2008)	Δ Cost (2009-2008)
Jan	422	R 297	426	R 301	4	R 3
Feb	364	R 251	353	R 242	-11	-R 9
Mar	362	R 250	439	R 311	77	R 61
Apr	382	R 266	488	R 350	105	R 84
May	402	R 282	489	R 351	87	R 70
Jun	482	R 346	435	R 308	-47	-R 38
Jul	375	R 260	482	R 346	107	R 86
Aug	425	R 300	507	R 365	81	R 65
Sept	368	R 255	394	R 275	25	R 20
Oct	432	R 306	384	R 267	-49	-R 39
Nov	468	R 334	523	R 379	56	R 45
Dec	431	R 305	411	R 289	-20	-R 16
Total	4913	3451	5329	R 3 783	416	R 333
Average	409	288	444	R 315	35	R 28
Total Jan-May	1932	R 1 345.76	2194	R 1 555	261.8	R 209.4
Average Jan-May	386	R 269.15	439	R 311	52.36	R 41.89
Total Aug-Dec	2124	R 1 499.20	2218	R 1 574.56	94.2	R 75.36
Average Aug-Dec	424.8	R 299.84	443.6	R 314.91	18.84	R 15.07

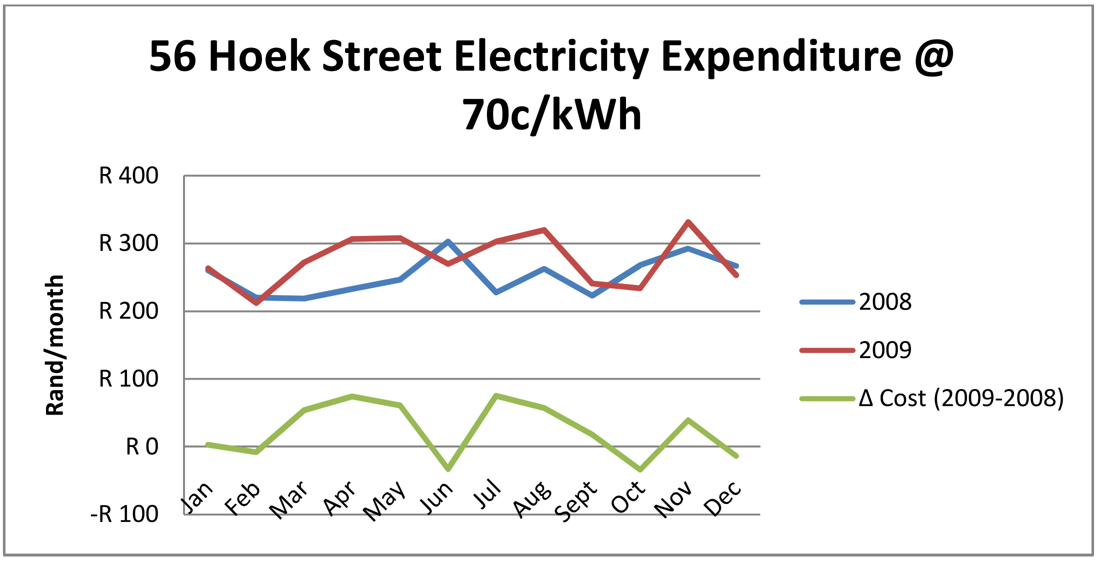
7 Mdandana Street						
	2008		2009			
	kWh's	Cost	kWh's	Cost	Δ kWh (2009-2008)	Δ Cost (2009-2008)
Jan	117	R 53	387	R 270	271	R 216
Feb	223	R 139	269	R 175	46	R 37
Mar	185	R 108	126	R 61	-59	-R 47
Apr	214	R 131	168	R 95	-46	-R 36
May	177	R 102	160	R 88	-17	-R 14
Jun	156	R 85	177	R 101	21	R 16
Jul	256	R 165	178	R 102	-79	-R 63
Aug	303	R 203	427	R 302	124	R 99
Sept	160	R 88	383	R 266	223	R 178
Oct	278	R 182	309	R 207	31	R 25
Nov	329	R 223	324	R 219	-5	-R 4
Dec	253	R 162	383	R 266	130	R 104
Total	2650	1640	3290	R 2 152	639	R512
Average	221	137	274	R 179	53	R43
Total Jan-May	916	533	1110	R 688.24	194.6	R 155.71
Average Jan-May	183	107	222	R 137.65	38.93	R 31.14
Total Aug-Dec	1323	R 858.08	1825	R 1 260.32	R 502.8	R 402.24
Average Aug-Dec	264.5	R 171.62	365.1	R 252.06	R 100.6	R 80.45

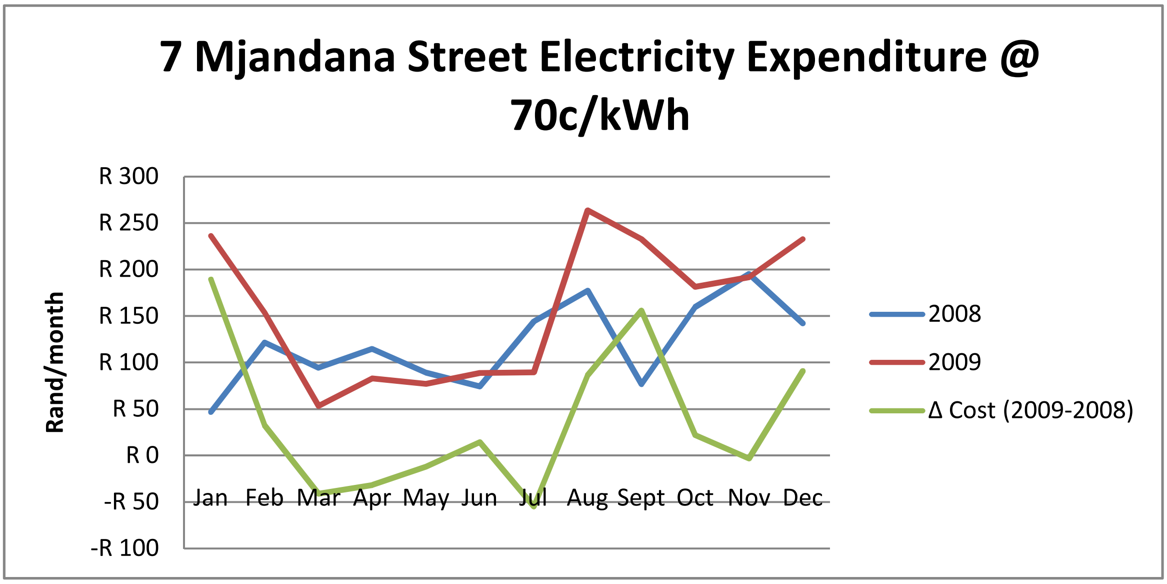
[106] The months wherein SWHs were installed and operational are shaded in pink.

Figure 42 Graphs Representing Electricity Usage and Cost at Case Study Homes during 2008/09









The data from the municipal meters do not bear out the qualitative findings of the interviews, nor the quantitative estimates of electricity that should be saved due to the installation of the SWHs. Subsequent interviews were conducted with both case study households to identify reasons why their estimates of what they were spending on electricity were so far off from what the municipal meters showed. Based on these further discussions likely reasons why a misperception about electricity expenditure exists include;

- The residents have limited understanding of the municipal electricity billing system. According to this system a fixed daily levy as well as a per unit charge is paid every time a household purchases electricity. The fixed levy arrears are subtracted from the payment before the balance is allocated to additional units. Because this fixed levy is multiplied by the number of days since their last purchase it varies and they do not understand the calculations behind that. All that they see is that sometimes a R20 purchase only provides 4 or 5 units and that the same expenditure a few days later provides them with 18.25 kWh's of electricity. This makes budgeting electricity expenditure very difficult.
- They buy small amounts of electricity on a need/ability basis. Electricity is purchased as it runs out and only to the extent that disposable income, which is variable itself, is available at that time. This ad hoc electricity purchasing process means that households struggle to keep track of how much they spent on electricity over a longer period of time.
- Each house has a backyard shack wherein tenants live. These tenants use electricity from the main house (but not hot water) and their electricity usage patterns are unknown to the residents of the main household.
- Increases in the price of electricity make it difficult for homeowners to understand which portion of increased expenditure on electricity is attributable to increased usage and which is attributable to price increases.

Given that these are the information constraints in discussing electricity usage with the case study households, the follow-up interview to investigate the disparity between municipal records, stated electricity savings and calculated electricity savings offered very few real insights. Both households maintain that they experience the SWHs as making a significant electricity saving contribution and that no other significant factor in their electricity usage behaviour changed. Possible factors discussed with households as potential reasons for increased electricity use in 2009 as opposed to 2008 include:

- An increase in household residents or backyard shack dwellers
- The acquisition of new electrical appliances
- The rebound effect according to which household residents could be less circumspect with electricity use due to perceived electricity savings generated by the SWH.
- They were still using electrical kettles and stoves to heat water.

Interviews indicated that none of these suggested reasons to account for the increased/stable electricity usage levels. The rebound effect was particularly difficult to assess, but interviews and discussions seem to indicate that residents have not become less circumspect in their expenditure on electricity, none of the homes had acquired any additional electrical appliances and the backyard dwellers had not increased. Both homes also reiterated that the hot water provided by their SWH was sufficient for their needs and that they no longer heated water by any other means (save for cooking and hot beverages.)

The reasons that the households themselves suggested for the increased electricity usage levels were;

The stove in 56 Hoek Street had been malfunctioning, requiring up to 2 hours to make a plate hot enough to cook on. The stove's light also indicated that it was on even when all switches had been turned off. This problem had been most acute since January 2010 but it is possible that its effects could have already impacted the electricity account in late 2010. Furthermore, women of the house are washing their hair more frequently and have thus started using hairdryers more often. This behavioural change could lead to a slight increase in electricity usage, but could not by itself account for additional electricity usage of 100 units per month. Other than the increased hair dryer use, no new appliances had been bought and no existing appliances were being used more often. The only new addition is one external light which is only switched on occasionally.

At 7 Mdandana a backyard shack was put up during December 2009 but no new residents had moved in prior to that. The residents also indicated that they had not acquired any additional electrical appliances or lights and that they were not purposefully spending more on electricity.

The conclusion drawn from this data is that it is very difficult to isolate a single source of electricity usage in these homes and to attempt to induce absolute electricity usage savings from these interventions. The case study indicates that SWH does offer a developmental service by increasing quality of life through the provision of hot water, but the effects on available disposable income are ambiguous. It is possible that one place where the additional disposable income was spent was on electricity through modified behaviour according to which residents felt that they could be more relaxed in their electricity expenditure because they were saving elsewhere. The five month period of analysis is too short to make reliable inferences about long-term electricity usage trends, but what can be deduced is that SWHs improve quality of life without adding additional stress to the electricity grid. Implicitly SWHs are therefore a means to decouple human development from increased greenhouse gas emissions by averting the need to generate more electricity as more fundamental human needs are fulfilled. Electricity usage increased in both households over the year on year January to May period as well as over the August to December period. Had electrical geysers been installed the increase over the year on year August to December period might have been much larger.

Unfortunately there is also a possibility that the statistics could be influenced by the research process itself. In both homes there is a spike in electricity usage during August 2009. This could very likely be in part due to the electricity used during the installation of the SWH systems[107] and especially due to payment given to residents of the homes to assist with the distribution of the demand analysis surveys. These payments provided each household with additional disposable income during the July/August period. It is possible that a large part of the additional income could have been spent on electricity.

A question for further research that arises from these findings is how the installation of SWHs affected overall water usage in the households. It is possible, and in fact probable, that the installation of SWHs has led to increased water usage and therefore that large rollouts of the technology could place further strain on already stressed water resources in the Western Cape Province. This problem has an ethical implication in that low-income households cannot be expected to maintain their low level of resource use while others use much more resources and a realist implication in that there may not physically be enough hot water available in the province to allow for everyone to use much more water. It is suggested that further research should be conducted to investigate these implications.

4.1.1.4 Summary

The case study indicates that SWH does provide an improvement in quality of life for low-income households and that they are efficient water heating devices. SWHs are able to substitute electrical heating appliances for all water heating purposes but cooking and hot beverage making. Unfortunately the absolute effect on electricity usage, and therefore harmful emissions from power stations, is difficult to determine from these case studies as other factors such as faulty appliances and additional sources of income have unrelated impacts on electricity usage that hide the effects of the SWHs. The fact that at least some of the “saved” expenditure on electricity attributable to the SWHs is again spent on electricity used for purposes other than water heating creates a rebound effect that masks the efficacy of SWHs. This additional expenditure on electricity would have occurred due to any developmental increase in disposable income and the SWHs cannot be seen as the cause of that increase, unless the objective is to maintain low-income households in a state of energy poverty. For the households that were part of the case study the SWHs, would also have the added benefit of protecting them against the projected Eskom electricity price increases.

The conclusion from these findings should be that SWHs improve quality of life by providing water heating and reducing the electricity used for that purpose, which does free up additional disposable income, which is spent on services, such as electricity, which in turn improves quality of life. If electrical geysers had been installed, the additional electricity usage would likely have been higher whilst no more electricity would have been used to satisfy other fundamental human needs. In such a scenario greenhouse gas emissions due to the level of energy usage in the households would also be drastically higher as development would not have been decoupled from electricity generated by coal power stations.

[107] Both households were given some money to compensate for electricity used during the installation but unfortunately the exact amount used was not verified

The conclusion is that SWHs do offer a developmental service and that the environmental and electricity demand reduction effects that they have are relative to development based on conventional electricity as compared to growth using off-grid renewable energy.

4.1.2 DEMAND ANALYSIS SURVEYS

In order to investigate how replicable the findings of the case study was and how SWHs might impact the lives of similar low-income households, a demand analysis survey was conducted in parallel to the case study. Its purpose was to quantify typical hot water usage in low-income households in Stellenbosch. Such an analysis was deemed essential in order to understand the service that SWH can provide to low-income communities in Stellenbosch and the wider Western Cape and as such at which price levels the technology would become a worthwhile intervention. Though the sample size was relatively small (90 households out of the total of roughly 12 000 low income households in greater Stellenbosch) the results correlated well with similar surveys done as part of the Kuyasa CDM project (Kuyasa CDM 2008, 2009). It offers interesting insight into the hot water usage patterns of low-income households in Stellenbosch. The findings and their implications are discussed below. The full questionnaire is available in *Addendum B: Questionnaire used for Hot Water Usage Survey in* Stellenbosch

Table 12 Key Findings of Demand Survey

Average stated electricity bill per month	R510[108]
Average expenditure on paraffin per month	R0
Average number of males in household	2.46
Average number of females in household	2.85
Average household size	5.35
Percentage of households with a working electrical kettle	96.39%
Percentage of households with a working electrical stove	97.59%
Percentage of households with a working paraffin stove	1.20%

[108] Written permission and a copy of each home owner's ID document are required to gain access to municipal electricity accounts. Households also do not receive electricity bills as they use prepaid electricity meters. As such it was impossible to see the actual electricity bills.

Percentage of households with a working gas stove	4.82%
Percentage of households with a working refrigerator	91.57%
Percentage of households with a working electrical geyser	10.84%
Percentage of households with a working electrical geyser that have switched it off due to financial constraints	71.43%
Percentage of houses using an electrical kettle as primary water heating method	95.78%
Percentage of houses using a pot on the stove as primary water heating method	21.69%
Percentage of houses that sometimes use an open fire to heat water	4.22%
Percentage of houses with a working washing mashing	59.04%
Average number of small baths per person per month	21.34
Average hot water consumption per household per month for small baths	288.64*l*
Average number of large baths per person per month	6.28
Average hot water consumption per household per month for large baths	362.33*l*
Frequency of washing hair per month: males	5.52
Frequency of washing hair per month: females	6.35
Average hot water consumption per household per month for hair washing	87.26*l*
Average frequency of laundry washing per month	7.9
Average hot water consumption per household per month for laundry	1.18*l* (only four of the 85 respondents actually use hot water for laundry)

Frequency of washing floors per month	16.52
Average hot water consumption per household per month for washing of floors	14.37*l*
Average frequency of washing dishes per month	62.86
Average hot water consumption for dishwashing per month	160.53*l*
Average hot water consumption for hot beverages per household per month	122.5*l*
Total volume of hot water used per month (cooking and hot beverages excluded)	914.69*l*
Average household income per month[109]	R2198
Average electricity used to heat hot water (hot beverages and cooking excluded)	98.63kWh
Average cost of electricity for water heating per month (hot beverages and cooking excluded)[110]	R69.04
Average amount of CO2 emitted per household per month due to heating of water in electrical kettles (hot beverages excluded)	98.6kg
Average amount of CO2 emitted per household per year due to heating of water in electrical kettles (hot beverages excluded)	1183.51kg

Surveys completed as part of the Kuyasa CDM project (Kuyasa CDM project 2008, 2009) found that, of 1774 household respondents, 10% spent less than R30 a month on electricity during winter, 72% spent between R31 and R100, 49% spent between R101 and R200, 12% spent R201 to 300 and 7.7% spent more than R301 on electricity per month during winter (Kuyasa CDM project 2008; Kuyasa CDM project 2009). The smaller survey completed in

109 This figure should be regarded with scepticism as few households were willing or able to provide their monthly income figures. Those that did often only provided figures for income received from state child support grants and pensions. In many of the households the parents work part-time whenever employment opportunities are available but the income from such opportunities is highly variable and they found it difficult to pin an average monthly figure to the amount. Despite efforts to prevent interviewer bias it is suspected that there was a strong perception that lower income figures would paint a more desperate picture, ultimately leading to faster realisation of government support initiatives. It is also suspected that some respondents were not convinced that the survey results would not be given to tax collection officials leading to further distortions.

110 Based on 2009 electricity rates in Stellenbosch of 70c/kWh.

Stellenbosch for this thesis found average electricity expenditure figures to be much higher. Though the households surveyed in Kuyasa are likely from a slightly lower income bracket than those surveyed in Stellenbosch both survey populations fall in roughly the same LSM group, between 5 and 8, and it is suspected that the electricity figures stated were inflated due to an upwards bias created by the presence of the researcher. It is possible that the research process created the perception that households might receive SWHs if their electricity bill was high. Based on the municipal accounts for the case study households and their own stated electricity bills it is likely that monthly figures were inflated by roughly R100.

