The socio-economic efficacy of improved wood stoves upon two non-electrified, low income peri-urban areas of Pietermaritzburg, South Africa.

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ABSTRACT

Persistent poverty, social and economic inequalities are some of the challenges in the process of national development efforts targeted in the United Nations Millennium Development Goals (MDGs). Yet in South Africa, poverty, hunger, social and economic inequalities are still on the increase especially among poor rural to urban migrants. Because of severe poverty in rural areas, large populations of rural poor migrate to urban areas in search of better life. However, the growing energy needs in the urban areas where these people settle and their use of inefficient energy technologies negatively impact on the balance of environmental resources on which their socio-economic development depends. Efficient, affordable and environmental friendly technologies are therefore vital for improving the livelihood conditions and protecting the much needed environmental resources of the country.

On the contrary, current practices presently dominating energy provision issues in South Africa are insufficient to solve the problems of socio-economic inequalities, especially for the increasing urban poor population. In addition, they are also failing to protect the environment and natural resources. Electrification of poor urban and peri-urban areas by both grid and off-grid systems through the top-down development practice is doing very little to change the socio-economic conditions of the poor section of the population in the country. Likewise, the provision of modern energy through public sector agencies such as Eskom is inadequate and inappropriate for the rapidly expanding urban and peri-urban poor areas in the country. One major reason that hinders provision of such services to the overcrowded consumer population in these areas is the massive capital investment required and inability to pay electricity bills by urban poor households.

Against the above background, this study examined the use of improved wood stoves in two peri-urban areas (Umsilinga and Isnathing) in Pietermaritzburg, South Africa as an alternative modern energy technology on how they would socio-economically benefit the peri-urban poor. It looked at the following:

- The efficiency of four improved wood stoves (Yamampera, Simunye, Household Rocket and Vesto) in comparison with the three stone open fire,
- The impact of the efficient burning of the four improved stoves,
- Factors influencing consumers in choosing a specific energy technology to use,
- The effectiveness of the improved wood stoves placed in 24 peri-urban households and observed for the specified period, and
- Additional potentials of such stoves to other prospective users.

The key finding of this research is that the use of these improved wood stoves could play a pivital role in household economic growth and improving livelihoods. Participants ranked smokeless burning, low selling price, fuelwood saving and light weight of the stoves as priority preferences for using these stoves. Speed of cooking and less constant attention to the fire were also ranked as important preferences. From women participants view point, the low selling price of the stoves and their considerable fuel saving would reduce strain on the household investment capital, household indoor pollution and tedious work of women's fuelwood collection. Low investment costs in acquiring the stoves would encourage women's participation as entrepreneurs in modern energy technologies.

However, results from focused group discussions and observations of usage of stoves that were placed in 24 homes showed that the incorporation of consumer preferences in the design of improved wood stoves would be key. This would enable stoves to adequately meet the energy needs of targeted users and be used frequently as an alternative energy solution by both urban and peri-urban poor who are currently lacking electricity and suffering from energy poverty.

DECLARATION

I **....McWilliam Chipeta Mabaso**.. declare that:

(i) The research reported in this thesis, except where otherwise indicated, is my original research.

(ii) This thesis has not been submitted for any degree or examination at any other university.

(iii) This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from those persons.

(iv) This thesis does not contain other author's writing, unless specifically acknowledged as being sourced from other authors. Where other written sources have been quoted, then:
a) their words have been re-written but the general information attributed to them has been referenced;
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(v) This thesis does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the thesis and in the References sections.

Signed: ……………………………………… Date: 14 January 2009……

As the candidate's Supervisor I agree to the submission of this dissertation/thesis.

Signed: …………………………………….. Date: 14 January 2009……………..
Professor J M Green.

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List of Abbreviations

ADB	African Development Bank
ARI	Acute Respiratory Infections
CBD	Central Business District
DFID	Department for International Development
DME	Department of Minerals and Energy
ERC	Energy Research Centre
ESCO	Energy Service Company
ESMAP	Energy Sector Management Assistance Programme
ETC	Educational Training Consultants
FAO	Food and Agriculture Organisation
FBE	Free Basic Electricity
GEA	Greater Edendale Area
HIV/AIDS	Human Immune Virus /Acquired Immuno-Deficiency Syndrome
ICS	Improved Cook Stoves
IDP	Integrated Development Plan
IEA	International Energy Agency
IGA	Income Generating Activities
IPCC	Intergovernmental panel on Climate Change
ITDG	Intermediate Technology development Group
KCJ	Kenya Ceramic Jiko
kW/h	Kilowatt per hour
LCHS	Lund Centre for Habitat Studies
LPG	Liquid Petroleum Gas
MDGs	Millennium Development Goals
NEP	National Electrification Programme
NER	National Electricity Regulator
NGOs	Non-Governmental Organisations
PMB	Pietermaritzburg
ProBEC	Programme for Biomass Energy Conservation
RDP	Rural Development Programme

RWEDPA	Regional Wood Energy Development Programme in Asia
SADC	Southern Africa Development Community
SEA	Sustainable Energy Africa
SECC	Soweto Electricity Consultation Committee
SHSs	Solar Home Systems
SME	Small and Medium Enterprises
TIASA	Thermo Insulation Association of South Africa
TLC	Transitional Local Council
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
US$	United States Dollar
VITA	Volunteers in Technical Assistance

CHAPTER ONE

BACKGROUND TO THE STUDY

1.1 Introduction

Throughout the centuries, energy has helped transform and underpin human development. It has helped light schools, cook food; heat homes; keep hospitals running; fuel industries; and transport people and goods near and far (ITDG, 2002a). In modern times, energy is required to increase productivity and create jobs (UNDP, 2005) and it has been described as vital for the achievement of the United Nations Millennium Development Goals of halving poverty rates, hunger and improving health by 2015.