Nevertheless the survey does indicate that electricity expenditure in these income groups comprises a significant part of monthly expenditure and that future rises in electricity prices will have a large impact on poverty levels in these communities. The data assembled on hot water usage is deemed to be more accurate as households seemed more comfortable in providing answers to these questions and the link between these figures and possible future benefits were less obvious. By finding out how much hot water was used per month for personal hygiene, dishwashing, laundry, hair washing and household cleaning it was possible to work out a figure for the monthly costs of water heating as 95.8% of households use an electrical kettle as their primary water heating device[111]. Based on the assumption that electrical kettles are the primary water heating devices the power rating of a typical electrical kettle was used to determine the amount of electricity used to heat water. Most households use a 1.7l capacity 2000W electrical kettle that takes an average of 5.5 minutes to bring 1.7 litres of water to the boil. The total amount of electricity used to boil 1.7 litres of water can then be calculated as:

$$2000W * 0.09166667\ hours = 183.3333334\ Wh = 0.1833334\ kWh$$

Based on this calculation it was found that houses spent an average of R69.04 per month on water heating. Based on the case study of installed SWHs it is very likely that these households would be able to substitute a very large portion, if not all, of their electrical water heating with hot water from a SWH[112]. If a conservative figure of 80% is used households could save around R55.23 per month and R828.45 per annum on their electricity bills due to the installation of SWHs (if all current water heating was substituted). Based on the findings in 56 Hoek Street at least some of these households would also experience a significant improvement in their quality of life through the installation of SWHs. From an environmental perspective the installation of SWHs would save 0.947 tonnes of CO_2e emissions per household per annum (again this is in line with the findings in Kuyasa). The implications of such savings for Stellenbosch and the Western Cape are discussed in section 4.3. Based on the findings of the demand side case study and calculations a payback period calculation for SWH in low income households is provided below.

[111] The totals for percentages of households that use different water heating devices come to more than 100% because some households indicated that they sometimes use a different device than the electrical kettle for water heating. These responses were counted for both the devices used (with a reduced weight for the device used less frequently).

[112] In this case the different water usage patterns of the case study households proved useful in that it showed that SWHs can provide all hot water required in households whether they use relatively small or large amounts of hot water

4.1.3 PAYBACK PERIOD CALCULATION

The case study indicated that SWHs are able to fulfil all water heating requirements in low-income households and that these do lead to savings on electricity used for water heating (though admittedly not on absolute electricity expenditure). The experience of 56 Hoek Street also indicates that the free availability of large amounts of hot water do fulfil some of the fundamental human needs identified in *Table 2*. The payback period calculation provided below will evaluate how attainable these benefits are for low-income households if they had to purchase the systems for themselves. It thus tests the part of the research hypothesis which states that the benefits of SWH *"cannot be realised without government sponsored intervention or regulation due to the high prices of the technology."*

The calculation is based on the data obtained in the demand side survey as well as average prices for SWHs obtained during supply side interviews. It has been established that an actual real saving of R55[113] might not be observed in electricity expenditure but it is assumed that the savings that are made are spent on electricity used for other purposes, still leading to increased quality of life and the fulfilment of additional fundamental human needs.

[113] If SWH can replace 80% of electricity used to heat water

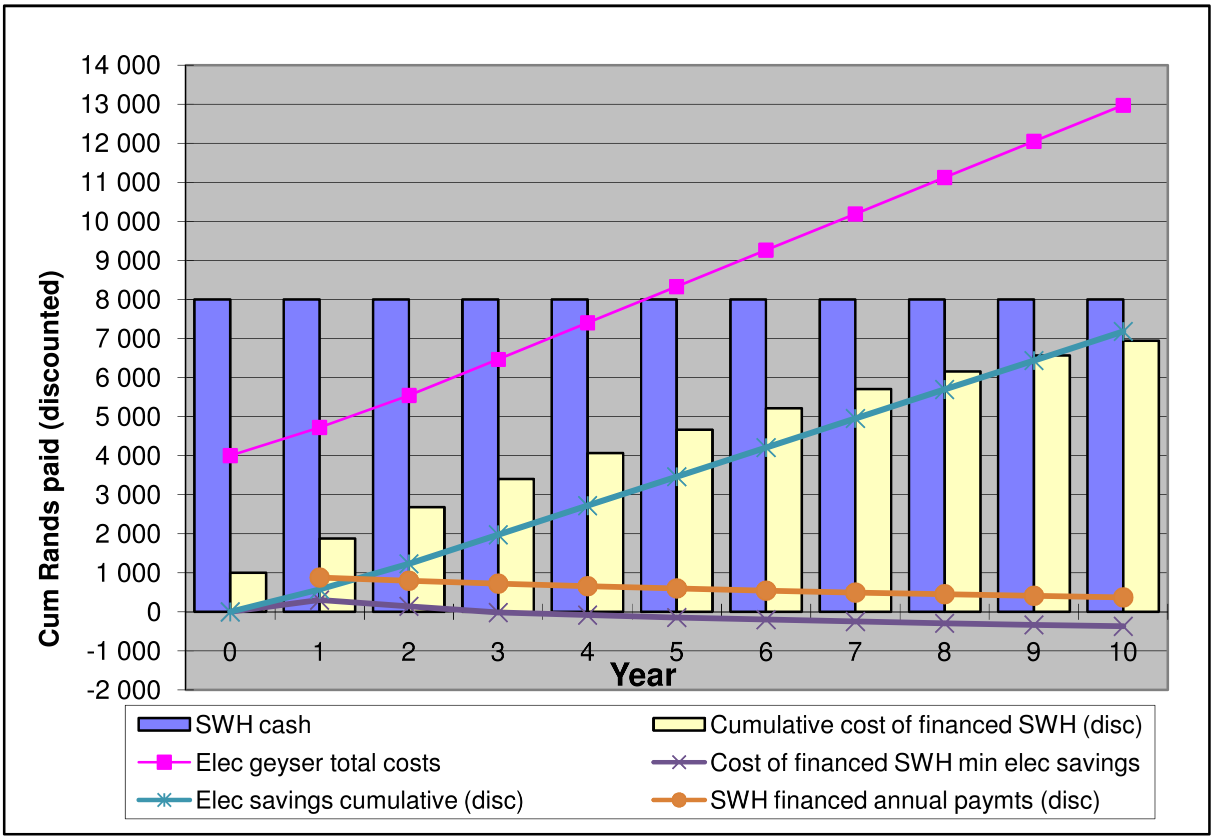
Table 13 Assumption Table for Payback Period Calculation		
Factor	**Cost/ Rate/ duration**	**Source**
100*l* Electric geyser cost (incl. installation)	R4 000	Average figure based on Klune 2004, Delport 2005 and Van Gass 2005 cited in Holm 2005:41-42, European Union & Republic of South Africa: Support Programme for Social Housing 2007, p.5, Geyserexperts 2010; Plumbing Masters 2010 assuming that electric geysers could also be more cheaply installed for larger rollouts.
Estimated contribution of water heating to electricity bill	R60	Table 12
Flat-Plate SWH cost (incl. installation)[114]	R8000[115]	For large scale rollouts based on industry survey
SWH elec. cost/month	R0	For systems installed without electrical backup
Finance rate	11%	Benchmark figure
Financed over (years)	20	
Elec. Inflation Rate (Years 1-3)	25%	(Pringle 2009; PMG 2009; Creamer 2010)
Elec. Inflation Rate (Years 4-20)	10%	Conservative assumption
Discount rate	10%	Benchmark figure

[114] The expected lifetime of a flat-plate SWH is at least 10 to 15 years (Eskom DSM 2010a). After ten years additional maintenance costs are possible. Most systems are guaranteed for five years (Eskom DSM 2010a). Based on interviews with SWH flat-plate suppliers as well as the very low failure rate in the Kuyasa and Western Cape SWH (Hertzog 2009, Wesselink 2010) rollout programs the assumption is that maintenance costs will be 0 for the first ten years of operation. Similarly it is likely that an alternatively installed electrical geyser will require maintenance/replacement after ten years and maintenance costs are therefore not included in the comparative analysis.

[115] Eskom rebates are not currently available on low-cost systems. SWH suppliers are unwilling to get their low-cost systems SABS certified due to the lack of a large market for the systems. Only when a guaranteed market of several thousand systems is secured will suppliers submit their systems for SABS testing. An Eskom subsidy could feasibly reduce system cost to R6000.

Estimate reduction in electricity used for water heating through the installation of a SWH in a low-income household	80%	Based on case study completed for this thesis

Figure 43 SWH vs. Electric Geysers Cost Comparison (Cumulative) Low-Income Sector[116]



[116] Refer to the Spreadsheet entitled *Low Cost SWH Payback Calculations* on the attached CD.

Figure 44 Sensitivity analysis for figure 41

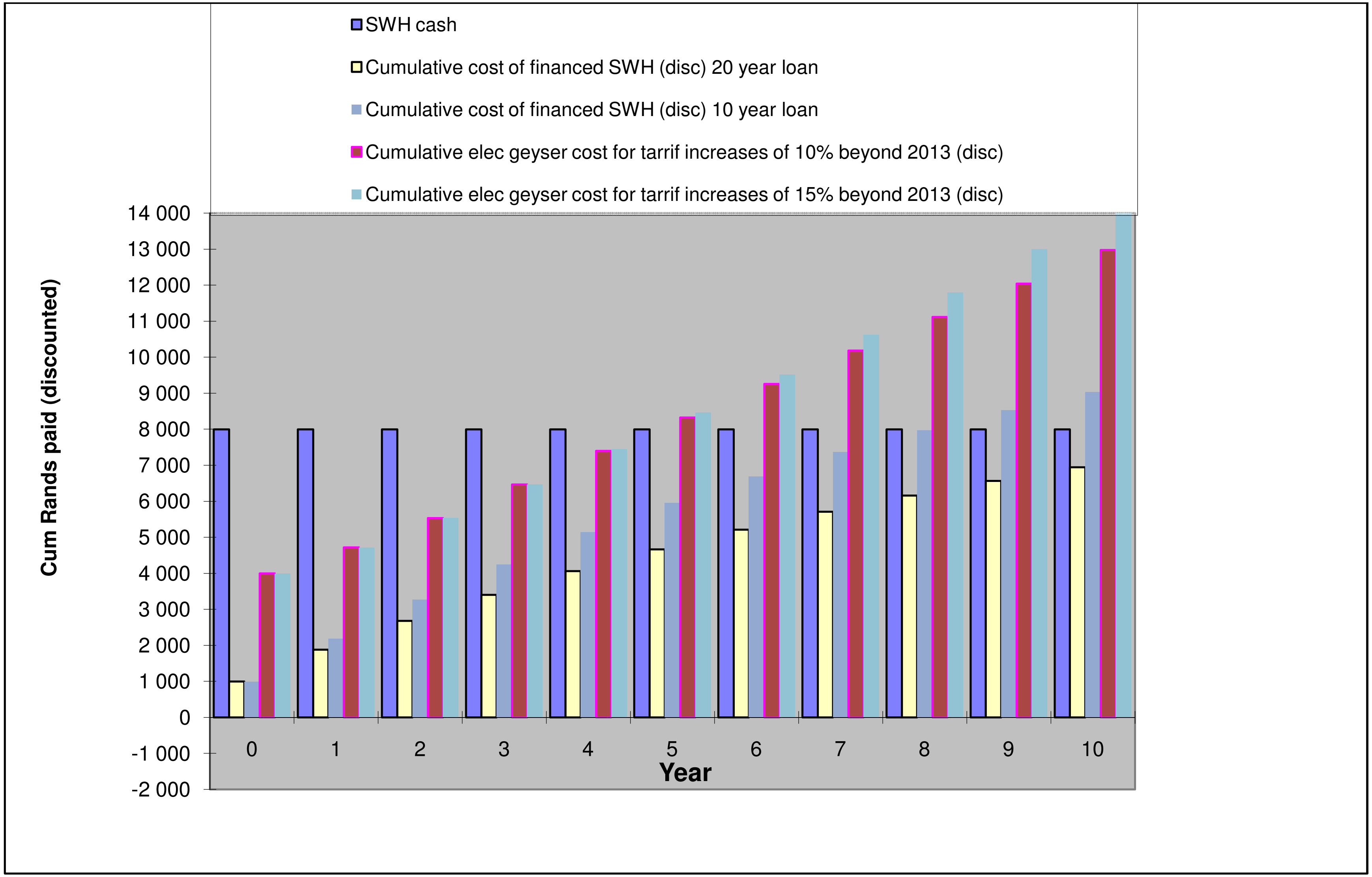


Figure 45 Annual Cost of Financed SWH for different assumptions

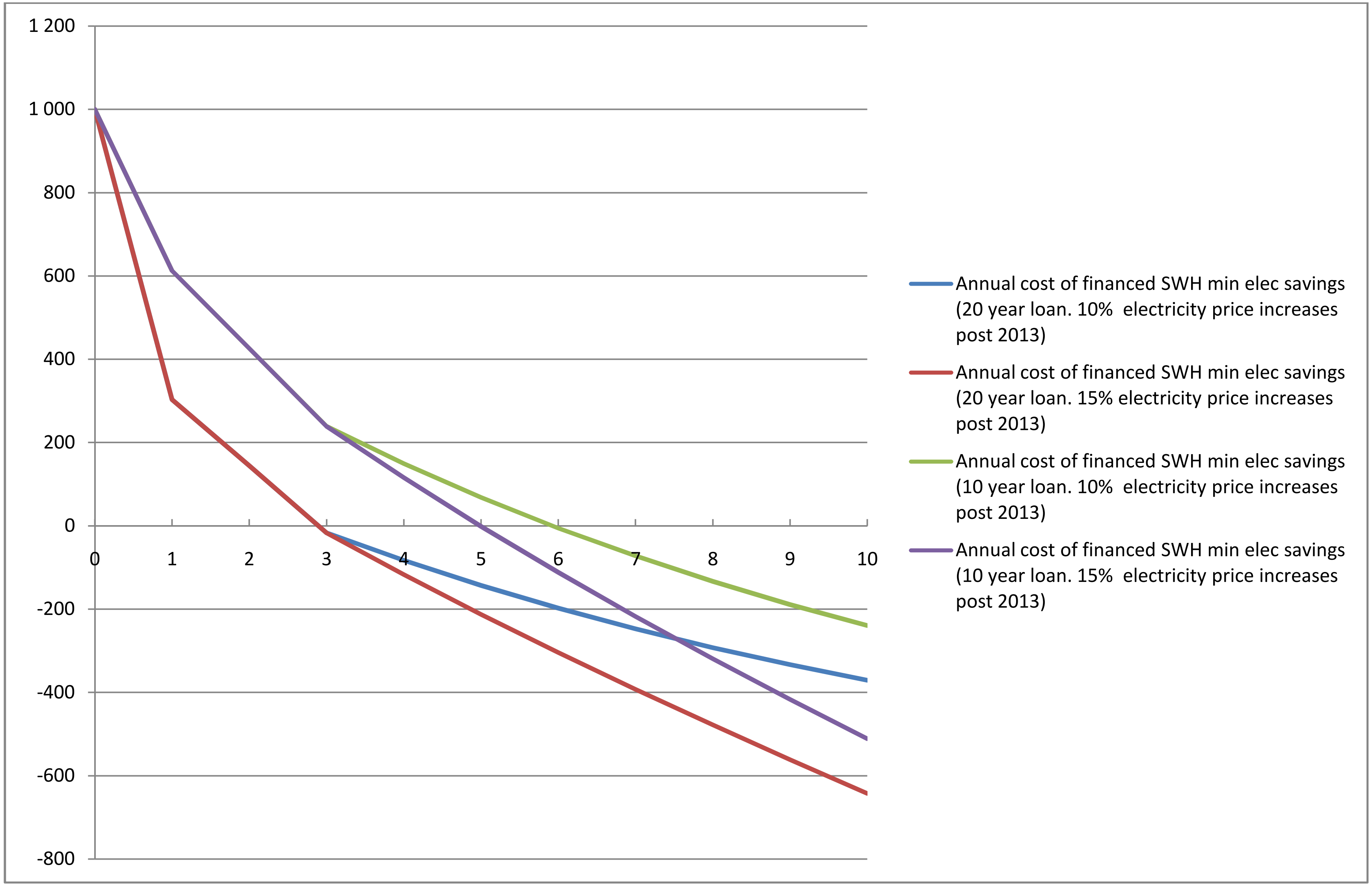
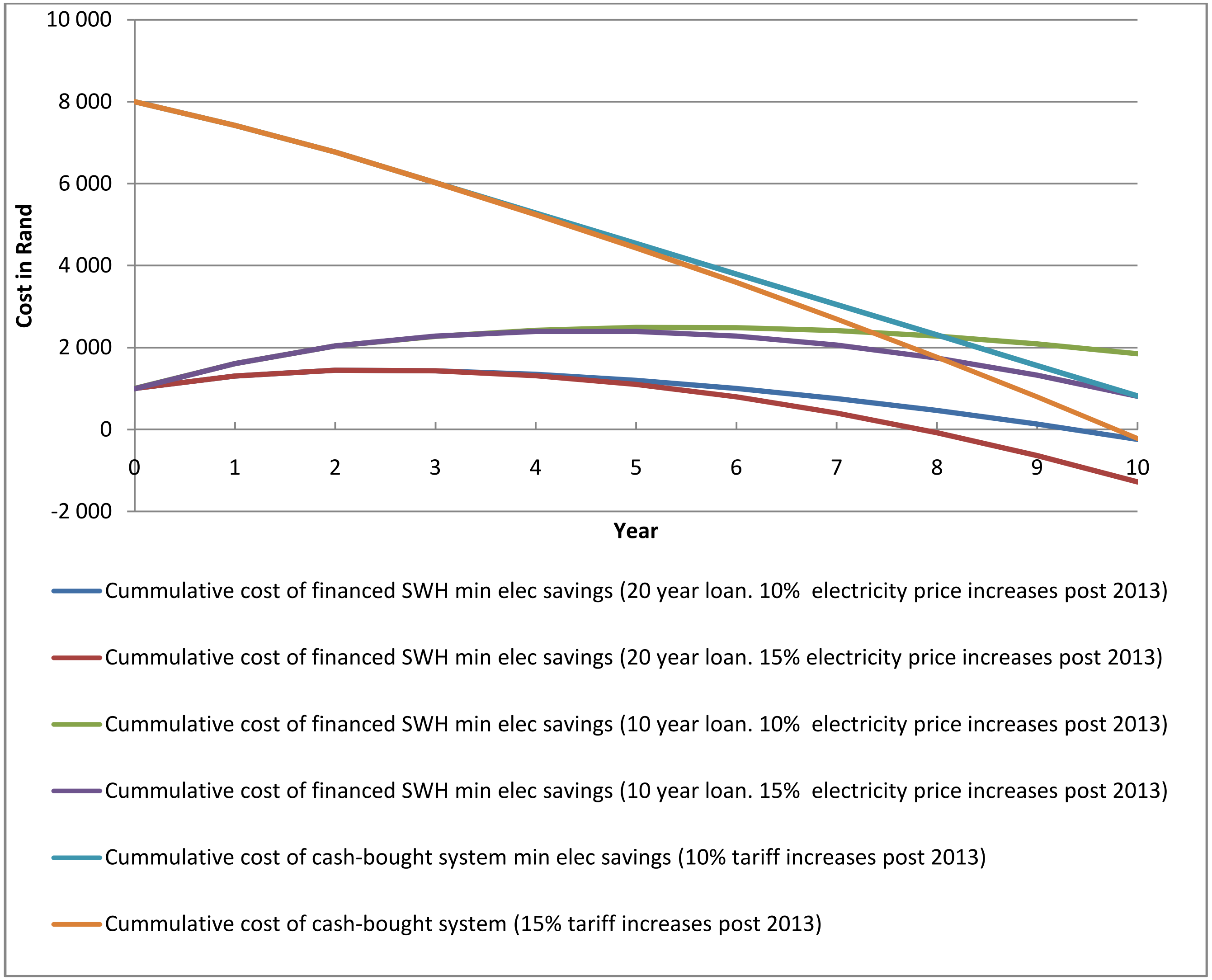


Figure 46 Cumulative Cost of SWH for different assumptions



From Figure 43 to Figure 46 it can be deduced that:

- The value of a SWH bought without any financing will not be recuperated through electricity savings within 10 years whether electricity tariffs increase by 10 or 15% post 2013.
- A SWH financed over 20 years will earn more in electricity savings per annum than the annual loan repayments after 3 years. If electricity tariffs increase at 10% per annum post, 2013 such a system will have paid off the initial deposit by the 10th year. If electricity tariffs increase at 15% post 2013 such a system will have paid off the initial deposit by the end of the eighth year.
- A SWH financed over 10 years will earn more in electricity savings per annum than the annual loan repayments after 5 years if electricity tariffs increase at 15% post 2013 and after 6 years if tariffs increase at 10%. Such systems will not have paid off their initial deposits within 10 years.

Compared to electrical geysers SWHs are a much more attractive investment (especially considering that that typical flat-plate collectors have been proven to last for 20 years (Ebb 2010) [whilst electrical geysers have lifetimes of around 10 years (NPPD 2010)], but the large capital expenditure and/or inability to access soft loans make them inaccessible to low income communities. Figure 46 and Figure 45 show that if soft loans are not available for the procurement of a SWH system, it could take up to 6 years before annual electricity savings exceed annual loan repayments. Even if 20 year loans are granted to low-income households the SWH would still be a net drain on resources for the first three years. Low-income communities are simply too poor in financial capital to be able to afford an expensive technology such as SWH. If the quality of life improvements offered by the availability of hot sufficient quantities of hot water are to be realised in low-income communities, some form of government intervention or the development of an alternative financing systems will be necessary. The free market has shown that it is unable to balance the supply and demand for the services delivered by SWHs. The externality benefits of the technology in terms of environmental and energy security, that are not reflected in prices, as well as the historic subsidisation of fossil fuels, prevents market forces from delivering SWHs at a price which maximises the potential of the technology. The suggestions made by this thesis will focus on the role that government can play in achieving the rollout of SWHs in low-income communities.

Of its own accord the private sector has not yet provided financing schemes for low income consumers to purchase solar water heaters. This is probably due to the perceived high risk of payment defaults in low income markets. It is therefore suggested here that government fulfil the role of a financing institution to facilitate the rollout of SWHs in low-income communities. The government has an added incentive to fulfil such a function that traditional private financiers do not have. Through encouraging the rollout of SWHs the government can achieve service delivery targets by giving low-income households the opportunity to enjoy the benefits of modern renewable energy services whilst wider of objectives of reducing electricity demand (or at least decoupling economic development from electricity usage to an extent) and greenhouse gas emissions can be achieved. The part of the research hypothesis under discussion has thus been proven to be correct. The rollout models developed in section 4.3 show that government can effectively play the role of a financier by subsidising the up-front capital investment required and then recovering its investment through the sale of carbon credits and the collection of small monthly payments from the households that have received the systems.

The approach advocated by this thesis is that government should bear the complete costs of installing SWHs for low-income communities in order to realise the maximum social benefits but a possible alternative approach would be the provision of soft loans to low-income households for the purchase of SWHs. The model in Figure 43 suggests a finance rate of 11% and a deposit of R1000. A financed SWH saves the consumer more money than it costs him/her after 3 years and after 6 years the initial capital expenditure of R1000 would be reclaimed through cumulative savings. Qualitative interviews with the case study households indicated that, because these income groups often have no income security, they would be very sceptical of such loans as they cannot guarantee their ability to pay it off. Such loans are however an alternative that warrants further investigation. There may also be other alternatives for public-private cooperation through community saving schemes or through NGOs that have access to international donor funding. As will be discussed under the supply side value chain analysis below, it is necessary that a large, reliable demand for SWH systems be created in order to develop the local industry to an internationally competitive level. To achieve this, a very large initial investment is required that would convince local SWH manufacturers that they will have a dependable market for low-cost systems for many years. Government is the only institution that would be able to provide such assurance unless the large banks decide to become involved.

The model shown in Figure 43 is based on two assumptions that could change quite drastically. NERSA has yet to indicate what the electricity tariff increase will be post 2013 and the projection that they will increase by 10% may be too low. A 20 year loan for the purchase of a solar water heater may also be too long a repayment period and 10 years may be more realistic. Figure 44 provides a comparison of the costs of low-cost solar water heaters and electrical geysers based on different levels of these variables. From the figure it can be seen that faster increases in electricity tariffs shorten the payback period of SWHs significantly. An R8000 system financed over twenty years will save more money than the annual loan repayment after only 4 years if electricity prices increase at 15% per annum after 2013. This illustrates how large a difference South Africa’s relatively cheap electricity makes in the financial argument for renewable energies. The figure also illustrates how much larger the financial burden of a SWH is if soft loans cannot be accessed and the system has to be repaid within 10 years. At electricity price increases of 10% after 2013 it will take 7 years before electricity savings from the SWH becomes larger than the annual loan repayment.

Government attempts to increase usage of the technology in low-income communities should strive to facilitate cost reductions that would eventually eliminate the current price barrier. If this can be achieved the market could eventually become self-sustaining and lead to the development of a South African low-cost SWH export sector. Entrepreneurs and business investors, as well as currently involved industries, also need to understand what the cost drivers in the SWH value chain. This information could help them to make intelligent business decisions that could eventually lead to the development of systems that are more affordable in low-income contexts. The supply side value chain analysis provided below discusses the barriers to cost reduction as well as the potential for job creation through the industry in order to further investigate the price barriers and synergic benefits identified in the research hypothesis. Research questions 2, 1.4, 2.1 and 2.2 are answered during this process.

4.2 FINDINGS OF SUPPLY SIDE VALUE CHAIN ANALYSIS

Two key elements of the research hypothesis for this thesis are that; cost barriers are the primary obstacle preventing the mass rollout of SWHs[117] in low-income communities and that a mass rollout of SWHs could be a synergic satisfier of fundamental human needs, in part through generating employment opportunities. The VCA analysis of the SWH industry discussed below tests and elaborates this hypothesis by discussing the cost drivers in the industry as well as the employment creation potential across the entire chain.

The findings of the value chain analysis are used to inform the recommendations section of the thesis through the identification of strategic leverage points where policy interventions might reduce production costs which would enable a mass rollout and thus lead to significant job creation. The insights and data presented in this section are based on extensive interviews with business organisations involved in the SWH industry in the Western Cape.

4.2.1.1 General Comments

Though a myriad of businesses have sprung up in the retail and installation sector of the supply value chain in the SWH industry in the last few years, there are still relatively few collector manufacturers in the Western Cape (Hertzog 2009; Anthony 2009a). From the SESSA (2010) and Eskom DSM (2010b) websites these were identified to be Atlantic Solar, Solarmax and Solardome other businesses in the industry source their collectors from these manufactures or from outside the Western Cape, mostly in Gauteng, China or Germany. Several companies involved in the retail/import sector were also interviewed including TASOL, Solartech, Ecosmart, Solek and ITS solar. Based on these interviews, the Kuyasa CDM project (Wesselink 2009) and the Western Cape SWH project (Hertzog 2009) a system that would satisfy the basic hot water requirements of a family living in a low-cost housing development such as Stellenbosch was identified. The minimum characteristics of such a system should be:

- 80-100l storage capacity
- Close-coupled direct thermosyphon system[118]
- At least 1.6m^2 of collector area
- Electrical backup is not a necessity

These systems do exist and have been proven to be operationally successful, as has been shown in the case studies and in the literature review of existing SWH rollout projects in low-income communities. The suppliers interviewed for the study all agree that the market for the systems does not quite exist yet and that it is unlikely to develop without state intervention. That SWH technology has matured to the extent where it is cost comparative with conventional electricity for water heating is apparent from continued market growth in the middle to high income sector. Many businesses involved in the SWH industry experienced sustained market demand growth during 2008 and 2009 in middle and high income markets.

[117] The literature reviewed also identified the same challenge

[118] Such a system would only work in areas that do not experience frost, typically near the coast.

Despite the economic recession of 2009, the long term trend for sales has remained positive. The increased Eskom rebate of 2010 combined with continued price increase has strong positive effects on sales (Therion 2010; McCallum 2010; Hallett 2010). This strong market growth indicates that people who can afford the capital outlay are turning to SWH as a cost saving device, but the high initial cost remains a barrier to access in lower income groups.

Some SWH manufacturers have however identified the low-income sector as a massive future market and have invested the time and resources in developing relatively low cost SWH systems specifically for this market. In this market the locally manufactured flat-plate collectors and the imported evacuated tube collectors are in direct competition. For larger rollouts of relatively simple installations, low-cost flat plate collectors manufactured in the Western Cape could be provided by companies such as Atlantic Solar and Solarmax for roughly R8000 (Van Dyk 2010; Hertzog 2009). Chinese manufactured imported evacuated tube systems are available from companies such as TASOL solar and ITS Solar for roughly R3500 (Bester 2010; Van Zyl 2009). Installation cost is included in both figures.

On the face of the matter, the imported evacuated tube systems have already broken the price barrier and are available at prices comparable to electrical geysers. For governments supporting SWH rollout programmes, the choice should however not be as simple as a basic cost comparison. There are some concerns about the longevity of the evacuated tube systems[119] and SWH technology would not be a synergic satisfier for fundamental human needs if imported systems were used as the employment creation potential would be much reduced. Imported systems would thus fulfil the definition of sustainable development as adopted in this thesis to a much lesser extent. They would not empower people to fulfil their own fundamental human needs in order to improve their quality of life. It would be an imposed solution to a singular aspect of poverty and it would not address the underlying causes thereof.

It is thus essential to develop an understanding of what the cost drivers are in local SWH industries, so that these can be addressed, as well as what the job creation potential is. Towards this end the general context of the SWH industry in the Western Cape will be overviewed based on the interviews conducted with businesses involved in the value chain. This overview can add on the existing literature on the SWH industry by providing an insight into the reigning circumstances in 2009 which is more recent than the literature sources currently available. After the overview is conducted the specific challenges and opportunities of the local SWH manufacturing value chain will be discussed before the cost drivers and employment creation potential is discussed. Section 4.3 will then provide a model for the potential rollout of SWHs in low-income communities in Stellenbosch and the entire Western Cape as well as the implications of such a rollout strategy.

4.2.1.2 Challenges of the Low Income Market

As part of the value chain analysis study to verify whether cost is in fact a primary barrier in accessing the low-income market for SWHs, companies in the SWH value chain were asked what they perceived as the challenges of entering the low-income market. Currently many established/larger companies such as Solartech are not even considering the low-

[119] Further discussed in section 4.2.2.7

income market. According to James McCallum (2010) the reasons for this are that, the market is too volatile and risky with small margins, that government contracts are too prone to corruption and that the tendering process for government projects is too complicated and politically loaded. Other companies such as Tasol, Solarmax and Atlantic Solar do see the low-income market as a potential opportunity if government does become involved through the sponsorship of large rollouts (Van Zyl 2009, Hallet 2010, Hertzog 2009). The large numbers of systems that would be installed in such projects would make the low-margins acceptable and reduce the risk element. These companies have low-cost systems available that would be suited to such rollouts. At present the customer base for these systems is mostly farms where systems are installed for labourers' homes and pilot projects sponsored by government institutions (such as the Western Cape and Zanemvula SWH projects). Barriers identified by players in the SWH value chain in the Western Cape include;

Primary Barrier: High Initial Costs

The largest barrier to wider private and government interest in SWH for the low-income market remains the capital cost barrier (Wesselink 2010; Hertzog 2009; Therion 2010; Anthony 2009b; Hallett 2010). Even at the reduced prices that low-cost systems have become available at, the expenditure of R3000 to R8000 on water heating technology for a poor household living just above the poverty line is too much. A government confronted by a massive housing shortage also faces difficult trade-off decisions between installing SWHs and providing more housing, even if SWH saves households money in the long run. An encouraging sign is that costs for SWH systems have remained more or less stable and have even fallen in nominal terms over the past few years (Therion 2010). They have generally become much more affordable for middle and high income customers[120] and more cost competitive with conventional electric geysers in low-income groups. High initial costs and relatively long payback periods remain the primary barriers to accessing low-income markets.

Secondary Barrier: Labour Issues

Though the manufacturing of flat-plate systems is relatively simple, labourers still need to receive on-the-job training. The installation of SWH systems is a dangerous job for which workers need to be trained and taught the necessary skills. That systems should be installed perfectly is essential to the success of the SWH industry. As a relatively unknown technology for consumers it is vital that its reputation should not be tarnished by faulty installations (Hallett 2010; Hertzog 2008; McCallum 2010).

Though there are some skills shortages for experienced carpenters and plumbers to install SWH systems, the shortage is not a major issue. Most companies have indicated that they could easily train new/additional personnel to sufficient skills levels. There are however some issues with labourers not staying at companies for sustained periods when they have acquired scarce skills such as plumbing. Companies that have overcome this problem do so by providing continual self-improvement opportunities to labourers as well as attractive financial incentives. Some of the larger companies have also complained that the unionisation of labour is a difficult issue, with increased union influence souring relationships between managers and workers. These difficulties are one of the reasons identified by companies why

[120] Especially with increased Eskom subsidies on SABS accredited systems

they would prefer greater mechanisation at higher output volumes – it becomes too difficult, costly and time consuming to deal with large bodies of unionised workers (McCallum 2010; Therion 2010). Though it is possible that this concern reflects an unwillingness of managers to consider the demands of organised labour in their decision making processes, it is also an issue that needs to be addressed sensitively to ensure that rollout programs lead to the development of as many employment opportunities as possible.

Secondary Barrier: Vandalism/Theft

Though it has not been identified as a problem in existing SWH rollouts in low-income communities, some suppliers are concerned that theft of the collectors might become a major issue for widespread rollouts. Copper theft has been a large problem in the telecommunications industry in South Africa for some time and should these thieves become aware that flat-plate solar collector panels contain significant quantities[121] of copper the systems may become their next target.

Evacuated tube collectors could be vulnerable to vandalism even though they are tested to be hail proof. In low-income communities in South Africa where there have been violent service delivery protests in the past amongst disgruntled community members, evacuated tube collectors would be easy targets (Van Zyl 2009; Hallett 2010). In the case study household, where an evacuated tube system had been installed and leaking problems experienced, the installer speculated that the feeder tank may have been damaged by vandals. The household that had received a flat-plate collector system also had an incident where someone had tried to clamber onto their roof one night for some unknown purpose, possible related to the SWH.

On the positive side, neither the Kuyasa project, nor the KwaNokuthula installations have experienced any such problems (Wesselink 2010; Hertzog 2009). It is probable that larger, community based rollouts are less likely targets for vandals and thieves as the community has a shared interest in protecting their SWH systems. In isolated installations such as the case study completed for this thesis no such community interest is involved and the systems are relatively easy targets due to other members of the community feeling excluded and disadvantaged.

Secondary Barrier: Specific Issues for Local Manufacturers

Many local manufacturers or firms that have investigated the possibility of manufacturing SWH systems or components thereof identify material costs, particularly glass, copper, steel and aluminium, as a major barrier to price reduction (Stohr 2010; Hertzog 2009; Van Dyk 2010; Bester 2010; Anthony 2009b). In large part due to these barriers local systems struggle to compete with imported Chinese systems on price and many companies involved in the SWH value chain offer imported systems as their primary product.

Secondary Challenge: Stable, Long-term Government Support

In most countries, such as Israel and the Barbados, where the SWH market experienced rapid, sustained growth it enjoyed government support, either in terms of financing or a legislative

[121] Roughly 10kg per system with 1.6m^2 collector area based on figures provided by SWH manufacturers

framework. The pattern holds true for South Africa where the industry grew most when it had government support (through awareness raising). Currently the South African Government has expressed support for the industry but tangible interventions have not yet been forthcoming. SWH suppliers that have the ability to deliver low-cost systems for the low-income market are loath to commit much more resources to the development of systems for this market unless government makes real commitments to large-scale low-income community rollouts (Van Zyl 2009; Hertzog 2009; Anthony 2009b; Bester 2010; Stohr 2010). Government needs to become an active participant in the value chain by guaranteeing the demand for low-cost systems and making long-term purchasing agreements with SWH suppliers. This would enable them to scale up their capacities and exploit cost-reduction opportunities. A possible way for government to ensure this demand is by acting as the financing partner that provides the up-front capital for large-scale SWH rollouts as shown in the models in section 4.3.

This factor is listed as a secondary challenge but, in fact if large-scale government sponsored SWH rollouts in low-income communities become a reality it could be a key factor in reducing costs, which would remove part of the initial cost primary barrier.

4.2.1.3 Opportunities of low-cost sector

The companies interviewed that had investigated the low-income market agreed that it presented a massive opportunity if the challenges identified above could be overcome. That the technology has become economically sensible is apparent from the increased interest shown by middle to high income consumers as well as farmers that have systems installed for their workers (Therion 2010; Stohr 2010; Bester 2010). Specific advantages and unique opportunities of SWH in the low-income context as identified by companies involved in the value chain are briefly discussed below:

<u>South African Solar Resources</u>

As was discussed in the literature review, South Africa, even the slightly less sunny Western Cape, has excellent solar resources that are ideally suited to the use of solar thermal technologies. Through its own research and development programmes, Solardome has found that only 36 or 37 days of complete overcast conditions are experienced per year. Three to four hours are sufficient for most SWH systems to heat water to a level that is hot enough for domestic use (Anthony 2009a).