However, exploration of urban poor household energy use has not examined the links between household income generation, neglected gender aspects (particularly at the intra-household level) and the strategies urban poor households use to develop livelihoods (Clancy, 2004). There has also been little reflection on the outcomes of privatisation and commercialisation in the energy sector on energy services for the poor.

According to DFID (2000), most programmes and projects aimed at improving the poor households' energy in the developing countries concentrated in the rural areas. The main drive for these programmes and projects was the need to reduce environmental degradation resulting from charcoal and fuel-wood production. However, fuel-wood has been shown not to be the main cause of deforestation, but rather land clearing for agricultural crops (World Energy Council, 1999). As such, many of those programmes failed due to a lack of attention to consumer tastes and market dynamics. This has led to empirical data about the urban poor, their lack of energy and much of the policy making to be based on ill informed assumptions (Clancy, 2000).

As poverty remains high due to falls in agricultural production in many of the rural areas, especially in sub-Saharan Africa, the rural poor migrate to cities due to the urban pull factors (such as rosy advertisements). Because of this, urban population growth rates in most of these cities are double national averages (Karekezi & Majoro, 2004). UNEP

(2002) estimates that for the next 15 years, the urban population growth rate in sub-Saharan Africa is expected to average as much as 3.5 percent.

The high population densities in the urban areas cause cities to be centres of concentrated energy consumption. However, because of greater integration in the market economy, energy needs for cooking, heating, lighting, small-scale industries and food processing are often now met by market arrangements. As such, the high levels of inefficient energy consumption by the poor settlers causes urban areas to contribute significantly to energy related problems such as localised resource depletion (UNEP, 2002), household indoor pollution and increased household poverty (World Energy Outlook, 2006; Karekezi & Majoro, 2004). Consequently, the rate of growth in demand for energy of all types is also high in these areas, and should be matched by increased, efficient and affordable energy technology supply.

While African urban areas are associated with the use of modern fuels like electricity, the consumption of electricity depends on the availability and adequacy of supply, as well as the income of consumers (Practical Action, 2005; Clancy, 2004). As such in most cities with rapidly growing populations in Africa, supply often becomes limited and high population growth rates are not matched by economic growth. In addition, declining economic conditions in most African countries limit investments in the generation of modern fuels. As a result, real incomes of urban residents fall, limiting their ability to afford modern fuels. Karekezi and Majoro (2004) have noted that urban poverty in Africa is growing, with the gap between the rich and poor increasing and the percentage of the poor getting bigger.

Income distribution data indicates that most African urban households are poor (Practical Action, 2005). The poor tend to depend more on inefficient fuel-wood using technologies like the three stone open fire to meet their energy requirements, thereby contributing to the problems of indoor pollution, scarcity of wood fuel and forest degradation. The inefficient use of biomass exposes private households and small-scale industries to the shortage of energy for cooking, baking and heating. It thus forces the poor to pay a higher price for their energy in the form of human time and labour, economic cost, health costs (mainly resulting from indoor pollution), social and gender impact of energy services[1] which are contrary to Millennium Development goals.

While it is governments' urgent need to provide modern energy to the urban and peri-urban poor to stimulate economic growth (Clark and Drimie, 2002), getting power to these people has been exorbitantly expensive. In many cases, because of the inability to pay by urban poor, conventional grid and fuel distribution networks mainly driven by commercial gain in developing countries, do not reach such areas. This leaves the poor with insufficient resources to escape poverty (Howells *et al,* 2005; Ogunlade *et al*, 2003).

Providing clean modern energy services to poor communities will thus require the expansion of choice of energy options, including conventional and non-conventional sources to expand the energy choices available to the millions of people living without electricity or clean fuels (Practical Action, 2005). Modern renewable energy technologies including affordable improved cooking stoves would likely be one of such non-conventional sources to effectively meet the current urgent challenge of meeting household thermal needs in the medium to long term future. These technologies would also offer a mix of decentralised energy saving products that would increase energy security as well as economic and social benefits.

While there have been localised attempts to include pro-poor energy technologies relevant to the existing energy problems in Africa, efforts to find appropriate technologies such as improved biomass cook stoves are hampered by the scarcity, limited scope and poor quality of existing data at both local and national levels. This negatively affects policy making as there is no data to inform policy makers when developing energy policies to ensure that appropriate, workable and affordable renewable energy technologies/services are promoted (SADC, 2006; Karekezi *et al*, undated).

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[1] ADB FINESSE Training Course on Renewable Energy & Energy Efficiency for Poverty Reduction, 19th – 23rd June 2006. Nairobi, Kenya.