<u>Brad Based Black Economic Empowerment (BBBEE):</u>

Though all of the companies interviewed for this study are owned by white businessmen, the majority of those involved in manufacturing and installation employ labourers and senior managers from previously disadvantaged communities. Though general skills shortages are a challenge, it is relatively easy to train unskilled labourers to contribute during the manufacturing and installation processes and in many of the larger companies such as Solardome, Extreme Geysers and Atlantic Solar workers from previously disadvantaged communities have attained positions of great responsibility as factory floor managers, production supervisors or installation team leaders. The industry has thus already shown that it can contribute greatly to BBBEE and that large rollouts leading to increased industry size would create even more opportunities for BBBEE. During interviews companies have indicated that they would employ additional labour from previously disadvantaged groups should a massive rollout of SWHs become a reality (Hertzog 2009; Therion 2010; Anthony 2009a; Hallett 2010)

Increasing Interest in Wider Southern African Markets

Interest in SWH from South Africa's neighbouring countries is growing steadily, from consumers in the high income sector and also from governments and farmers (also for workers' homes), in the low income sector. Companies interviewed have had particular interest from Namibia[122] and Zimbabwe for low-income systems. In Zimbabwe concerns about energy security and the desire to become grid independent are driving consumers to look for off-grid solutions such as SWH (Hallett 2010).

Simple Installation and Maintenance in Low-Income SWH Rollouts

A major benefit of government sponsored rollouts of SWHs in low-income communities is that the installation of the systems can be done quickly, efficiently and cheaply. In the high income sector each house has a unique roof and challenges that complicate installations and make them expensive, slow processes that can take several days to complete. For large rollout programmes such as those completed in KwaNokuthula and Riversdale the installation process can be standardised due to the homogenous nature of the roofs. Installation teams can also stay in the area and avoid the additional costs of driving between sites. These benefits mean that teams can install multiple systems per day, greatly lowering the installation costs (Wesselink 2010; Hertzog 2009; DME 2002).

Because the systems that are installed in low income households are comparatively simple without complex pumping systems, local community members can easily be trained to fulfil basic maintenance requirements that prolong the lifetime of systems and improve customer experience of the technology. Though an inherent advantage of SWH technology is that it does not require much maintenance, the fact that basic maintenance can be conducted by trained local people allows for the creation of a few long-term maintenance jobs in the communities where SWHs are rolled out. This is a model that has been applied with some success in the Kuyasa and KwaNokuthula rollouts (Wesselink 2010; Hertzog 2009; Van Dyk 2010).

4.2.1.4 SABS Standards

Though SABS certification for SWH systems is currently only a requirement for systems that are installed as part of the Eskom SWH programme, it is suggested that large government rollout programmes should only make use of SABS certified systems. This would ensure that the image of the technology is not tarnished by the installation of sub-standard systems. The SABS accreditation system could also be used to aid the development of the local SWH industry by preventing market dumping from foreign firms.

122 ITS solar have however also mentioned that it is difficult to install systems in Namibia due to the highly corrosive elements in the natural climate (Bester 2010).

Because the SABS system can play such a key role in the rollout of SWH systems in low-income communities, industry perspectives on the accreditation process was investigated as part of the research. The investigation of SABS standards fits into the VCA method by investigating them as a potential barrier to entry. This barrier can have negative as well as positive effects. The standards could be used to protect the South African SWH industry through the imposition of stringent quality controls until the local industry has achieved the scale necessary to compete internationally. Such protection could be useful, especially in the low-income sector where imported Chinese systems are available much more cheaply than locally manufactured systems (Van Zyl 2009). On the negative side the standards could also create a barrier to the development of new technology and stifle healthy competition.

Though most manufacturers interviewed expressed discontentment with the high costs of the SABS tests as well as the long time that it takes for an application to be accepted and passed through the system they would be willing to shoulder the burdens if it became clear that future, government supported, mass rollouts of SWHs would only make use of SABS certified systems (Anthony 2009b; Hertzog 2009; Stohr 2010; Bester 2010; Hallett 2010).

The SABS testing system does make it difficult for companies to innovate and develop new systems because each new system has to be separately tested, even if all the components have been approved in other accredited systems (Hallett 2010). Because margins in the low-income market are so low, it only becomes worthwhile to have a system tested if the supplier can be reasonably assured that there is a probability that thousands of the systems could be sold (Hertzog 2009). This is a typical example of why it is so critical that government should take the lead in financing rollouts of SWHs in low-income communities. In order to make low-income rollouts feasible the standards themselves may have to be reviewed slightly to be more low-cost system specific. Some suppliers have indicated that the current standards are designed for complicated high-income sector installations. These installations are typically high pressure systems with electrical backup – a very different proposition than a basic low-cost system.

The Eskom programme and concurrent SABS testing system have had a significant impact as an awareness raising tool for middle to high income consumers on the benefits of SWH (Hallett 2010). The standards have however made it very difficult for new small and medium sized players to enter the market as the costs of getting systems SABS certified are as high per system as the value of the final rebate for that system. This means that the rebate system has little real price reduction impact. Some suppliers indicated that they only apply for SABS accreditation because customers want to see the SABS mark of approval and not because it enables them to provide their systems at lower costs. With the increased rebates of 2010 the equation has changed to an extent with the value of the rebate per system starting to exceed the cost of accreditation, but of course this depends very much on the scale of production (Stohr 2010; Hallett 2010; Hertzog 2009; Anthony 2009b; McCallum 2010). Suppliers have found that a larger market growth driver has been increased electricity tariffs. Many middle to high income consumers have become much more interested in electricity saving technologies such as SWH (Hallett 2010; Hertzog 2009; Anthony 2009b; Therion 2010). It can be reasonably assumed that low-income consumers, who are even more vulnerable to increases in electricity rates, are similarly interested in electricity saving opportunities but that they are unable to afford high initial capital outlays. They may also be unaware of the available alternatives and their potential contribution to savings.

Since there are no specific import taxes levied on imported SWH systems[123] the SABS standards are the only existing mechanism that could be used to provide locally manufactured systems with some protection until they become cost competitive with imported evacuated tubes. This is can be achieved by protecting the market from sub-standard, but cheap, imports (Therion 2010). The challenge for locally manufactured systems is that they are of a high quality but that they are too expensive for the low-income market (McCallum 2010). Depending on government intentions with the SWH sector the SABS standards could also be viewed as a barrier to price reductions. The SABS approval system for SWHs is currently not linked to other international standards systems and this often leads to a technically unnecessary re-testing of systems that already have reliable international accreditations. The retesting of internationally approved systems is expensive and time consuming which eventually translates to increased market prices. If the focus of government sponsored SWH rollout programmes is thus only to get as many systems installed at as low prices as possible, the SABS testing process could be changed to recognize international quality standards, thereby eliminating the additional expense and time lost through retesting. If government wishes to achieve wider developmental aims with a SWH programme, the SABS standards could be used to protect the South African industry during its infancy to allow it to develop into a global competitor.

Similar to the literature reviewed and the demand analysis, the price barrier has once again been identified as the primary obstacle to achieving large scale low-cost SWH rollouts. Suppliers concur with the research hypothesis that government rollouts are the most realistic way of overcoming this barrier and that many of the secondary barriers will be overcome through mass rollout processes. The following part of the thesis will investigate the cost drivers leading to the high prices to ascertain if government policy can assist in reducing costs. Thereafter the job creation potential of the industry will be evaluated.

4.2.2 FLAT-PLATE INDUSTRY IN THE WESTERN CAPE

The argument of this thesis as developed in the literature review section is that the SWH industry in the Western Cape is a potential driver of economic growth and that SWH technology can become a synergic satisfier for a range of fundamental human needs in a way that would lead to sustainable development of poor communities. The potential of SWHs to serve as synergic satisfiers for fundamental human needs can be broken down into two components.

- The contribution that each system makes to a household by providing them with running hot water and reducing their electricity bill.
- The contribution that the industry can make to local economic development through the provision of jobs across the value chain.

To date this argument has been made by showing that SWHs can make a real tangible contribution to the quality of life of low-income households, that government sponsored rollouts have been completed successfully and that the installation of SWHs contribute to

[123] Imported manifolds for indirect systems are taxed (Stohr 2010)

reduced strain on the national electricity grid and reduce GHG emissions[124] as shown by the Kuyasa project.

The primary challenge in realising the development potential of SWHs has been identified as the high initial cost of the systems. The next part of the thesis will evaluate the cost barriers in the local industry so that the correct level of government policy can be identified. Policies need to be efficient in reducing prices so that systems become more affordable in the low-income sector and to ensure that industry development incentives contribute efficiently to making South African SWH systems cost competitive with imported systems. The analysis of cost drivers would also enable industry players to benchmark their own processes and to target their research and development activities at sectors where cost reductions are most necessary.

When cost drivers are identified, recommendations can be made on what role a municipality such as Stellenbosch can play in developing and/or attracting parts of the SWH value chain so that it can enjoy the local economic development benefits of the industry. The focus for this thesis has been on the SWH industry in the Western Cape as the focus area was Stellenbosch and the Western Cape Province and the possibility of enlarging the existing SWH value chain in the province. This is done in the hope that the industry can become an important driver of local development. Industry averages for cost breakdown figures are provided in Table 14 below[125].

[124] The case study households have shown that this reduction is not so much in terms of current absolute levels but rather in terms of avoided emissions and electricity use that would have resulted through normal "development" if this development were to include water heated through electrical appliances/geysers.

[125] The cost breakdown figures were obtained during interviews with companies involved in the SWH value chain in the Western Cape. For more information on the methodology please refer to section 3.4.5.

4.2.2.1 Cost Drivers in the Western Cape SWH Industry

Table 14 Value chain Analysis cost breakdown (percentage breakdowns)

Component of system	Average (percentage of total cost)	Range	Sub-components	Average (percentage of total sub-component cost)	Range	Component	Average(percentage of material cost)	Range
Flat-plate collector panel	25%	17 to 33%	Material	68%	55 to 79%	Aluminium/steel	25%	11 to 25%
						Copper	42%	16 to 44%
						Glass	23%	10 to 26%
						Other (incl. insulation)	11%	4 to 13%
			Labour	11%	4 to 22%			
			Overheads	20%	7 to 38%			
Hot Water Storage geyser	28%	17 to 38%						
Installation	45%	33 to 59%	Materials/ installation kit	65%	62 to 67%			
			Labour	35%	33 to 38%			

The simplicity of Table 14 belies the difficulty that was experienced in convincing manufacturers to provide estimated cost breakdowns. The SWH industry has grown tremendously over the past decade with many new players coming on board and companies are reluctant to reveal any information that might jeopardise their competitive position.

Nonetheless the table does provide some very interesting insights. The fact that the installation component carries the heaviest weight is slightly misleading. This is based on the fact that most companies recuperate a significant portion of their overall overheads and profit margin as part of "labour" costs in quotes. Materials[126] used as part of the installation kit also account for 65% of installation costs. Similarly, material accounts for 68% of the costs of manufacturing a flat plate collector. Of the two geyser manufacturing companies interviewed only one was willing to provide a rough cost breakdown of their activities and as part of the confidentiality agreement signed this figure cannot be published. Both geyser manufacturers interviewed indicated that material input cost was the primary cost driver.

In the panel manufacturing part of the value chain material inputs account for an average of 68% of total manufacturing cost. Copper contributes 42% of the material costs and 28.56% of the total manufacturing costs. If geysers with a large copper component are used this contribution would be even higher and many installation cost quotes include copper tubing to transmit the hot water from the geyser to the hot water tap outlet. Other materials that serve as primary cost drivers are prismatic glass and aluminium. It is very interesting to note that labour costs are a relatively small component of total costs, accounting for only 11% of manufacturing cost and 35% of installation cost for a total cost contribution of only 18.5%. Included in this figure are several other hidden overheads. Though some players in the value chain complained that the unionisation of labour was a difficult issue in the industry it seems that labour is not a primary cost driver and that the price differential between locally manufactured systems and imported Chinese evacuated tube systems cannot be attributed simply to high labour costs in South Africa. Instead it seems that the cost of materials in manufacturing local systems, particularly copper, is the single largest barrier to cost reductions[127].

The manufacturers interviewed for this thesis indicated that material costs were the primary cost drivers for the systems that they supplied. Due to the comparatively small volumes produced, these suppliers still sourced materials such as copper, aluminium and prismatic glass from South African suppliers, even though they are all available from international suppliers for 15-20% cheaper. At the volumes of SWHs that are currently installed importing materials is not worth the shipping costs but at larger volumes these firms all indicated that,

[126] The production of glass, copper and particularly aluminium are very energy intensive processes. In order to quantify the total environmental benefits of solar water heating it would be crucial that the negative environmental impacts of the materials used to manufacture the systems be calculated. This data should then be used to evaluate the total energy savings achieved by the systems. The impact of the input materials used for solar water heaters will also have to be compared to the impact of the materials used to manufacture electrical geysers and kettles. Such a process should form part of a life-cycle cost analysis of the solar water heating industry and it is suggested that further research be conducted to complement the work completed here.

[127] Some suppliers have complained that the cost of having systems tested by the SABS is another driver of cost but this is only true for low numbers of installations. The testing costs are fixed and as such do not have a significant impact on the cost of systems used in thousands of installations. The initial costs might inhibit the entrance of new players in the industry but they also serve to screen manufacturers so that only those with sufficient financial backing and long-term business plans can enter the market.

even though they prefer to support local industry, they would start importing most of their materials. Subsequent interviews with South African glass suppliers revealed that the prismatic glass used in the SWH industry is still to a certain extent a fringe product and that if the demand therefore increased they would be able to reduce their costs by 10% or more. This would bring their costs in line with international costs (Cook 2010). The relatively high costs of copper inputs are however an even more complicated matter. Many of the firms interviewed for this thesis believe that the South African copper tubing suppliers that they source their copper from are basing their prices on import parity[128] levels and not real production costs. The supposition is that they are able to do this because two large firms hold significant market power and are able to use their influence in the value chain to pursue monopolistic practices.

Copper mining and manufacturing in South Africa is a massive industry containing large firms that are careful about what information they make available but the South African Copper Development Association as well as Palabora copper mining and manufacturing company were very helpful in providing some insights and figures about the copper industry in South Africa. Maksal Copper Tubing company also provided as much information as they felt comfortable revealing. Without accurate figures on production costs[129] it is difficult to develop a rigorous analysis of the cost drivers. When copper tubing manufacturers were queried about their reaction to the perception that they follow monopolistic pricing policies based on import parity pricing they reacted that *"This may have been the case years ago but as markets have opened up over the last few decades this has become impossible as cheap imported materials have become readily available. If you look at our company's prices over the last few years you will see that they have followed the cost of copper relatively closely"* (Jordaan 2010). Jordaan (2010) agreed that South African copper tubing producers do take international prices into account when they set their own prices but that the cost of copper itself is the primary cost driver.

According to the literature on VCA, a reason for the high costs of material inputs may be due to distorted power relationships in the value chain. The following section investigates the existing power relationships to see if this might be the case.

4.2.2.2 Power Relationships in the SWH Value chain

Figure 47 below provides a schematic of the structure of the current value chain as well as indications of where non-collaborative relationships across the value chain are creating barriers to capacity expansion and price reductions. The paragraph below discusses these links in terms of the power relationships in the value chain based on the literature reviewed about VCA techniques. The SWH value chain structure is quite complicated, with most panel manufacturers involved in all activities from panel manufacturing to final installation. There are however also companies that purchase geysers and panels and that are only involved in retail and installation. For large government sponsored installations of SWHs, companies involved solely in retail and installation need not form part of the value chain as the system

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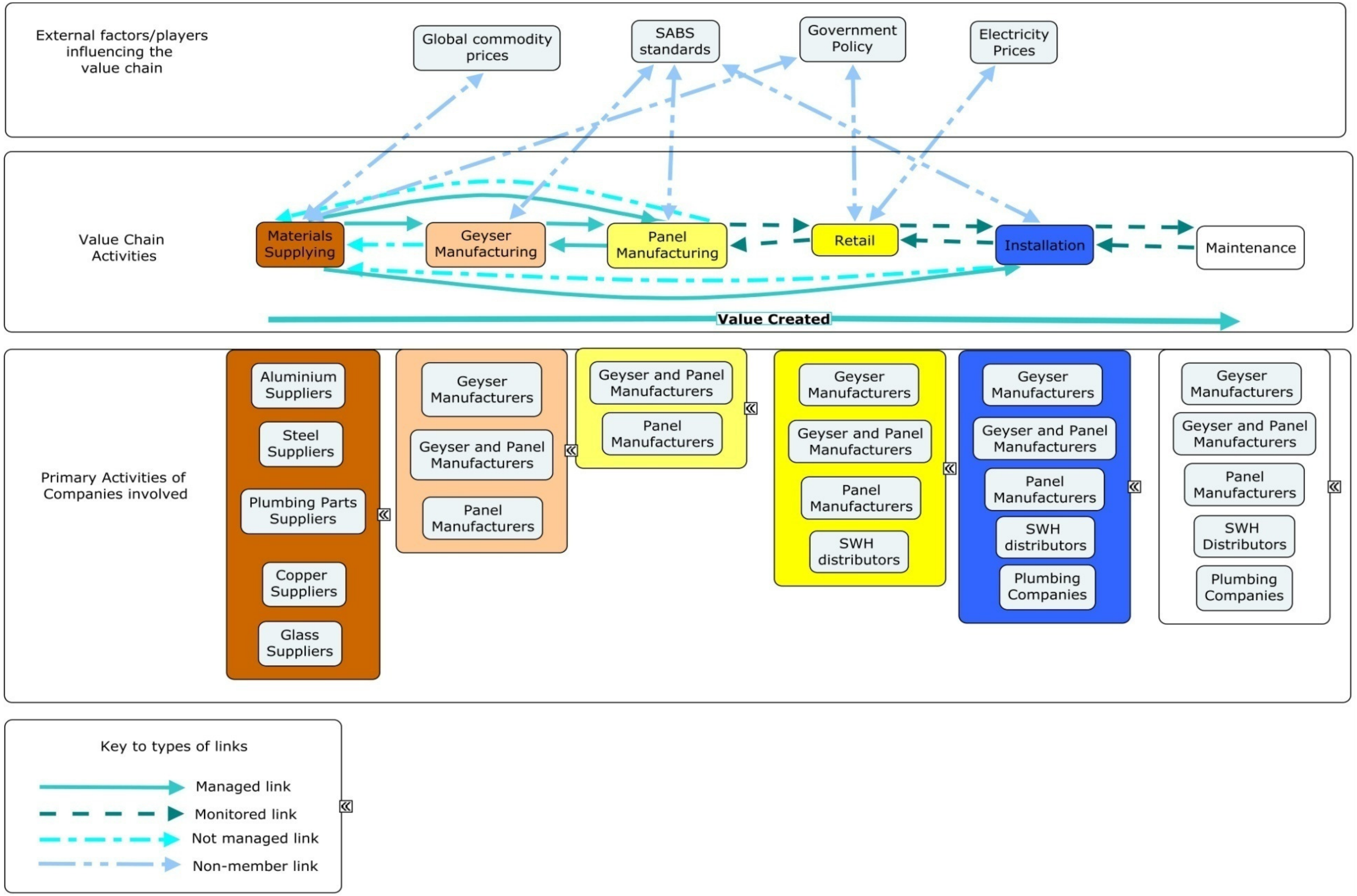
[128] This entails that the suppliers sell the copper tubing at international copper market prices plus costs of importing to South Africa.