1.2 Purpose of the research

The purpose of the study is to assess the socio-economic benefits of using improved wood stoves in comparison with the current technologies used by the un-electrified peri-urban and urban informal poor households in and around Pietermaritzburg from both the technology efficiency point of view as well as users' perspectives which influence their choice of cooking fuel and appliances. The results will be brought to the attention of the leadership in the study areas and responsible policy makers. They are intended to contribute to relevant and possible energy solutions that would help reduce energy related socio-economic challenges experienced by the un-electrified urban poor households.

1.3 The research problem

The aim of this research is to determine whether the use of improved wood stoves would feasibly address the energy related challenges of 1) efficiency, 2) affordability, and 3) accessibility faced by the majority of the urban poor in the un-electrified peri-urban and urban informal households. This is explored through investigating the following three sub-problems.

1.3.1 The research sub-problems

1. How does the efficiency performance of the four improved wood stoves compare with that of the three stone open fire?
2. What difference would the use of the improved wood stoves have on poor households in the un-electrified peri-urban and urban informal areas in and around Pietermaritzburg?
3. What role would user perception play in the possible use of improved wood stoves in the peri-urban and informal urban poor areas?

To answer the above questions effectively, the following were studied.

1. The comparative efficiency performance test in a controlled environment using the water boiling test was conducted on the four improved wood stoves and the three

stone open fire. The open fire was used as a baseline because it was the commonest technology used by households in the research area. The following factors were studied and recorded;

   i. time and fuel-wood used by each stove;
   ii. frequency of attendance to the fire during cooking;
   iii. implied comparative fuel savings between the improved wood stoves and the three stone open fire.

2. The baseline study of fuels and appliances used and socio-economic characteristics of households in the two study areas was conducted using a structured questionnaire. The following were probed;
   i. the demographics of the sample (household heads, household sizes, and gender);
   ii. socio-economic characteristics of the sample which included employment status, level of education and income;
   iii. the households' cooking fuel costs and situation before the demonstration of stoves.
3. Demonstrate the stoves in focus groups and place stoves in homes to assess their adaptation to users' expectations in real life cooking situations. The following were probed using structured questionnaires;
   i. consumer preferences in the choice of types of the stove to be used;
   ii. the perceived socio-economic benefits of the demonstrated and placed stoves from consumers' point of view;
   iii. the consumers' perceptions of the improved wood stoves as demonstrated in comparison with existing alternative energies and technologies used in the study area.

1.4 Assumptions

The study assumes that one dish is cooked at a time and irrespective of poverty in the study area. It also assumes that poor people do not aspire to being poor; their aspiration is to use good quality products with status. This necessitated the use of single pot and good looking portable stoves.

The study further assumes that energy needs for lighting is not as serious as that of cooking and that much work on the former has already been conducted by other researchers (Ogunlade *et al*, 2003; Clark, undated). As such, this study exclusively focuses on cooking energy technologies without incorporating lighting energy during efficiency test, feasibility study and consumer perception stages.

Additionally, this study assumes that the diffusion of a technology goes beyond the technology itself. Therefore the water boiling test was carried out during the stove demonstrations to focus groups in order to visually present efficiency advantages. This would appeal to financial, sociological and psychological interests that could not be perceived only by looking at or hearing about the stoves.

The study also assumes that willingness to use the stoves by 16 percent of participants in the baseline study, after the demonstration of stoves in focus groups and homes where stoves were placed for further observation would signify acceptable readiness of the people to adopt using the stoves. This is based on Roger's theory of diffusion (2003) where 16 percent was identified as early adoption success.

1.5 Limits of the Study

This study does not test the smoke and gasses emitted from burning wood for hydrocarbons and air pollutants during cooking nor does it test the scientific thermal efficiency of stoves in the field. The range of emissions is however based on ranges of similar stoves widely reported in literature (World Energy Council, 1999; Global Environmental Facility, 2000). A thermal efficiency test was done on one of each prototype of stoves in an outdoor atmospheric condition similar to the field conditions before taking the stoves to the field.

Two areas, Umsilinga near Swapo (an informal settlement) and Isnathing (including two areas, one informal and one traditional settlement) both in Pietermaritzburg, were used as examples of peri-urban areas in KwaZulu-Natal. These areas were selected in order to provide for the generalisation of the results to other similar areas in KwaZulu-Natal and South Africa.

1.6 The Theoretical Framework

This study is based on the concept of sustainable energy development (Figure 1.1 below) by Elizabeth Cecelski (2000) adapted from Munasinghe (1995) where household choice and use of energy technology affects the household's sustainable development. This includes:

- Environmental sustainability: preserving forest resources, and avoiding pollution;
- Economic sustainability: cooking efficiency, savings and stability; and
- Social sustainability: potential of poverty alleviation uses consultation, empowerment of the beneficiaries, and preservation of culture and heritage (technology acceptance).

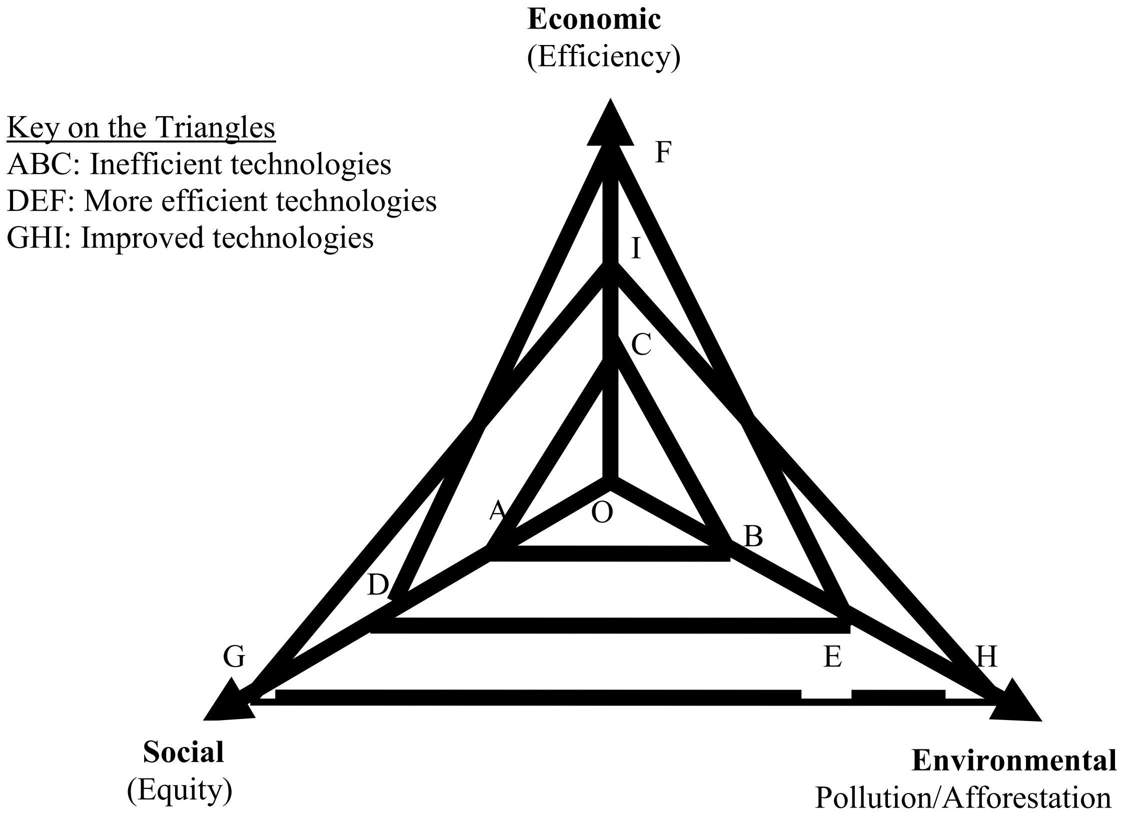

Figure 1.1 Complementaries and trade-offs among social, economic and environmental dimensions of sustainable development (Source: Cecelski, 2000)

The concept assumes that the majority of poor peri urban people use the traditional inefficient energy technologies (inner triangle ABC) in Figure 1.1 which have negative environmental impact, moderate economic efficiency and low social status. This limits the development of the household because the use of such technologies exhaust their scarce resources, cause households to spend more money or labour and time to yield the required benefits and therefore also increase poverty.

Maximum household economic benefit would increase in the second triangle DEF (Figure 1.1) where more efficient energy technologies would also provide health, environmental and economic benefits. However, many of these energy technologies do not fall into this extreme "win-win-win" area. Social, environmental and economic sustainability require difficult trade-offs. For example, there might be large numbers of photovoltaic systems sold on a commercial basis, yet it is known that such technologies are not affordable to the poorest 25-50 percent of the peri-urban population in developing countries even with subsidies (Makino, 2003; Cecelski, 2000). As such the improved cook stove technologies fitting in triangle GHI (Figure 1.1) may seem to score less on economic efficiency but have quite high overall impact on the environmental sustainability as well as on all social equity or poverty alleviation because of their affordability, familiarity and safety.

The relative familiarity with technology is important for new technology transfer. Hurst in Martinot *et al* (2002) suggests that the success of solar hot water heaters in several countries, micro-hydro in Nepal and wind turbine water pumps in Argentina during the 1980s occurred because relatively little change of consumer behaviour was involved. Similarly, the ethanol vehicle-fuel program in Brazil was successful partly because using ethanol required little change in consumer’s attitudes and / or behaviour.

The application of this concept to this study was useful because it guided the selection of the technology that would fit triangle GHI which increased chances of acceptance of the improved wood stoves in the research areas. As mentioned earlier, this was because the operation of improved wood stoves is nearly similar to the three stone open fires commonly used by the target population.

1.7 Structure of the thesis

This Thesis is structured into seven chapters as follows.

Chapter 1 introduces the background of the research. Included in this chapter is the introduction and description of the theoretical frame work used in the choice and analysis of energy technology. It also gives the outline of the rest of the chapters of the thesis.

Chapter 2 provides a literature review of urban poor household energy consumption, the influences of users' choice of energy and technology from policy as well as household perspectives and how this impacts on the livelihoods of low income earners especially in urban and peri-urban setups. The demographic and economic characteristics shaping energy use in peri-urban and urban informal areas is presented. It provides an overview case study of how emphasis on specified energy technologies such as electricity and paraffin has affected access to and use of other energy sources and technologies in South Africa. It also highlights the past successes of improved stoves as a motivation for this study.

Chapter 3 provides a physical and demographic background of the study area.

Chapter 4 introduces and describes the methodology used in the collection of data during efficiency test and focus group discussions.

Chapter 5 outlines the results which include the outcome of the efficiency test, the energy situation before the research and priority consumers' preferences in the choice of improved wood stoves during demonstration and placement in their homes.