[129] Internet and journal literature searches also yielded no detailed information on the costs of copper mining and manufacturing in South Africa

manufacturers can provide these services directly. This should lead to cost reductions as some of the intermediary players will be cut out of the value chain. Ultimately the idea should not be to facilitate the creation of a single value chain containing only one company that is involved in each activity, but rather a weaved value chain that contains several competing companies involved in each activity. Such competition should facilitate continuous innovation and price reductions that would hopefully eventually make the South African or Western Cape SWH industry internationally competitive.

Figure 47 Western Cape SWH Industry Structure, Links and Power Relationships



Cox (1999, p.173) identified three essential insights that are required to categorise value chains according to power-based typologies. According to his theory power relationships in the Western Cape SWH value chain can be identified based on;

1. The physical resources required to create the finished product,
2. The exchange relationship between supply chain resources and the flow of revenue and
3. The ownership structure of strategic resources.

According to this typology, materials suppliers wield most power in the value chain as they control the physical resources required to manufacture the finished product, thus owning the strategic resources. They also control the exchange relationship between themselves and SWH manufacturers due to the relatively insignificant buying power of SWH manufacturers. Though this thesis does not quantify revenue distribution, the high portion of costs attributable to material inputs indicates that a significant portion of the revenue in the value chain does accrue to materials suppliers.

Power concentrations in the SWH value chain play a major role in cost structures, influence the ability of suppliers to satisfy existing demand and would affect the ability of the local industry to meet the volume output requirements of large low-income rollouts. Though the research experience has shown that there is fairly healthy collaboration between panel manufacturers and geyser manufacturers, it seems that other links in the value chain are almost dysfunctional in the way that they are controlled by powerful players in the value chain. Currently the SWH value chain is very much demand driven and the market remains volatile with suppliers unsure about how large the demand will be, even in the near future. This volatile market leads to a state of affairs wherein every participant is trying to pass the risks on to other links in the value chain and most firms are reluctant to stock large inventories that would enable them to meet sudden spikes in demand (Hallett 2010; Therion 2010; McCallum 2010).

Companies focussed on activities in the SWH value chain find themselves in a disadvantaged position vis-à-vis suppliers of materials that are produced by large firms involved in many value chains amongst which the SWH industry is but a small, relatively insignificant player. The scale of the SWH market is simply too small for SWH suppliers to have the amount of buying power in the SWH value chain that would enable them to negotiate better deals and develop collaborative supply relationships.

Relationships with materials suppliers for flat-plate manufacturers are particularly strained, especially since most manufacturers have found that they could import materials more cheaply than they can buy them locally[130] (Hertzog 2009; Hallett 2010; Anthony 2009b). The materials providers are massive companies that are not at all dependent on the SWH industry for their markets and they use this power to ensure that the SWH companies carry all the risks and are solely responsible for all the logistics of moving the materials. Figure 47 shows

[130] This is not to say that SWH manufacturers do not use locally manufactured materials. Even though these materials are available more cheaply on international markets they are also very difficult to import on small scale, but the awareness that materials could be sourced cheaper internationally strains the relationship between local companies at different levels of the value chain.

that the link between materials suppliers and SWH geyser and collector manufacturers is controlled by materials suppliers who have the ability to manage these links whilst the SWH companies have to accept these links as “not-managed” from their perspective. Due to their small size they have to accept the conditions and prices set by materials suppliers.

The relatively small size of the SWH companies also makes it difficult for them to import input materials as these need to be shipped in bulk. Even if such materials would be cheaper per tonne the SWH manufacturers have little capacity to afford and store such large quantities of materials. This means that material importer/distributor companies wield significant power and local material suppliers have the power to price their products at import parity (Stohr 2010; Hallett 2010; Therion 2010). This makes it difficult for South African manufacturers to cut costs and compete with imported systems.

On the other end of the scale, retail and installation companies that are offering SWH systems manufactured by other players in the value chain are adding their own mark-ups, which inflate prices unnecessarily (Therion 2010). These players can be cut out of the loop quite easily if low-income rollout projects are completed directly by SWH manufacturing or importing companies. The retail/installation companies do not create significant additional employment opportunities and most manufacturing companies have their own installation capacity.

Though the retail and installation companies can set their prices independently of system manufacturers, the ability of most manufacturers to provide their own retail and installation services allows them to monitor the link with independent retailers and installers and act accordingly. Similarly, because retailers can source systems from a variety of manufacturers, they can monitor the conditions and prices set to them and switch manufacturers if deemed necessary. Figure 47 shows these monitored links between companies involved in the latter stages of the value chain. For instance, where the manufacturing, retail and installation activities are integrated within single firms, the links between the activities are “managed.”

The key links in the value chain that need to change are those between panel and geyser manufacturers and material suppliers. This is necessary to allow South African SWH manufacturers to negotiate better prices and to open up new areas for innovation.

4.2.2.3 Potential for Innovation in Western Cape SWH Industry

The Western Cape SWH value chain faces competition for the market from the value chain that exists in other provinces, particularly Gauteng, and, more importantly, also from international SWH producing value chains. Kaplinsky and Morris (2003, pp.37-38) contend that the only way for a value chain to remain sustainably competitive is for firms therein to continuously innovate so that the value chain perpetually offers a competitive product. The ability of firms to innovate is dictated by (Kaplinsky & Morris 2003, pp.37-38);

i. Whether the internal processes facilitate adaptation and learning,
ii. The position of each firm in terms of its access to required competencies
iii. The “path” that firms are on as change is always dependent on what has happened in the past.

In their research Prasad and Visagie (Prasad & Visagie 2005, p.29) found that no major new innovations have been made in SWH technology in the last decade or more. The technology is considered to be relatively mature with SWH manufacturers across the globe focussing on incrementally improved designs, materials and manufacturing processes. Interviews conducted for this thesis found similar perspectives amongst SWH manufacturers and suppliers in the Western Cape with innovation being focussed on improved manufacturing processes and marginal improvements in materials. Both of which improve quality without having large impacts on prices (Hallett 2010; Bester 2010; Hertzog 2009).

As discussed earlier, Kaplinsky and Morris (2003, p.38) identified four options that firms have for upgrading; process upgrading, product upgrading, functional upgrading, and chain upgrading. The current innovation activities can be characterised as process and product upgrading. Beside some collaboration between geyser and collector manufacturers as well as where single firms manufacture, assemble and install systems most of this process upgrading is based on internal process upgrading through the development/acquisition of improved manufacturing equipment and processes. The relatively high contribution of material costs to total costs, as well as the poor relationship between materials suppliers and manufacturers, presents an area where significant process upgrading can take place through collaborative innovation between the parties involved in the different parts of the value chain. The current incremental product upgrading process could also receive a massive boost if the innovation attempts in materials used could be attempted in partnerships between material suppliers and SWH manufacturers.

For the purpose of this VCA functional upgrading and chain upgrading are not considered as key opportunities for innovation as the ideal is that companies involved in the SWH value chain should not shift production into other value chains. The existing value chain structure wherein manufacturing firms are involved in most activities of the value chain (from production to installation) is deemed to be suited to the challenges of large-scale low-income context rollouts. If the aim was to expand the market in the mid to high income sectors, one could consider the outsourcing of retail activities to large retail firms that are more skilled and experienced in marketing and customer service. In this case such outsourcing would not be necessary and would likely only add additional cost. Some of the SWH collector manufacturing firms indicated that they are considering outsourcing their installation activities but if such restructuring would lead to weaker links between parties in the value chain it could hamper process innovation that can currently happen in the links between manufacturing and installation.

The most strategic opportunity for innovation is thus concluded to be between geyser and panel manufacturers and materials suppliers. Unless the linkages between these activities in the value chain become managed from both sides, such innovation is unlikely. An external intervention to realign power in the value chain is therefore needed. A government sponsored rollout of thousands of SWHs could serve as such an intervention by increasing the buying power that SWH manufacturing companies hold. As the ability of SWH manufacturers to imported cheaper materials improves, the local material supply sectors will have to pursue more collaborative relationships with manufacturers to maintain their own share of a rapidly growing market.

4.2.2.4 Summary of findings

The implications of this finding for government policy to develop the SWH industry are that local municipalities can play only a supporting role in aiding the development of the industry. Developing industrial zones especially for SWH companies to attract manufacturers will not have a significant impact on the costs of systems as overheads, including factory space rent, are not a major barrier to cost reduction. Companies that were willing to provide this figure indicated that rent contributed significantly less than 5% of the cost of a total SWH system.

Large investments in reducing this cost would thus yield very little results in terms of cost reductions.

The most positive role that municipalities can play in developing the SWH industry is by providing a guaranteed market. It has been shown that sustained demand is necessary to encourage inter-firm process innovation and to reduce material input costs by realigning power relationships in the value chain. This could entail bylaws mandating the installation of SWHs on all middle and high income homes and municipally sponsored rollouts of low-cost systems on formal low-income houses. It has been shown that the payback period and capital investment required keeps the satisfiers of SWH technology out of reach for low-income households.

For a municipality the local economic development potential would be comparatively small as the systems would be manufactured elsewhere and installed by non-local installation teams. A potential way to leverage more local economic development through support of the SWH industry would be to impose a condition that SWH installers should train and use local labourers for a certain portion of the rollouts. Large municipalities, such as the City of Cape Town, can award tenders for large low-income rollouts to companies who are willing to shift at least a portion of their production to the municipal area. This would only be possible for municipalities that would be able to guarantee the rollouts of tens of thousands of systems which would make relocation worthwhile for SWH manufacturers. In order to ensure that existing local industries do grow, develop and become large national players, municipalities could consider awarding tenders to locally based firms rather than to firms from distant parts of the country. Provincial governments would however be able to create the large markets that would lead to reduced costs and that could attract SWH manufacturers to identified nodes of production in the province. Section 4.3 compares models for the rollout of low-cost systems in Stellenbosch to a provincial rollout.

Rollouts could also be sponsored by National Government but, where it could play a unique role would be through launching an investigation into the copper, glass and aluminium production sectors to investigate whether there may be a need to increase competition in these sectors.

If large government rollout programs are what are required to make the benefits of solar water heating a reality in low-income communities through the creation of a strong SWH industry, it is important for to ensure that the money invested contributes to sustainable development by delivering synergic satisfiers. As such, job creation should be an essential objective of SWH rollout programs if the technology is to contribute to sustainable development as defined in this thesis. The job creation potential of the SWH value chain is discussed below.

4.2.2.5 Job Creation throughout the Flat-Plate SWH Value chain

A core argument of this thesis is that sustainable development can only be achieved through systemic interventions that fulfil many fundamental human needs whilst also decoupling said human development from increased natural resource use. Part of any systemic intervention to improve human development in Stellenbosch and/or the Western Cape therefore has to provide opportunities for poverty relief and employment creation as critical components for the satisfaction of fundamental human needs. In order to understand the potential that SWH technology holds for poverty relief and human development, an analysis of the job creation potential is essential. The paragraphs below will quantify and discuss the employment generating potential of the flat-plate collector SWH value chain in the Western Cape and, because many of the inputs are sourced elsewhere in South Africa, the country as a whole. Table 15 presents an averaged breakdown of the number of jobs created directly in the SWH industry, Table 16 provides an estimated breakdown of the jobs created in supporting industries higher up the value chain.

Table 15 Direct Jobs Created Through a Rollout of 1000 Systems per Year[131]

	Geyser Manufacturing	Panel Manufacturing	Installation	Office support	Total
Average number of jobs created per 1000 systems installed per year	4.130	4.997	2.323	0.696	12.146
Percentage contribution	34	41.16	19.1	5.73	100

Table 16 Estimated Number of First Order Indirect Jobs Created per 1000 Systems Installed per Year[132]

Average number of first order indirect jobs created per 11500 systems installed per year	Amount of material needed per system	Material needed for 1000 systems	Unit	Weight of material per system (kilogram)	Weight of material for 1000 systems (tonne)	Employment opportunities created per tonne of material produced/annum	Employment opportunities created per 1000 low-cost SWH systems	Estimated indirect opportunities created
Copper tubing for all water circulation	15.44	15440	meter of 22 mm tubing	9.127	9.127	0.052	0.474	4.735
Total Aluminium required for frames, backing and collector fins	0.003	3.3711	$meter^3$	9.102	9.102	0.005	0.042	0.424
Prismatic glass manufacturing	1.6	1600	$meter^2$ (4mm thickness)	14.848	14.848	0.040	0.598	5.978
Total				33.078			1.114	11.137

[131] These figures are based on information on number of employees and annual system output provided by firms in the SWH value chain.

[132] The method for calculating these figures is discussed in section 3.4.5.4

The figures in Table 15 are slightly lower than the estimates made by AGAMA (shown in Table 6) of roughly 20.8 jobs created per MW of SWH capacity installed). If average collector size of $1.6m^2$ is assumed the nominal power capacity of $0.7kW_{th}/ m^2$ of SWH's in South Africa gives a power capacity per system of $1.12kW_{th}$ per system. For an industry rolling out 1000 low-cost systems per year the total collector area would be $1600m^2$ providing nominal installed power capacity of 1792 kW_{th}, 1.792 MW_{th}. That gives an employment creation figure of 12.146/1.792 MW_{th} or 6.778 jobs created per MW_{th} SWH capacity installed. The discrepancy between this figure and that calculated by AGAMA could be attributable to faster learning curves in the SWH than anticipated by AGAMA and by the fact that the focus for this study was primarily on direct thermosyphon low-cost SWH systems which are significantly simpler and faster to install and manufacture than higher cost systems which were the primary focus of the AGAMA study.

If imported systems are used for installations all jobs in panel manufacturing and geyser manufacturing would be lost. Interviews for this thesis indicated that the office staff complement of importing companies is not significantly larger than that of local manufacturers and no additional jobs would thus be created in that sector. From the data assembled for this thesis the use of imported systems will create 75% less jobs directly as well as less jobs in materials supplying industries. This is a significant loss in terms of the opportunity to realise synergic satisfiers to achieve sustainable development. However, before the impact of rollouts using local systems can be calculated the ability of local industry to meet increased demand needs to be evaluated as is done below.

4.2.2.6 Industry Ability to Expand Production Capacity

In order for government interventions to realise the maximum job creation potential of the SWH industry, policies need to be formulated with regard for the ability of system manufacturers and suppliers to meet increases in demand, especially considering that current power relationships and market conditions make it expensive for suppliers to hold large stocks of finished products. The literature reviewed for this thesis found that local manufacturers can expand their production relatively easily. Interviews conducted with Western Cape SWH businesses came to a similar conclusion. Manufacturers indicated that they could increase their capacity up to five fold and more through appointing additional staff members to man the various assembly stations on the production lines. If demand were to increase rapidly, extra overnight shifts could also be added to churn out significantly larger numbers of SWHs (Anthony 2009b; Hallett 2010; Hertzog 2009; Therion 2010).

Manufacturers also indicated that isolated large orders created more problems than they solved, and would not reduce costs significantly. Smaller orders over an extended period facilitated improved production efficiency, enabled manufacturers to obtain volume discounts when ordering materials, and as a result effect significant cost reductions. In large once-off orders similar benefits could not be realised. Therefore, if job creation is a central objective, government rollout programs and support should be long-term in nature and take into account the ability of the local industry to increase capacity to meet demand. For the rollout models industry local industry production expansion ability of 30% per year is assumed based on these interviews. Such a growth rate would also enable the government agency responsible for rollout programs to phase SWH rollouts into its budget whilst allowing opportunity for additional SWH production and installation staff members to be trained in companies.

4.2.2.7 Evacuated Tubes vs. Flat Plate

Based on the calculations above, using imported evacuated tube collectors will create 75% less direct employment opportunities. On a technical level it is difficult to find unbiased expert opinions on the comparative performance of the two technology types. Evacuated tube technology is fairly new in South Africa compared to flat-plate technology which has been available for more than 30 years, with individual systems operating in excess of 20 years, and it is particularly difficult to find real comparative examples on the long term quality and longevity of the two types of systems in South African climatic conditions. The primary arguments for the use of evacuated tube collectors are that they are available for roughly half the price of flat-plate collectors and that they have excellent heating abilities in colder, more overcast, weather. Conversely it is argued by supporters of flat-plate collectors that evacuated tubes were originally designed for colder climates in the Northern hemisphere such as China and Germany and that in South African conditions with high average radiation levels evacuated tubes often heat water beyond boiling point. This causes severe strain on seals and other components of the systems and drastically reduces the longevity of the systems. The dangerously heated water also presents a threat to household inhabitants in the case of leaking systems or even through normal daily usage. There are also many doubts about the long-term reliability of the vacuum tubes themselves (Hallett 2010; Hertzog 2009; McCallum 2010). However, in the two years that the SWH systems in Kuyasa have been operating only a handful of tubes have lost their vacuum[133] (Wesselink 2010). It is suggested that further technical tests should be conducted to determine the expected lifetime of evacuated tube collectors in South African climatic conditions.

It is particularly interesting to note the arguments of James McCallum of Solartech in this regard. Solartech is a large SWH supplier that stocks both evacuated tubes and flat-plate collectors for the mid to high income sector. Most other suppliers stock either one or the other collector type and as such the opinion of Solartech is the closest to an unbiased perspective that could be found. According to McCallum (2010), evacuated systems look "sexy" but the technology is too complicated for the African development context. Even in more developed countries, with similar climatic conditions to South Africa, where SWH uptake has been high, such as Greece, Cyprus and Israel, flat-plates dominate the market. According to McCallum (2010) evacuated tubes might seem like a better option in the short run due to the high temperatures that they are able to generate, but their tendency to overheat water in South African climatic conditions will lead to long-term issues with system seals, fittings and vacuums unable to withstand the high temperatures over a longer period of time.