Chapter 6 presents the discussion of the results.

Chapter 7 presents the conclusion and recommendations regarding the feasibility of introducing the tested stoves for use. The chapter also summarises the results of the dissertation and suggests recommendations for further research.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Introduction

The United Nations in its drive to achieve the Millennium Development Goals (MDGs), has categorized among others, household use of improved energy services and more efficient household energy appliances as central in reducing hunger, poverty and health hazards by the poor majority in the world today (UNDP, 2005). However, there are currently 2.4 billion people in developing countries world wide living below the poverty line (US$1 per day) that do not have access to electricity and other modern energy. These depend on biomass and other traditional fuels using inefficient appliances in fulfilling household energy needs of cooking, space heating and lighting.

The use of biomass and other traditional fuels in rudimentary inefficient technologies and appliances such as the three stone open fire, traditional unimproved stoves, etc limits the achievement of the millennium development goals (UNDP, 2005; Millennium Project Task Force 1, 2004). The inefficient technologies and appliances greatly emit sub-noxious gases which cause acute respiratory infections (ARI), use excessive quantities of fuels thereby greatly contributing to deforestation and environmental degradation, cause higher proportions of households' income and time to be spent on fuels thereby increasing household poverty (Smith, 1987). These are contrary to the MDGs (UNDP, 2000).

2.2 Household biomass use in Africa

In spite of rapid urban growth experienced by sub Saharan Africa over the last two decades, the majority of people in these countries still depend on biomass as their main fuel to meet almost all of their energy needs. The International Energy Agency (1998) estimated that biomass constituted 60 percent of the total final energy consumed in Africa in 1995. It is further estimated that the absolute number of people relying on biomass energy in sub-Saharan Africa will increase by approximately 27 percent from 583 million to 823 million between 2000 and 2030 (IEA, 2002a). The majority of this population increase will be the poor, living in slums and peri-urban settlements with unmet needs greater than those from the rural areas. In most countries with the exception of South Africa, biomass will account for 70 percent - 90 percent of primary energy supply and 86 percent energy consumption (UNDP, 2003; IPCC, 2003; Karekezi, *et al*, 2002).

The heavy reliance on biomass as the main household energy in Africa is unlikely to change in the near future, given the stagnant and in other cases, declining per capita modern energy usage as well as slow economic growth (World Energy Outlook, 2002). In addition, the high costs and lack of electricity and other modern forms of energy will continue to prevent the poor from moving to newer energy types for cooking which is the poor people's most energy intensive use.

In South Africa, electricity has proved very expensive to both the government and targeted users. For example, rural grid electricity connections have been costing R1 billion per year at the average cost of R3213 per connection. This is in addition to the users' subsequent payments. Furthermore, basic investment in photovoltaic has been costing R3150 ($450) per simple system which most of the targeted users cannot afford. This is because most of the targeted users are faced with declining income due to the prevailing unemployment, poverty and HIV/AIDS (Makino, 2003; ITDG, 2002a). As a result, most poor households cannot afford an electricity connection and even if they have a connection, they can only afford to use electricity predominantly for lighting and radio (Prasad & Visagie, 2005).

Unfortunately, little work in improving biomass fuel and appliance efficiency has been undertaken except for one isolated project by Programme for Biomass Energy Conservation (ProBEC) and little information has been published (Karekezi, 2002; Economic Commission for Africa, 2006). In addition, there is very limited scholarly information available on the socio-economic benefits of improved biomass energy technologies and appliances used for cooking and space heating at household level in southern Africa (Karekezi & Majolo, 2004).

Earlier attempts to improve household energy situations for the poor in the region have been electricity based. In South Africa, the post apartheid government committed itself to address the historical inequalities by formulating a new energy policy that sought to address the energy requirements of the poor (Eberhard & van Horen, 1995). The policy was designed to widen access to adequate and affordable energy services for both urban and rural households. Furthermore, it aimed at providing cleaner and safer forms of energy for low income households (Spalding-Fecher & Matibe, 2003). This led to the department of Minerals and Energy Affairs embarking on accelerated electrification programmes in many rural and urban areas of the country (DME, 1998) with the view that poor people would automatically switch to using electricity. This was irrespective of the fact that coal-based power generation, producing 90 percent of the country's electricity, is responsible for 43 percent of Africa's atmospheric pollution (Sustainable Energy Africa, 2006). The emissions released into the air contribute to global warming.

Thus, by the end of 1998, many households in rural and urban areas still relied on firewood or paraffin use. According to the South African Energy White Paper (1998), by 1998, approximately 40 percent of all homes in South Africa as well as tens of thousands of schools and clinics, still had no access to electricity. Most homes, schools and clinics obtained 65 percent of their energy from fuel-wood, 9 percent from coal, 8 percent from illuminating paraffin and the remainder from liquid petroleum gas (LPG).

According to FAO (2000), South Africa remains the highest per capita user of fuel-wood in the region in spite of its extensive electrification programme (Figure 2.1). Currently, there are still millions of households especially in the peri-urban and urban informal settlements which are without electricity. Moreover, it is estimated that the existing power generation capacity will be insufficient to meet the rising national maximum demand from 2007 to 2012 (TIASA, 2006; Prasad & Visagie, 2005).

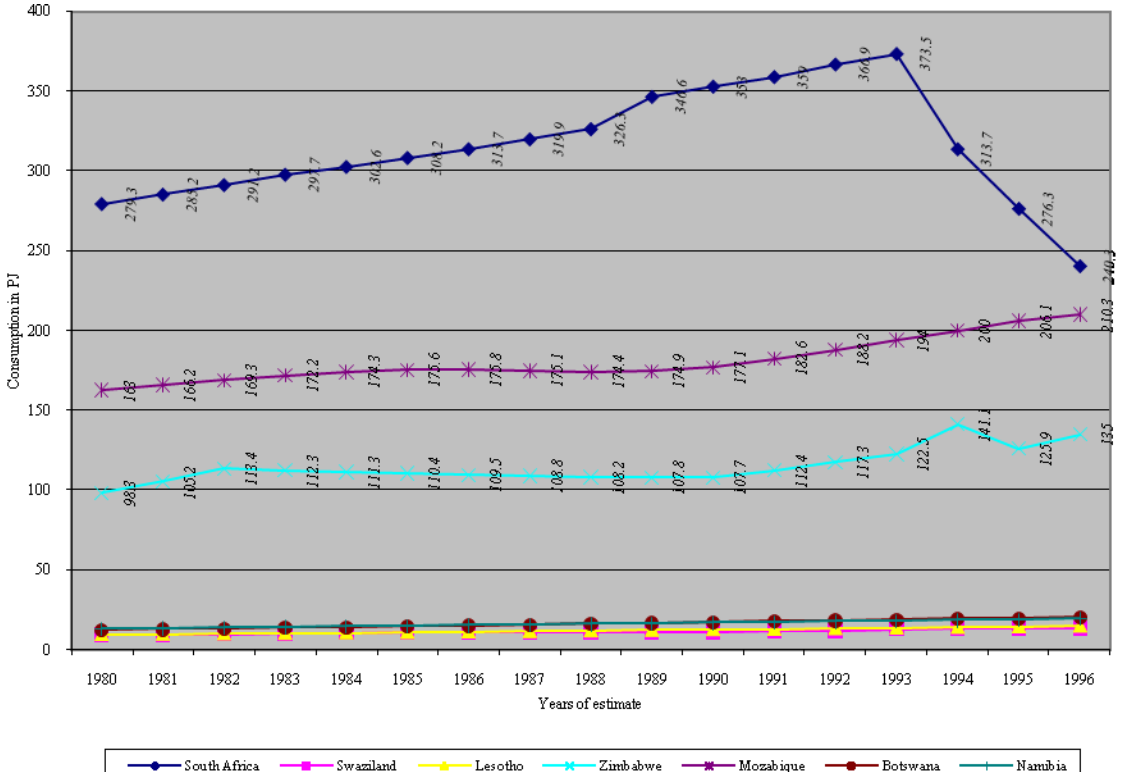

Figure 2.1 Comparative fuel-wood consumption per capita per year in Southern Africa (FAO, 1999).

2.3 The Peri-urban Household Energy Situation

In determining national supply-demand energy balances, there has been a distinction between rural and urban household consumption. The total peri-urban energy system has rarely been considered in isolation (Brook & Dávila, 2000). Previous studies in addressing poor households' energy constraints have tended to concentrate on the energy efficiency of supply to end user in either rural or urban settings (Winkler *et al*, 2005; Clancy, 2004; ETC, 1996), and have failed to take account of the particular needs of the peri-urban environments. Traditional fuels and the modern traditional mix in peri-urban areas have relatively been under-studied.

While much has been learnt from the technologies, implementation strategies and operating experiences of energy efficiency technologies in the rural or urban settings, it is necessary to establish a new methodology and a clear set of criteria for the analysis and selection of the most appropriate technologies and technology transfer mechanisms for the peri-urban interface.

2.3.1 Acquisition and Consumption

Peri-urban environments are frequently characterised by rapid growth of settlements of rural migrants which are in most cases informal, unplanned and without secure tenure which in itself is a direct challenge to electrification (Karekezi & Majolo, 2004). In these settlements, there is often shortage of housing, pressure on all forms of infrastructure, inefficient use of energy, low productivity rates, unemployment and increased poverty levels (Williams, 1993; Qase and Annecke, 1999) which according to Howorth *et al* (1997) indicate a relocation of rural poverty into urban areas.

Consumption of fuels is affected by the ability to pay and is therefore not synonymous with demand because low consumption levels hide demands that are never fulfilled (Anthony and Wafer 2004; McDonald 2002). In addition, energy expenditure occupies a prominent place in the economies of poor households. Usually it accounts for a larger proportion of monthly expenditure which influences them to choose fuels that cost less, are available, convenient and have appliances that are available and appropriate (Karekezi & Majoro, 2004; Soussan *et al*, 1992).

Biomass dominates household fuel supply and use because it can be collected free and where purchased can be bought in smaller quantities and on daily basis, matching low income households budget constraints (Soussan, 1991). The economic status of the household and the existing structure providing energy also influence household fuel acquisition. Low income households often use a wide range of fuels (Howorth *et al*, 1997). Thus any scarcity or increase in the cost of fuel-wood supplies will be significant because households will be compelled to balance the costs and availability of alternative fuels and respond rapidly to locate a substitute fuel.