Dawie Therion of Extreme geysers (2010) also points out that boiling water in evacuated tube systems lead to the loss of up to 2*l* of water per day through their overflow systems that are designed to prevent pressure build-up's. In a country suffering water shortages a rollout of millions of systems that waste a litre or two of water per day would be a very unsustainable intervention.

More technical studies may be necessary, but based on comparable performance by the two systems installed in the case studies, concerns about the long-term quality of EV systems and the potential of creating jobs and an export sector in South Africa, this thesis advocates the

[133] Loss of vacuum is easily identified because the tubes are designed to discolour when their vacuum is compromised

use of locally manufactured flat-plate systems. The following section will provide a possible model for the rollout of such systems with calculations of electricity savings and financial and environmental costs and benefits.

4.3 PROPOSED MODELS FOR THE ROLLOUT OF SWHs ON LOW-INCOME HOUSES

Based on the literature reviewed and the research conducted the tables below provide suggested models for the rollouts of low-cost SWHs in Stellenbosch or the Western Cape Province. The models are drawn up based on the exclusive use of locally manufactured systems under the assumption that job creation should be a central objective of an investment in green technology. The assumptions used to draw up the tables as well as the sources providing the data are given in Table 17.

Table 17 Assumption Table for Low-cost SWH Rollouts

Total systems to be installed in Stellenbosch over 5 years	**28000**	The total number of low-income households in Stellenbosch (Sustainability Institute & Probitas Real Estate Finance Education CC 2006)
Total existing Government Subsidised Houses in the Western Cape 2010	289907	(Department of Housing 2009; Social Housing Foundation 2009, p.17)
Annual additional Government subsidised homes to be constructed in the Western Cape (conservative estimate)	31000	Based on the rollout rate in 2007 and 2008 (Department of Housing 2009).
Estimated potential capacity expansion per year for SWH manufacturers	30-32%	Conservative estimate based on research discussed above.
Jobs created in manufacturing and installation per 1000 systems installed per year	12.146	Based on Table 15
Jobs created in maintenance activities[134] per 1000 systems installed	1.515	Based on the assumption that a maintenance team of two can inspect, clean and maintain six systems a day for 220 days per year. This is based on the experience in the Kuyasa CDM project (Ndamane 2009).
Average annual electricity savings per system installed (MWh)	0.948	80% of electricity used for water heating as found in Table 12
Average annual electricity bill savings per system installed	R 663.60	Based on Table 12
Electricity price 2011	R 1.09	Based on electricity rates in 2009 of 70c/kWh (Stellenbosch Municipality Electricity Department 2009) increasing at 25% for 2010 and 2011

[134] Based on a team of 2 people maintaining 6 systems/day, 220 days per year (allowing for weekends, holidays and bad weather). Therefore a single labourer maintains (checks) an average of 660 systems per year. 0.001515 maintenance jobs are thus created per annum per system installed.

Estimated selling price of CERs €11/tonne of CO_2 (R10/€1 exchange rate)	R 110	Price of Carbon on global markets as provided by Carbonpositive (2010a)
Carbon Emission Reductions per 1000MWh of electricity produced (tonnes)	1.02	Figure provided by Pegels (2009)
Cost of low-cost flat-plate system installation[135]	R 8 000	Industry average based on interviews (Hallet 2010, Hertzog 2009, Therion 2010)
Cost of flat-plate system installation min Eskom rebate[136]	R6000	Based on interviews with manufacturers of Flat-plate collector systems in the Western Cape (Hallet 2010, Hertzog 2009, Therion 2010).
Discount rate	10%	
Potential annual contribution from households (increasing @ 10%/year)	R 480	Based on a R40/month contribution which is similar to the contributions made by Kuyasa CDM project recipients (Ndamane 2009, SouthSouthNorth Africa 2005). This figure is less than the estimate savings calculated as in Table 12
Estimated system failure rate per annum	1/300	Based on failure rate in KwaNokuthula project (Hertzog 2009)
Estimated average cost of replacement	R 2 000	Assuming that every second failure requires the replacement of either the geyser or collector panel.
Annual Salary per maintenance worker	R80000	Based on the daily wages paid to a plumber in the Kuyasa CDM project (Ndamane 2009)
Maintenance employment opportunities created per annum per installed system	0.001515152	Based on a maintenance worker working for 220 days a year. Performing "maintenance" work on an average of three[137] systems per day.

135 It is assumed that for every doubling of output, system cost is reduced by 20% as found by Holm (2005). At installation increases of 30% per year, output would double roughly every 3 years. Therefore prices should fall by 20% every 3 years, roughly 6.667% per year. This is only slightly above the reserve bank inflation target of 3-6%. The assumption is thus that prices of low-cost SWHs would remain roughly constant in nominal terms and fall by 6% per year in real terms.

136 Manufacturers in the Western Cape have not as yet submitted their low-income market systems for SABS accreditation. The costs of the tests are not justifiable unless a large market is secured which would ensure the investment cost could be reclaimed through large volume sales. For large scale rollouts, the initial cost of accrediting systems is negligible per system. Interviews with suppliers indicated that if a dependable demand for systems is created they would get their low-cost systems accredited. In line with Eskom rebates currently available on smaller systems a rebate of at least R2000 per system can be expected on accredited low cost systems (Eskom DSM 2010a).

137 This is an average figure. "Maintenance" will mostly consist of checking on systems and only in rare cases will larger jobs be needed when system components need to be replaced.

Table 18 Suggested Rollout of SWH Systems in Low-Income Housing areas in Stellenbosch[138]

	2011	2012	2013	2014	2015	2016	2017	2030	Total 2011-2030
Number of systems installed per year	3000	3960.0	5227.2	6899.9	9107.9	0	0	0	28194.9773
Cumulative number of systems installed	3000	6960.0	12187.2	19087.1	28195.0	28195.0	28195.0	28195.0	
Number of employment opportunities created/sustained during manufacturing and installation	36.4	48.1	63.5	83.8	110.6	0.0	0.0	0.0	
Number of employment opportunities created/sustained during maintenance	4.5	10.5	18.5	28.9	42.7	42.7	42.7	42.7	
Total number of employment opportunities created	41.0	58.6	82.0	112.7	153.3	42.7	42.7	42.7	
Cumulative cost of systems installed (discounted) Million Rand	R 18	R 40	R 66	R 97	R 134	0	0	0	R 134
Total Electricity Savings/year (MWh)	2844.00	6598.08	11553.47	18094.57	26728.8	26728.8	26728.8	26728.8	466751.5
Cost of maintenance[139] (part replacement discounted)	0.4	0.9	1.5	2.4	3.5	3.5	3.5	3.4	61.0
Additional Annual Carbon emission reductions (tonnes)	2900.9	6730.0	11784.5	18456.5	27263.4	27263.4	27263.4	27263.4	476086.6

[138] To see the formulas used to calculate the amounts please refer to the document entitled *Model for rollout of SWHs in Stellenbosch* on the included CD.

[139] The assumption is that salaries will increase by roughly 10% per annum but then the future values are also discounted by 10% per annum.

Total avoided carbon emissions cumulative (tonnes)	2900.9	9630.9	21415.5	39871.9	67135.3	94398.8	121662.1	476086.6	
Value of carbon emission reductions/year (discounted) Million Rand	R 0.32	R 0.67	R 1.07	R 1.53	R 2.05	R 1.86	R 1.69	R 0.49	R 21.22
Potential revenue from household contributions increasing @ 10%p/a, (disc) Million Rand	R 1.44	R 3.34	R 5.85	R 9.16	R 13.53	R 13.53	R 13.53	R 13.53	R 236.33
Cost of systems installed per year (discounted) + Maintenance cost Million rand	R 18.38	R 22.49	R 27.46	R 33.51	R 40.87	R 3.53	R 3.52	R 3.45	R 194.96
Total Income (disc) Million Rand	R 1.76	R 4.01	R 6.92	R 10.69	R 15.58	R 15.40	R 15.23	R 14.02	R 257.55
Total Cost - Total Income Million Rand (disc)	R 16.62	R 18.47	R 20.54	R 22.83	R 25.29	-R 11.86	-R 11.70	-R 10.58	-R 62.59

Table 19 Suggested Rollout of SWH Systems in Low-Income Housing Developments in the Western Cape[140]

	2011	2012	2013	2014	2015	2016	2017
Projected total number of RDP homes	320907	351907	382907	413907	444907	475907	506907
Number of systems installed per year	7050	9165.0	11914.5	15488.9	20135.5	26176.2	34029.0
Cumulative number of systems installed	7050	16215.0	28129.5	43618.4	63753.9	89930.0	123959.0
Number of employment opportunities created/sustained during manufacturing and installation	85.629	111.318	144.714	188.128	244.566	317.936	413.316
Number of employment opportunities created/sustained during maintenance	10.7	24.6	42.6	66.1	96.6	136.3	187.8
Total number of employment opportunities created	96.3	135.9	187.3	254.2	341.2	454.2	601.1
Cumulative cost of systems installed (discounted) Million Rand	R 42	R 92	R 151	R 221	R 304	R 401	R 516
Cost of maintenance Million Rand (Part replacement discounted)[141]	0.9	2.1	3.6	5.5	8.0	11.3	15.5
Total Electricity Savings/year (MWh)	6683.4	15371.8	26666.8	41350.2	60438.7	85253.7	117513.2
Additional Annual Carbon emission reductions (tonnes)	6817.1	15679.3	27200.1	42177.2	61647.4	86958.7	119863.4

140 To see the formulas used to calculate the amounts please refer to the document entitled *Model for rollout of SWHs in Western Cape* on the included CD.

141 The assumption is that salaries will increase by roughly 10% per annum, but then the future values are also discounted by 10% per annum.

Total avoided carbon emissions cumulative (tonnes)	6817.1	22496.3	49696.4	91873.6	153521.1	240479.8	360343.2
Value of carbon emission reductions/year (discounted) Million Rand	R 0.75	R 1.57	R 2.47	R 3.49	R 4.63	R 5.94	R 7.44
Potential revenue from household contributions increasing @ 10%p/a, (disc) Million Rand	R 3.38	R 7.78	R 13.50	R 20.94	R 30.60	R 43.17	R 59.50
Cost of systems installed per year + Maintenance costs(discounted) Million rand	R 43.20	R 52.05	R 62.64	R 75.33	R 90.53	R 108.79	R 130.74
Total Income (disc) Million Rand	R 4.13	R 9.35	R 15.97	R 24.42	R 35.23	R 49.11	R 66.94
Total Cost - Total Income Million Rand (disc) [142]	R 39.07	R 42.70	R 46.67	R 50.91	R 55.30	R 59.69	R 63.80

[142] The Western Cape Provincial government predicted total receipts of R33.7 billion for 2010. The Department of Transport and Public Works received an allocation of R11.5 billion for 2010-2012 (R3.83 billion/year). The Department of Economic Development and Tourism received a budget of R770 million over the 2010 MTEF (Winde 2010). These figures indicate that an expenditure of 40 million per year would account for 0.1% of the total income of the Western Cape Provincial government, 1%of the budget of the Department of Transport and Public Works and 19.25% of the budget of the Department of Economic Development and Tourism. As solar water heating could help in the achievement of job creation as well as economic development targets different departments could contribute to the financing of a rollout of systems. Such combined expenditure would make a rollout an affordable, realistic development initiative

Table 19 Suggested Rollout of SWH Systems in Low-Income Housing Developments in the Western Cape, Costs and Benefits (continued)

	2018	2019	2020	2021	2022	2031	Total 2011-2031
Projected total number of RDP homes	537907	568907	599907	630907			
Number of systems installed per year	44237.7	57509.0	74761.7	97190.2			397657.6926
Cumulative number of systems installed	168196.7	225705.7	300467.5	397657.7	397657.6926	397657.6926	
Number of employment opportunities created/sustained during manufacturing and installation	537.311	698.505	908.056	1180.473			
Number of employment opportunities created/sustained during maintenance	254.8	342.0	455.3	602.5	602.5	602.5	
Total number of employment opportunities created	792.2	1040.5	1363.3	1783.0	602.5	602.5	
Cumulative cost of systems installed (discounted) Million Rand	R 653	R 814	R 1 004	R 1 229	R 1 229	R 1 229	R 1 229
Cost of maintenance Million Rand (Part replacement discounted)[143]	21.0	28.1	37.3	49.2	49.1	48.6	670.6
Total Electricity Savings/year (MWh)	159450.5	213969.0	284843.2	376979.5	376979.5	376979.5	5158314.7
Additional Annual Carbon emission reductions (tonnes)	162639.5	218248.4	290540.0	384519.1	384519.1	384519.1	5261481.0
Total avoided carbon emissions cumulative (tonnes)	522982.7	741231.1	1031771.1	1416290.2	1800809.3	5261481.0	

[143] The assumption is that salaries will increase by roughly 10% per annum, but then the future values are also discounted by 10% per annum.

Value of carbon emission reductions/year (discounted) Million Rand	R 9.18	R 11.20	R 13.55	R 16.31	R 14.82	R 6.29	R 176.73
Potential revenue from household contributions increasing @ 10%p/a, (disc) Million Rand	R 80.73	R 108.34	R 144.22	R 190.88	R 190.88	R 190.88	R 2 611.80
Cost of systems installed per year + Maintenance costs(discounted) Million rand	R 157.17	R 189.03	R 227.51	R 274.05	R 49.13	R 48.59	R 1 899.34
Total Income (disc) Million Rand	R 89.92	R 119.54	R 157.78	R 207.18	R 205.70	R 197.16	R 2 788.54
Total Cost - Total Income Million Rand (disc)	R 67.25	R 69.49	R 69.73	R 66.87	-R 156.57	-R 148.57	-R 889.19

The table for a rollout of systems in Stellenbosch is set up according to the underlying assumption that the municipality would strive to equip all low-income households with SWHs within five years. That assumption is changed for the Western Cape rollout, since the number of systems that would need to be installed per year to complete the rollout would be far beyond the ability of local industry to meet. Instead, the assumption is that a rollout would start from a fairly low base (about the full capacity of one of the larger local SWH manufacturers) and grow by 30% per year and continue until all low-income state subsidised homes are eventually equipped with SWHs. For the table, the initial rollout for the first ten years is considered, including the benefits of these initial systems for the following ten years. Obviously the rollout can continue beyond this point, but additional installations and their costs are not included in the table above in order to allow for the calculation of costs and benefits over a 20 year period for installed systems. Systems are estimated to have a lifetime of 15 to 20 years. Table 19 does not reflect that many of the systems installed in 2011 will still be operational beyond 2031. This is however, the date at which one would expect to see the need for replacement of the earliest original systems installed and, as such, modelling is suspended at this stage.

The tables above provide interesting insights. For a Stellenbosch Municipality sponsored rollout of roughly 28000 systems over the five years between 2011 and 2015, the most jobs that will be created during one year would be 153, in the final year of installation when slightly more than 9000 systems would be installed. Thereafter, roughly 43 people could be employed permanently to perform standard maintenance activities such as cleaning systems and checking seals. How many of the other people who had been employed during the manufacturing and installation phase would retain their jobs, would depend on how other towns and the Western Cape Province reacts to the rollout of SWHs in Stellenbosch. It is likely that interest in SWH would grow and that these employees would retain their jobs as wider rollouts of SWHs take place. Unfortunately, with material costs being the primary cost driver in the value chain, there is no specifically alluring incentive that Stellenbosch Municipality can provide that would necessarily encourage SWH manufacturers to relocate their manufacturing activities to the municipal area. A partial solution may be to award supply tenders to manufacturing companies based on their willingness and ability to relocate to Stellenbosch. The employment opportunities created for maintenance personnel should be strictly reserved for local residents and tendering companies should be forced to include as part of their SWH rollout programme training opportunities for locally based maintenance teams.

Setting up such tenders could prove to be difficult and for a business opportunity that is not guaranteed for longer than five years it might be difficult to attract SWH manufacturers. The findings suggest that the rollout of SWHs would be better supported from a higher level of government such as the Western Cape provincial government. Encouragingly, the rollout models also suggest another important consideration; SWHs for low income homes do not need to be a net drain on municipal budgets. The technology provides an opportunity for revenue generation through the sale of CER's and household contributions. The Kuyasa CDM project has shown that it is possible to obtain CDM funding for SWH rollout programs and that residents can be asked to make a small contribution to the costs of the system based on the savings that they should experience on their electricity account. The potential contributions from households were set at R40/month[144], increasing at 10% per year (which is equal to or less than the projected increase in electricity prices). If such a model is followed SWHs can be an affordable investment for the municipality which would stand to earn R 257.55 million (2009 values) through the installations at a cost of R 194.96 million for a total net revenue of R 62.59 million over 20 years[145]. Though the return on the investment is relatively low, the figures should be quite attractive for an investment that will be seen as a flagship "greening" project whilst improving quality of life and creating several local jobs[146].

For a provincial rollout the scale of the project would naturally be much larger. The model provides a possible strategy to rollout SWHs on all existing and new government subsidised homes in the Western Cape. Based on a relatively low initial rate of installations increasing at 30% per year, 97 190 systems could be installed by 2021. These systems would account for about 15% of the 630 907 projected then existing government subsidised homes[147]. Because the potential target market for the rollout of SWHs is so much larger on a provincial level, this may be the level of government intervention that is necessary to gain buy-in and commitment from local industry that could lead to the development of a strong manufacturing sector with the potential to become an export industry. To achieve the rollout above, the provincial government would need to invest a total of R1 899.34 million between 2011 and 2031, and earn total income of R 2 788.54 million for a net return of R889.19 million. Again, the return on investment is not significant percentage-wise for such a long term investment, but when viewed with the creation of up to 1800 employment opportunities per year (600 of which are guaranteed for 20 years), a significant reduction in electricity consumption, a reduced ecological footprint (reduced by 384 519.1CO_{2e} tonnes per annum) and improved quality of life for 100 000 households, a SWH rollout project would be money well earned.

A continued provincial rollout to supply the remaining government subsidised homes with SWHs would guarantee that employment created through system manufacturing and installation is retained whilst the industrial sector would develop the capacity and ability to export systems to the rest of Africa.