Like with their rural counterparts, cooking is seen as the most energy intensive need of the urban poor (Table 2.1). It constitutes a very large share of household energy consumption and the largest single energy use in low-income urban households (Michel, 2004; Kuhnhenn, 2003; Cecelski, 2000).

Table 2.1 Residential Energy by Activity for 2000 in South Africa: (Source: Department of Minerals and Energy, 2002:35)

Residential Energy Activity	**Energy (Pelajoules)**
Cooking	113.4
Lighting	15.4
Other	35.1
Space heating	90.8
Water heating	29.5
Total	**284.2**

For most peri-urban poor, satisfying their energy needs for cooking is just as challenging as it is to secure essential needs such as food, shelter, water, health care, transport, and education. These are concerns most of which are provided free or by the community in the rural areas where they came from (Clancy, 2004; DFID, 2002; Howorth *et al*, 1997). As such, household energy planning occurs against a background of great complexity and change. In terms of energy use, the consumption patterns are urban in character in that energy services are monetarised and culturally new. Change in energy utilisation is often rapid and includes the energy consumption patterns of low, medium and high income groups.

The available evidence suggests that peri-urban and urban poor people buy their fuel even though there is little quantitative data on the use of non-purchased fuels (ESMAP, 2003; Karekezi & Majoro, 2004). However, poor people prefer to purchase fuels in small quantities on daily basis to match their fluctuating income (Barnes *et al,* 1994). The consequence is that they pay a higher unit cost than for bulk purchases and spend a higher proportion of their income on energy than higher income households.

Few studies that have focused on household energy expenditure patterns have found that households with the lowest incomes tend to spend higher proportions of their income on energy (Statistics South Africa, 2001; Eberhard & van Horen, 1995; Qase & Annecke, 1999). McCall and Witherden (2002), estimate that the average poor home in South Africa spends 25 percent of its income on energy compared to 2 percent for more affluent homes. SEA (2003) observed that poor households in Cape Town spent between 10 percent and 25 percent of their income on energy while wealthy households spend between 3 percent and 5 percent.

2.3.2 Household fuel choice

Regardless of income, households use a mix of fuels although the fuel of preference varies with household income (NRI, 1996). However, household fuel choice has often been conceptualised using the energy ladder model (Figure 2.2) which is loosely based on the economic theory of household behaviour. This assumes that modern fuels (electricity and gas) are normal economic goods while the traditional fuels such as wood and crop residues are inferior (Chambwera, 2004).

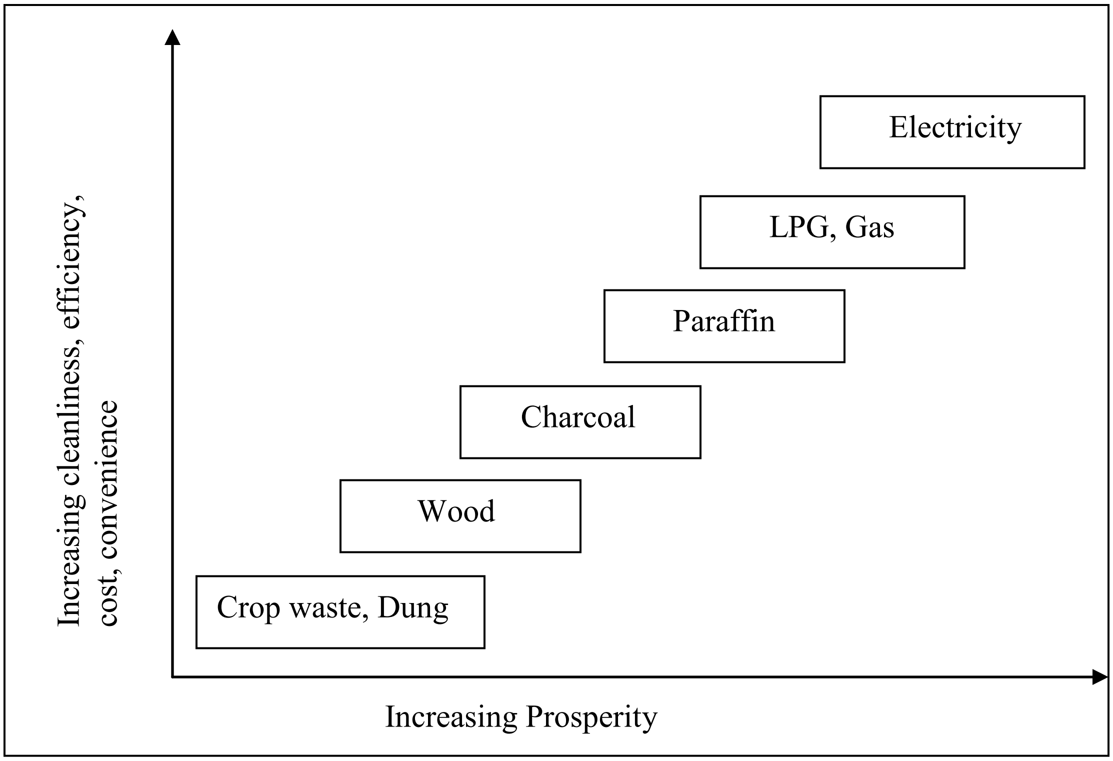

Figure 2.2 Energy ladder representing the fuel types used by households as their prosperity increases (Source: 2006 Energia News 9(1): 21**)**

As such, most governments in developing countries promote the use of electricity, gas and paraffin on the assumption that these would replace fuel-wood and improve household socio-economic situations.