If imported evacuated tube systems from China were used for the installations, initial costs would be reduced by 40-50%, but there would be a larger possibility of system failure after five years which would taint the image of the technology. More importantly, SWH would become an import economy and the millions spent by the provincial government would leave the country rather than remaining in circulation in the Western Province where it could lead to further local economic development. The SWH rollout programme would also create 75% less employment opportunities and thus much less opportunities for local skills development activities.

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[144] Based on the Stellenbosch survey conducted for this thesis this is roughly two thirds of the amount they should save on their electricity expenditure.

[145] All values are given in 2009 Rand (using a 10% discount rate) and nominal figures will be much higher.

[146] From these figures it is again clear the direct financial benefits of providing loans for SWH installation in the low income context is not an attractive opportunity for private sector financiers and that government may have to step in to fill the void to ensure that the developmental benefits of SWH as a synergic satisfier are realised.

[147] If the department of housing continues to subsidise the construction of roughly 30 000 homes per annum

For the rollout to achieve maximum local economic development potential it would be essential that the provincial government award tenders to locally based companies or companies that are willing to relocate part of their manufacturing facilities to the province.

4.4 SUGGESTED INTERVENTIONS

The research findings indicate that a SWH rollout in low-income communities would;

- Reduce electricity consumption for water heating, thereby reducing relative levels of electricity usage per level of economic development in communities. An absolute reduction in electricity usage is hidden as households spend a significant portion of their additional expendable income on buying more electricity for other uses,
- Reduce the amount of electricity required to satisfy the suppressed demand for hot water when homes achieve economic development and have a positive environmental effect through the reduction of carbon emissions,
- Create some local economic development opportunities (whether systems are locally manufactured or not) and
- Improve quality of life for low-income households. Both case study households were very pleased with the technology[148]
- Not cost sponsoring institutions anything over the long run if the rollout is administered efficiently. This could be achieved by reclaiming capital expenditure through the sale of CERs and small monthly contributions from households.

However, based on the rollout models created above, municipal-level government intervention may not be the ideal scale. Even in larger municipalities, such as Stellenbosch, the “market” for low-income systems is not large enough to kick-start significant industry development. It is unlikely that SWH manufacturers will move their production facilities to a municipal area for the installation of a few thousand systems. The potential for local job creation would thus be fairly limited.

Given these constraints, the capital investment required to start a SWH rollout program remains a massive barrier due to the high costs of the systems. On a larger scale the advantages provide a much stronger justification for the capital expenditure required. The model for a rollout of SWH systems in the Western Cape has shown that a rollout of low-income SWHs would be financially affordable in the long run and that it would hold significant job creation potential. Based on sustained demand in the province the industry could also develop into a powerful economic sector with export revenue generating potential. The mandates of provincial government as discussed in section 2.3.2.5 also indicate that Provincial Governments have the legislative powers to support a rollout of SWHs.

[148] Whether it changed ingrained behaviour immediately or not.

By committing to a long term rollout of SWHs for all state-subsidised housing in the province, the provincial government would create a reliable market for low-income SWHs. This would encourage manufacturers to scale up their production capacity and achieve economies of scale that could lead to reduced prices. Lower prices would make the technology more affordable for households that fall outside government rollout programmes, in South Africa and further afield.

For a provincial rollout programme, it is suggested that further research and initial pilot projects be completed in areas where SWHs have already been installed nearby, such as Khayelitsha (Kuyasa CDM project), Nyanga, Elsiesriver and Riversdale (Western Cape SWH project) and Stellenbosch where research conducted for this thesis has already created interest in the technology. Such locally based interventions provide the opportunity for interaction between local community organisations, local municipalities and provincial government. From these areas SWH installations could then be expanded to neighbouring towns and cities at an installation increase rate of 30% to allow local manufacturers of SWHs enough time to expand capacity to meet increased demand. As the local industry grows, prices of SWHs should fall in real terms, even if they remain constant in nominal terms. After a few years, this would make the Western Cape SWH industry competitive with imports (at least when system longevity is brought into consideration) and export markets in the rest of Southern Africa can then be targeted. It is also recommended that the implementers of the Kuyasa CDM project be approached during the project planning for SWH rollouts as they have unique experience in executing the rollout of large SWH rollout projects and accessing carbon financing to supplement income.

The value chain analysis has shown that the primary cost driver is that of input materials and there is unfortunately very little that provincial government could do directly to assist in the elimination of this barrier. Indirectly, it could contribute through increasing the scale of the SWH industry by creating a market for tens of thousands of systems. As their material buying power increases, SWH companies would gain more negotiating power vis-à-vis materials suppliers. It would also allow SWH manufacturers greater leverage to import large quantities of materials that are currently available more cheaply internationally than locally. This possibility would grant SWH companies more power in the value chain and could contribute to reduced SWH prices in the long run. Locally manufactured SWH-specific materials such as prismatic glass would however, also benefit from economies of scale and thus cost less.

If local material producers are unable or unwilling to reduce their prices the import of materials will not have a significant impact on the amount of jobs created through the SWH industry. Only 1.1 jobs are created in materials manufacturing per 1000 SWH systems installed per year. The sourcing of materials from abroad would, however, mean that a significant part of the money invested by the South African government would be paid to foreign firms and not remain in circulation in the local economy.

A mass rollout of SWHs guaranteed by a provincial government through long-term contracts would also significantly reduce risk in the SWH value chain. When firms in the value chain are no longer in adversarial relationships trying to shift risks to each other, they would be able to start building collaborative relationships to achieve inter-firm process upgrading that could further reduce costs.

These cost reduction processes are likely to at least keep the prices of locally manufactured flat-plate SWHs constant in nominal terms, thus increasing their competitiveness with the prices of imported evacuated tube systems over time whilst retaining the higher quality and reliability standards that flat-plate systems are advocated to have. A provincial government sponsored rollout would also contributing to local economic development through job creation and the creation of strong local SWH industry that generates additional tax revenue and attracts other industries.

This thesis has focussed upon the development potential of SWHs in Stellenbosch and the Western Cape. A national SWH rollout program would have further benefits leading to further economies of scale and more market power for SWH manufacturers that could lead to further process-upgrading and price reductions but a provincial rollout program should be more than sufficient to create the initial demand certainty that SWH require to expand their production capacity. If a provincial rollout starts from a relatively low base, increasing at 30% per year, local manufacturers will be able to meet the demand for all systems and maximum local economic development can be leveraged through the funds spent. For an immediate national rollout it is likely that many systems would need to be imported.

If the National Government decides to induce a countrywide low-cost SWH rollout it would however also have the power to additionally destroy some of the structural barriers to cost reduction in the material value chain. A few measures that could be considered include;

- Tax breaks for SWH companies that purchase local materials;
- A review of legislation and policies that may have created barriers to entry in material markets, especially copper. If such policies are found these should be amended and
- Import taxes on foreign SWH systems.

5 CONCLUSION

Though renewable energy has been identified as a priority by national and local government, as shown by the white paper on renewable energy (DME 2003), the government's commitments at COP 15 (The Presidency 2009) and local government initiatives such as the Kuyasa and Western Cape SWH programmes, other more pressing priorities such as poverty, inequality and unemployment still often holds precedence over all other concerns (DIE 2009). This thesis has shown that the policy priorities do not have to be a trade-off. SWHs can offer a synergic partial solution to all of these challenges by alleviating poverty, reducing inequality and creating employment opportunities. If rollout programmes are managed responsibly, they could even more than reclaim the initial investment made by government through the sale of CERs and small monthly payments by households. The appropriate level of government intervention is found to be at Provincial level. Local municipalities will be unable to provide the scale that is required to reduce the cost of SWHs while a national scale rollout would exceed the current capacity of the SWH industry leading to the need to import systems.

The key conclusions of the research are summarised and discussed below by answering the research questions and thereafter critically re-evaluating the research hypothesis.

5.1 RESEARCH QUESTIONS

In summary the secondary research questions can be answered as follows based on the research findings.

1.1. <u>What are the benefits of SWH for a low-income household?</u>

It has been shown that SWHs are effective at substituting all existing water heating devices being used, mostly electrical kettles and stoves, and that they improve quality of life through providing large quantities of readily available hot water which increases personal care and improves personal hygiene. This leads to an improved sense of self-worth and fulfils several fundamental human needs as identified by Max-Neef. Through the ready availability of hot water daily washing chores have become pleasurable activities that increase a sense of personal well-being. The case studies illustrated that the available technology can fulfil the need for hot water and that it does offer a marked improvement in the quality of life, dependant on how deeply ingrained water usage patterns in households have become as the psychological effects of energy poverty may erode slowly in some cases.

1.2. <u>What would be the extent of electricity savings if a mass rollout of SWHs is achieved for all low-income households in Stellenbosch or the Western Cape?</u>

The effect on electricity savings was ambiguous in that no absolute reduction in electricity usage levels was observed but all water heating in electrical kettles and on stoves (save for the making of hot beverages and cooking) was substituted with water from the SWH. The conclusion is that there is a large suppressed demand for energy services in low-income households and that any savings made in one area are immediately used to increase usage for other applications. Thus, despite not reducing absolute levels of electricity usage, the research suggests that SWH should be an integral part of electricity saving interventions due to a reduction in electricity used relative to the level of development of households. If energy saving devices such as SWHs do not become part of development strategies the national electricity infrastructure will not be able to support increased quality of life for low-income communities.

1.3. What would the environmental benefits be of achieving a mass rollout of SWHs for all low-income households in Stellenbosch or the Western Cape?

The environmental benefits of SWH are closely related to the reduction in electricity use due to the reduced need for electricity from heavily polluting coal power electrical power stations. Through a reduction in electricity usage relative to the level of development SWH fulfils a suppressed demand for hot water services by giving people access to more hot water and substituting part of their expenditure on electricity. SWHs do thus reduce greenhouse gas emissions relative to what they would have been had SWHs not been installed. The basic savings per low-income households are estimated to be 946kg of CO_2 per household per annum through substituted demand for electricity. SWHs thus do hold significant environmental benefits through the reduction of greenhouse gas emissions and they would contribute to a reduction of the ecological footprint intensity of households in the Western Cape. Quality of life improvement would be achieved without increasing the current footprint.

1.4. What is the job creation potential of the SWH value chain?

The research indicates that the SWH industry is not particularly employment intensive. Though most of the jobs that it creates are suitable for currently unskilled, unemployed labourers whilst offering opportunities for on-the-job skills development the amount of jobs created are not massive. It has been found that 12.146 jobs are created per 1000 locally produced systems per year. In addition to these 1.515 maintenance jobs can be created per 1000 installed systems and 1.114 jobs are created in the materials supply sectors higher up in the value chain. This means that a realisable provincial rollout of SWHs in the Western Cape could create 1700 jobs. Though this figure by itself will not be able to significantly reduce unemployment in the province, it does consist of jobs that would cost the provincial government nothing in the long run. According to the rollout models developed SWH can become an income generating sector for government if it collects small monthly payments from households and registers rollout programmes as a CDM project reducing the emission of greenhouse gasses. If imported systems were to be used in rollouts, the employment generating potential of the industry would be reduced by more than 60% and the local industry would not grow into an export sector. This thesis has argued that initiatives to facilitate sustainable development need to empower people to satisfy their own fundamental human needs. Imported systems would not achieve this due to being an externally generated solution for only the very specific problem of insufficient access to water heating services. Though the job creation potential of locally manufactured SWHs is not massive it is considered to be sufficient to warrant their use above that of imported systems, especially since a well planned rollout will not cost government anything in the long run.

2.1. What are the barriers to cost reductions in the SWH value chain?

The literature review identified the high prices of SWH and lack of public awareness about the technology to be the primary barriers to the rollout of SWHs in general. The research interviews with SWH suppliers confirmed these findings, but the thesis adds to existing knowledge by identifying material costs, and particularly copper costs, as the primary cost drivers. The high prices of South African manufactured input materials are barriers to cost reductions in the SWH industry. These must be overcome for the local industry to become competitive with imported Chinese systems. Fixed costs such as that of SABS testing, equipment procurement and factory rental are not large contributors to system cost, especially at large scale production and they only serve as secondary barriers to cost reduction. This means that local municipalities have little room to influence the prices of SWHs through the development of incentives such as industrial development zones. The research completed indicates that large scale, guaranteed, sustained rollouts are what are required to overcome the cost barriers.

2.2. <u>How can these barriers be overcome?</u>

Interviews with companies involved in the value chain have indicated that locally manufactured input materials are the primary cost drivers in the South African SWH industry. The finding is that economies of scale could break down these barriers and reduce the costs of systems by up to 20%. Sustained, increased demand for low-cost systems would lead to cost reductions by giving local SWH manufacturers access to international material markets where input materials could be sourced for prices that are 14-25% lower than those available on the local market. At present South African SWH manufacturers cannot afford the shipping and inventory costs of importing input materials, but at scale these costs would be negligible. Larger buying power and the option of sourcing materials from abroad would give local SWH manufacturers more bargaining power in the SWH value chain that could lead to falling prices for local materials, especially as the material producers would also be able to reduce their own costs due to economies of scale. The glass industry in particular has indicated that larger demand for SWH glass such as prismatic glass would lead to falling production costs on their side.

The demand side analysis found that the price barrier makes it highly unlikely that the private sector would be able to create the scale of demand that would be necessary to achieve the economies of scale that can eliminate the barrier. It is therefore suggested that government should provide SWHs for low-income households. Such rollout programmes should be carefully structured to ensure that the highest possible number of jobs is created by sourcing systems from local suppliers. Through registering SWH rollout programs for CERs and by collecting small monthly contributions from households it would be possible to ensure that the SWH rollout program is not a net drain on government resources but rather that it could become an earner of additional revenue. Key parameters should be that the rollout programmes should take into account the level of domestic production and capacity expansion potential of SWHs manufacturers and that the rollouts should guarantee long-term commitment to sourcing SWHs from local suppliers. Such long-term guaranteed rollouts would enable SWH manufacturers to make the investments that could lead to cost reductions. Tenders for companies to supply SWHs for communities targeted by rollout programmes should give preferential procurement contracts to manufacturers who are BEE compliant, have large local component proportions in their systems and that provide skills development and training for their employees.

Due to the high initial capital investment that would be required from government to set a SWH programme of sufficient scale in motion it is found that local municipalities, such as Stellenbosch, are unlikely to be able to afford the initial investment that is necessary to achieve economies of scale. It is therefore recommended that the ideal level of government support would be on a provincial or national level.

Based on the answers to the research questions the research hypothesis can now be critically re-evaluated.

5.2 RESEARCH HYPOTHESIS

The research conducted has proven that SWHs are a synergic satisfier for fundamental human needs that could facilitate sustainable development in low income communities, even though electricity savings are relative to a level of development rather than absolute and embedded water usage patterns may take some time to change in some households. The job creation potential, though less than expected is significant, especially considering that SWHs could serve as a source of income for government rather than as a net drain on resources. The high initial price barrier does prevent the benefits of SWH from being realised by making the technology inaccessible to low-income communities and in order to overcome this barrier state sponsored rollouts of SWHs for these communities are necessary. It has been found that the most appropriate scale of government intervention should be on a provincial level and that municipalities are unlikely to be able to realise the full synergic benefits of a SWH rollout programme due to their inability to provide the large market sizes that would allow economies of scale to develop. Though national government could play a role in addressing the market failures that lead to the high input prices of materials it is suggested that rollouts should be funded by provincial government, or at least focussed on a specific province in the initial stages. This will allow the local industry to develop to a stage where it could provide enough SWHs for a national rollout.

6 SUGGESTIONS FOR FUTURE RESEARCH

During the course of the research several areas that may warrant further study were identified. These are quite wide in range and some of the areas have already been quite well researched but it is necessary that links be drawn between the existing literature and studies on solar water heating.

6.1 ALTERNATIVE DEVELOPMENT INTERVENTIONS

The Kuyasa CDM project has found that the installation of ceilings and insulation has made a much larger improvement to quality of life than either increased lighting or the provision of hot water through solar water heating. For programmes with the ultimate goal of improving quality of life it is essential that thorough research be completed, in participation with the recipients of the development aid, to ensure that development initiatives target those areas which would benefit the receivers most. Participation by all stakeholders should be a key component from the design to closing phases of a project. Further research is necessary to determine whether hot water provision is actually a primary concern for low-income communities in the Western Cape or whether they may prefer other interventions such as the provision of ceilings and insulation for their homes.

6.2 COMPETITION IN SOUTH AFRICAN COPPER, GLASS, ALUMINIUM AND STEEL SECTORS

The value chain analysis of the existing solar water heating industry in South Africa has shown that the input material suppliers wield most of the power in the value chain through their control of scarce resources. Further research in the economics field related to these sectors is necessary in order to determine what their own cost drivers are and how these can be overcome. Further research should also attempt to find avenues by which government policy could ensure that South African industries enjoy the benefits of the comparative advantage that the South African economy has due to its rich natural resource endowment.

6.3 SOLAR WATER HEATING AND WATER PURIFICATION

Interviews with copper producing firms indicated that copper has several antibacterial properties that could aid in the purification of water. Water that is exposed to prolonged high temperatures or UV light radiation is also sterilised. Future research can be conducted to identify potential synergies between water purification and heating technologies.

6.4 CENTRALISED WATER HEATING

This thesis has focussed specifically on alternative water heating in free-standing low-income housing units such as those constructed as part of the RDP housing programme. For higher density residential developments centralised water heating systems offer completely different prospects and have different development implications. It is recommended that further research be conducted in order to understand the synergic satisfying potential of centralised water heating systems in such housing units. Such insight can contribute to decisions about which housing strategy is more sustainable. It could also lead to further arguments for government support of the South African solar water heating industry as the private market for such systems is much more established in the hotel and hospitality industry.

6.5 WATER SHORTAGES

Water availability in the Western Cape, and much of South Africa, is already under pressure and it is likely that the rollout of SWHs would increase water usage in low-income communities. The extent of this effect needs to be researched so that SWHs do not solve the electricity crisis at the cost of contributing to a more severe water shortage crisis. Grey water recycling in low-income homes with SWH should thus be researched to develop a complimentary water saving programme for large SWH rollouts.

6.6 LIFE-CYCLE COST ANALYSIS

In order to ensure that the SWH systems that are rolled out are in fact produced in an environmentally sustainable manner, research should be conducted to determine the life-cycle costs of the systems. Research needs to be conducted to evaluate the embodied energy in solar water heating systems. It is likely that evacuated tubes in particular, have large embodied energy levels due to the high temperature processes required to manufacture the collector tubes as well as due to the long distances that the systems have to be transported. Copper from many other applications is easily recycled and it needs to be tested if the same would be true for copper used in SWH systems. The environmental impacts of the insulation, fibre glass storage tanks, and aluminium and steel components also need to be evaluated in order to determine what the full life-cycle costs of SWH systems are. Aluminium mining and manufacturing are specifically energy intensive activities. As a major component of solar water heating systems it may have a significant impact on the life-cycle sustainability of SWHs.

7 CLOSING REMARKS

This research journey has shown that SWHs can break the "*circular cumulative causation processes that keep the poor, poor inasmuch as their dependence on exogenously generated satisfiers increases,"* (Max-Neef 1991) without adding to the environmental strain already caused by conventional energy sources. SWHs can break the circle of poverty by creating employment opportunities and providing people with improved energy services that they do not currently have access to. By achieving this, SWHs, can fulfil fundamental human needs in a way that the process becomes a motor of further development leading to *"...healthy self-reliant and participative development, capable of creating the foundations for a social order within which economic growth, solidarity and the growth of all men and women can be reconciled"* (Max-Neef 1991).

At present, the benefits of solar water heating remains inaccessible for low-income communities due to the relatively high initial price of the technology. It is essential that government should become involved in realising the development potential of solar water heating. This thesis has shown that the state can overcome the price barrier through creating economies of scale in the SWH industry by funding the rollout of thousands of systems. If such rollout programmes are carefully planned, they can lead to the development of a strong local industry that could create employment opportunities and eventually become an export sector. The technology also allows for a partial decoupling of human development and electricity usage. These benefits can be realised through rollout programmes that could become long-term earners of revenue for the state through the sale of CERs and the collection of small monthly service fees from households that receive SWHs. The Kuyasa CDM project has shown that such a model can work.

If government rollouts of SWH are delayed or based on imported systems a golden opportunity would be missed to improve the quality of life of South Africa's poorest citizens. The country would fall behind others in developing solar water heating technology and miss the opportunity to create a new strong industrial sector. By providing the initial capital provincial level government can ensure that these benefits are realised. These benefits can be realised at no long-term financial cost to government. SWH can break the cycle of poverty whilst reducing the strain of human development on environmental resources. It simply remains for the provincial or national government to provide the initial funding that will make the benefits of the technology accessible in low-income communities. This is the area where it would serve well as a potent synergic satisfier for the achievement of sustainable development.

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9 ADDENDA

9.1 ADDENDUM A: KEY DEMOGRAPHIC DATA FOR THE STELLENBOSCH MUNICIPAL AREA[149]

Stellenbosch Total Population by Ethnic Group

Ethnic Group	***2001 Census***	***2006 projection***	***Growth rate***
African	24 188	31 975	**9.3%**
coloured	67 520	74 496	**1.4%**
Indian	239	283	**2.1%**
white	25 760	29 121	**0.7%**
Total population	***117 706***	***135 874***	**2.0%**

Stellenbosch Population Distribution (2006)

Ethnic Group	**High concentration**	**Low concentration**
African	Wards 1,13,15: Wemmershoek; Langrug; Mooiwater; Franschhoek; Rural area north of the R45 / Kayamandi (Zones A, B, C, D and E and Costa Land) / Kayamandi (Zones J, K, L, M, N and O)	Wards 10,8,6,5: Cloetesville; Tennantville; Welgevonden Estate / Stellenbosch Central / Stellenbosch East / Idas Valley and Lindida
coloured	Wards 1,3,4,5,6,18,19,17,10,11: Wemmershoek; Langrug; Mooiwater; Franschhoek; Rural area north of the R45 / La Motte; Groendal; / De Novo; Muldersvlei; Bottelary; Devon Valley; Devon Vale; Lynedoch (west of the R310); Vlottenburg (west of the R310) / Lynedoch (east of the R310); Raithby; Jamestown / Klapmuts; Rural area south of Klapmuts up to and including Nietvoorbij Farm / Elsenburg; Koelenhof; Cloetesville (west of Long and north of the Terraces open space) / Cloetesville (east of Long and south of the Terraces open space); Tennantville; Welgevonden Estate / Idas Valley and Lindida (excluding Gratitude Park and the erven east of Gorridon) / Gratitude Park; Idas Valley (east of Gorridon); The Ridge; the Idas Valley; the Jonkershoek Valley; the Banghoek Valley; Kylemore (South) / Johannesdal; Pniel; Lanquedoc; Groot	Wards 8,13,14,15: Kayamandi (all zones) / Stellenbosch Central

149 (Sustainability Institute & Probitas Real Estate Finance Education CC 2006):

	Drakenstein; the Dwars River Valley	
white	Wards 6, 7,8,9,12,16: Vlottenburg (east of the R310); Techno Park; Die Boord (east of Formosa and south of Van Reede); Dalsig; Brandwacht; Paradyskloof; Blaauwklippen Valley / Onder-Papegaaiberg; Plankenbrug; Die Boord (west of Formosa and north of Van Reede); Stellenbosch Central (south of Paul Kruger and West of Bird and Herte); Krigeville / Stellenbosch North (bordered by the railway line in the west; Dr Malan, Helshoogte Road and Kromme River in the north; Lelie, Cluver, Banghoek and Verreweide in the east and Merriman in the south) / Stellenbosch Central (bordered by Krige, Herte and Bird in the west; Merriman in the north; Marais, Bosman and Die Laan in the east; and Hofmeyr and the Eerste River in the south) / Stellenbosch East (bordered by Cluver, Verreweide, Marais, Bosman and Die Laan in the west; Helshoogte Road in the north; the eastern boundary of Rozendal and Karindal in the east; and the Eerste River in the South	Wards 5, 13, 14,15: Kayamandi (all zones) / Idas Valley and Lindida

Stellenbosch Level of Education by Ethnic Group – 2006 projection

Ethnic Group	None	Primary	Secondary	Grade 12	Higher	N/A
African	0.7%	35.1%	33.1%	18.4%	0.9%	6.7%
coloured	4.8%	36.5%	32.0%	20.3%	0.9%	5.5%
Indian	3.6%	17.3%	10.8%	41.5%	22.0%	4.9%
white	1.1%	9.4%	10.1%	46.8%	31.9%	0.7%
Average	*2.55%*	*24.58%*	*21.50%*	*31.75%*	*13.93%*	*4.45%*

Formal/Non-formal Dwellings by Ethnic Group – (2006 projections)

Ethnic Group	Formal	Informal	Traditional	Other
African	36.1%	48.2%	11.5%	4.3%
Coloured	84.5%	11.3%	4.0%	0.2%
Indian	100%	0.0%	0.0%	0.0%
White	96.4%	2.6%	1.0%	0.0%
Average	79.25%	*15.53%*	*4.13%*	*1.13%*

Household Access to Water Supply in Stellenbosch (2006)

Mode of Access	
Dwelling	58.4%
Inside yard	16.1%
Community stand	23.6%
Community stand200m	n/a
Borehole	0.1%
Spring	n/a
Rain tank	0.4%
Dam /pool/stagnant	0.2%
River/stream	n/a
Water vendor	n/a
Other	1.2%

9.2 ADDENDUM B: QUESTIONNAIRE USED FOR HOT WATER USAGE SURVEY IN STELLENBOSCH

Dear Madam/Sir,

This survey is conducted as part of a Master's thesis research programme. The objective will be to determine the demand for hot water in low-income households to understand the potential of fulfilling the hot water requirements with solar water heaters.

The survey does not represent an implicit promise that Solar Water Heaters will be provided or installed for any of the participants. It is merely completed as part of ongoing research to understand whether or not Solar Water Heaters can actually provide a useful service to those who currently have no access to water heaters.

Your personal details will not be revealed in the actual thesis. The data obtained will be processed into an aggregate form to represent general trends.

Your participation in this survey is very highly valued. Thank you for agreeing to participate in the research.

Biographical Information:

Address line 1: ____

Address line 2: ____

Time of Interview: ☐☐ : ☐☐

Date: ☐☐☐☐☐☐

Primary Language spoken at home:

Afrikaans	English	Xhosa	Zulu	Other: _________
☐	☐	☐	☐	

Language Interview is conducted in:

Afrikaans	English	Xhosa	Zulu	Other: _________
☐	☐	☐	☐	

Survey Questions:

How much do you usually spend on electricity per week?				
What is your monthly bill for water?				
How much do you usually spend on paraffin per week?				
How many men older than 15 live in your house?				
How many boys younger than 15 live in your house?				
How many women older than 15 live in your house?				
How many girls younger than 15 live in your house?				
How many people in total live in your house?				
Do you have a working electrical kettle in your house?	Yes	No		
Do you have a working electrical stove in your house?	Yes	No		
Do you have a working paraffin stove in your house?	Yes	No		
Do you have a working gas stove in your house?	Yes	No		
Do you have a working refrigerator in your house?	Yes	No		
Do you have a working electrical geyser for water heating?	Yes	No		
Do you mostly use a pot on the stove to heat water in your house?	Yes	No	Only sometimes	
Do you mostly use an electrical kettle to heat water in your house?	Yes	No	Only sometimes	
Do you mostly use an open fire to heat water for your household?	Yes	No	Only sometimes	

Do you have a working washing machine in your house?	Yes	No		
How many times a week do the members of your household wash themselves in a small basin?				
At what times of the day does this typically happen?	6-10am	10am-1pm	1pm-8pm	8pm-10pm
How much hot water do they use to wash like this? Equivalent amount in electrical 1.7 litre kettles:				
If the members of your household sometimes wash themselves with a larger amount of water such as in a large bath, how often per month would each member wash like this?	Times per month	N/A		
How much hot water do they use per person to wash like this if it does happen? Equivalent amount in standard 1.7 litre electrical kettles:		N/A		
How often do the men of your household wash their hair separately from their regular washes? Times per month				
How much hot water do they use for this? Equivalent amount in standard 1.7 litre electrical kettles:				
How often do the women of your household wash their hair? Times per month:				
How much hot water do they use for this? Equivalent amount in standard 1.7 litre electrical kettles:				
How often is a large batch of laundry done in your household? Times per month				
How much hot water is used for this? Equivalent amount in standard 1.7 litre electrical				

kettles:				
How often are the floors and surfaces in your house washed with hot water? Times per week:				
How much hot water is used for this? Equivalent amount in standard 1.7 litre electrical kettles:				
How often are dishes washed in your house? Times per day				
How much hot water is used for this? Equivalent amount in standard 1.7 litre electrical kettles:				
Could you please give us an estimate of how many cups of coffee and tea in total are made in your house per day?				

Do you use hot water for any activity that has not been mentioned in the questions above?If you do could you please give us an indication of how much hot water you use for this and how often this activity happens?

Activity:	Frequency per month or per week?	How much hot water does your household use for this activity each time? (Quantity of electrical kettles or large pots)

What is the average monthly income of your entire household, including wages as well as other sources of income such as unemployment insurance and social grants from the state? This information will be viewed as extremely confidential and is only required to calculate the portion of your income that is spent on electricity and water.

Thank you very much!

9.3 ADDENDUM C: MATRIX OF NEEDS AND SATISFIERS[150]

		Existential Needs			
		Being	**Having**	**Doing**	**Interacting**
Axiological needs	**Subsistence**	Physical health	Food, shelter, work	Reed, procreate, rest, work	Living environment, social setting
	Protection	Care, autonomy	Insurance systems, savings, rights, family, work	Plan, take care of, cure, help	Social environment, dwelling
	Affection	Self-esteem, respect	Friendship, relationships with nature	Make love, share, cultivate, appreciate	Privacy, intimacy, home
	Understanding	Curiosity, rationality	Literature, teachers	Investigate, study, experiment	Schools, communities
	Participation	Solidarity, determination, respect	Rights, responsibilities duties, privileges, work	Cooperate, share, dissent, express opinions	Parties, associations, churches, family
	Idleness	Curiosity, imagination, tranquillity, sensuality	Games, spectacles, peace of mind	Daydream, relax	Privacy, intimacy, free time, surroundings, landscapes
	Creation	Passion, determination, rationality, autonomy, curiosity	Abilities, skills, work	Work, invent, build, design	Productive and feedback settings, workshops, temporal freedom
	Identity	Sense of belonging, self-esteem	Symbols, language, historical memory, work	Commit oneself, actualize oneself, grow	Social rhythms, everyday settings
	Freedom	Autonomy, self-esteem, passion, open-	Equal rights	Dissent, choose, differentiate,	Temporal/spatial plasticity

150 (Max-Neef 1991, p.32)

		mindedness, boldness		run risks, commit oneself	

9.4 ADDENDUM D: EXAMPLE OF STANDARDS THAT A SWH SYSTEMS IS SUBJECT TO[151]

	Tests conducted:	Specification, Clause	Result:
1	Stagnation test (Exposure Test)	SANS1307- **5.2**	**Complied**
2	Rain Penetration	SANS 1307- **4.11.1**	**Complied**
3	Hail Test: 11J ±1J	SANS 1307- **4.11.2**	**Complied**
4	Freeze Test	SANS 1307- **4.11.3**	**Complied**
5	250 000 Pulsation test	SANS 1307- **4.11.4**	**Complied**
6	Marking	SANS 1307- **6.1**	**Complied**
7	Thermal performance- Q factor	SANS 6211-1 **5.5**	**Complied**
8	Heat loss	SANS 6211-1 **5.7**	**Complied**
9	Fixed electric storage water heaters	SANS 151	**Report WCT 09/0631**
10	Safety of household and similar electrical appliances – Part 2: Particular requirements for storage water heaters.	SANS 60335-2-21 SANS 1307 **4.11.6**	**Report WCT 07/0685**
11	Production standard	IS0 9001	**-**
	Remarks:		

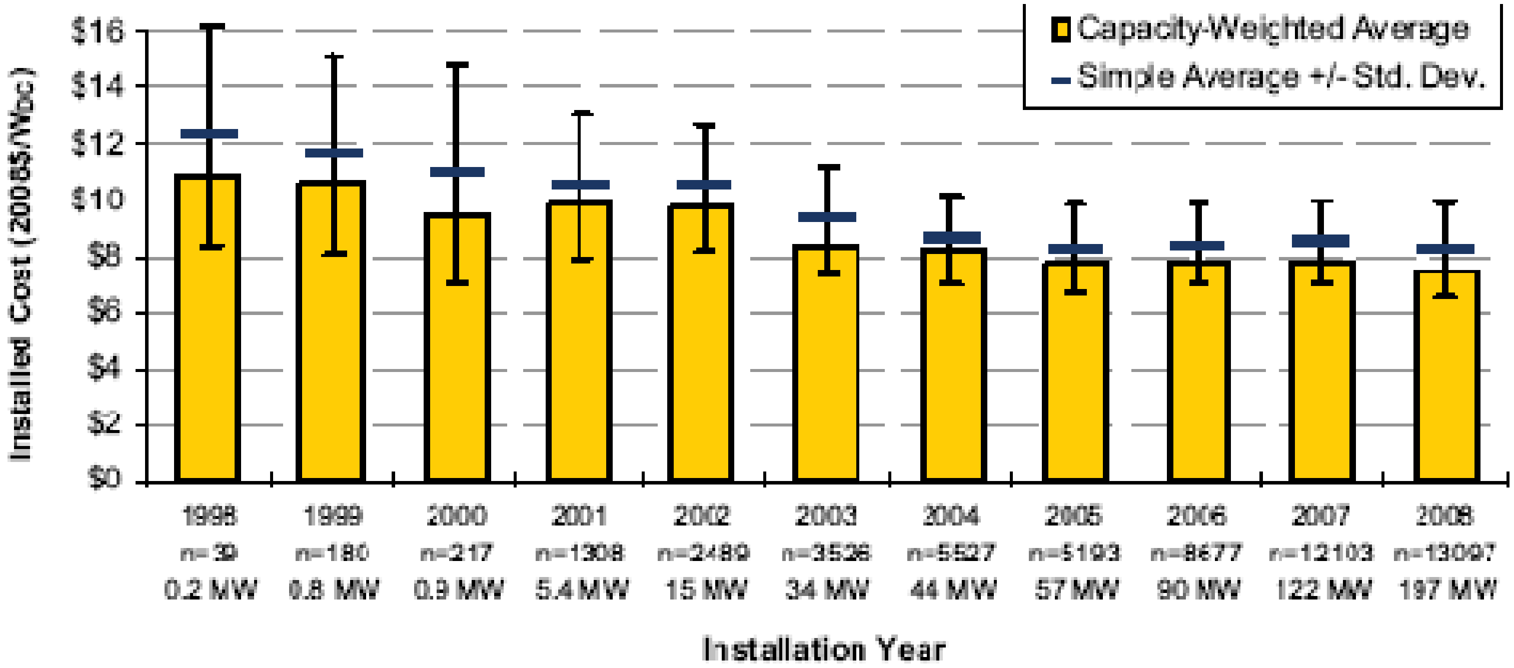
151 (Ledger & Gauteng Solar Solutions 2009)

9.5 ADDENDUM E: CALCULATION TABLE FOR ESTIMATED PAYBACK PERIOD OF LOW-COST SWH[152]

		Discount Rate	***10%***	0	1	2	3	4	5	6	7	8	9	10
Elec geyser		Elec geyser cost (incl install)		3 000										
		Elec bill per month (disc)			60	71	84	84	84	84	84	84	84	84
		Cumulative (disc)		3 000	3 720	4 571	5 577	6 582	7 588	8 593	9 599	10 605	11 610	12 616
SWH cash		SWH cost		8 000										
		Elec bill/mth (disc)			0	0	0	0	0	0	0	0	0	0
		Cumulative (disc)		8 000	8 000	8 000	8 000	8 000	8 000	8 000	8 000	8 000	8 000	8 000
SWH financed		**SWH cap cost**		8 000										
		Deposit		1 000										
Fin rate:	11%	SWH financed payments (disc)			879	799	726	660	600	546	496	451	410	373
Fin years:	20	Elec bill/month (disc)			0	0	0	0	0	0	0	0	0	0
		Cumulative (disc)		1 000	1 879	2 678	3 405	4 065	4 665	5 211	5 707	6 159	6 569	6 941
		Elec savings cumulative (disc)		0	720	1 571	2 577	3 582	4 588	5 593	6 599	7 605	8 610	9 616
		SWH Financed min elec savings		1 000	1 159	1 107	828	483	78	-382	-892	-1 446	-2 042	-2 674

[152] The expanded table including the data sets for the sensitivity analysis is available on the attached CD under the file name expanded low-cost SWH payback calculations.

9.6 ADDENDUM F: PRICE TREND FOR SOLAR PV SYSTEMS[153]



153 (Blackburn & Cunningham 2010, p.6)