Being connected to electricity does not automatically ensure that households are able to use it to the optimum. Fuel use is determined by cost, affordability of fuel, the outlay on related appliances, gender and cultural ideology of the users.

In a study in Tanzania, although electricity was the cheapest cooking fuel, connected households did not show a significant switch even though they were in a high income group (Hosier & Kipondya, 1993). People continued cooking their staple food (Beans and Ugali) on charcoal because of their cooking practices and the intra-household decision making. Long slow simmering is easily done on their specialized charcoal cookers than on an electric stove (Hosier & Kipondya, 1993).

A World Bank study in Niger quoted by Leach and Mearns (1988) found that despite cooking being cheaper with paraffin than wood, wood was still the preferred fuel. Amongst the reasons given were: (i) the power output of the paraffin stove was significantly less than the traditional wood stove and made cooking take longer; (ii) the paraffin stove did not support the round-bottomed cooking pot used in the area and tended to overbalance during the frequent stirring necessary with staple local foods; and (iii) the paraffin stoves were not robust. As such, paraffin stoves were only used for rapid cooking and water boiling, while wood and charcoal were used for staples. A similar pattern with LPG and electricity was also found in Dar-es-Salaam, where these fuels were used when time was of essence (at breakfast and for hot drinks in the evening).

2.3.3 Household fuel switching

In peri-urban environments, household fuel switching is sometimes a seasonal or short term response to changes in supply or a more long term measure. The Lund Centre for Habitat Studies (LCHS, 1993) found that households with access to electricity still relied on charcoal or wood for cooking because of inadequate supplies, power cuts or high electricity prices.

The concept of the energy ladder where people change to higher quality fuels and technologies based on growing income elasticity, is complicated in peri-urban areas. This is because poor households use fuels that are readily available. As such, energy security is a key issue and not income elasticity to purchase commercial fuels. Fuel switching is therefore determined by household choices about expenditure (Lloyd *et al*, 2004; Watson *et al*, 2002). In addition, in households where there are adult men and women, the gendered division of labour generally allocates to women the responsibility for household energy provision related to activities centred on the kitchen (Clancy et al, 2003). However, when energy has to be purchased, men will often decide on the stove technology if it is to be bought (Cecelski, 2000). Men also decide the type of materials for kitchen walls and roofing without considering their effect on cooking and kitchen comfort (Dutta, 1997). In some households, recreational equipments, such as TVs and radios, are bought before labour-saving equipment for domestic chores (EDRC, 2003; McCall & Witherden, 2002).

The shifting of households to modern commercial fuels in peri-urban areas is also dependant on the extent to which industrialization has caused the urbanization (Hosier & Kipondya, 1993). In areas where industrialisation has created employment opportunities and improved the incomes of urban and peri-urban dwellers, householders can afford modern sources of energy. Without these income opportunities created by industrial growth, the affordability of modern fuels remains low because there are high populations of unemployed people (Howorth *et al*, 1997).

In general, continued urban growth drives urban energy demand and without growth in the industrial sector, energy demand entails an increased intensity in the use of traditional fuels (Hosier and Kipondya, 1993).

2.3.4 Urban poor and informal enterprises

The informal sector (SME) is a major producer of goods and services for the urban poor and an important source of employment (Barnes, 1995). The informal enterprises such as street food vending, form an important part of livelihood strategies particularly by women for a larger source of income generation and improvement in their living conditions (Tedd *et al*, 2001). In the Philippines, after the closure of large number of factories and small business due to the financial crises in Asia, there was a five-fold increase in street food vendors over a period of 3 years.

In some countries, informal SMEs have played a crucial role in providing energy services, as well as the manufacture and distribution of low cost clean energy technologies. In Bangladesh, any improvement in household energy use, in particular the cooking aspects of street food (using twigs), improved the livelihoods of street food vendors (ITDG, 2002b; Tedd *et al*, 2001). A similar in-depth study was done in Colombo, Sri Lanka where 76 percent of vendors were supported from street food. In Kenya, the whole charcoal and fuel-wood stove manufacturing process is carried out by the informal sector.

However in South Africa, street food vending as an informal enterprise has not been pursued by the urban poor in spite of existing evidence of success in other developing countries. This has largely been due to lack of efficient, safe and affordable cooking technologies that would be backed by government to enable street food vendors to sustainably run their businesses. The commonly available devices like the liquid petroleum gas (LPG) and paraffin panda stoves are in most cases expensive and unsafe (particularly paraffin stoves) (Kruger, 2005).

2.4 Past examples of low income household energy interventions in South Africa

2.4.1 The grid electrification programme

The National Electrification Program (NEP) is a government-financed initiative targeted at the previously disadvantaged. The key objective of the programme is to raise national electrification levels to about 66 percent by the year 2001 with an average electrification level of 46 percent in rural areas and 80 percent in urban areas (Davidson & Mwakasonda 2004). This implies providing electricity to an additional 2.5 million households. By the end of 1997, nearly 3 million homes (Table 2.2) were installed with electricity instead of 2.5 million proposed in the RDP document. However, electricity contributed only 20 percent of household energy consumption.

For many poor South Africans, true access to electricity was a problem that was beyond connectivity and ultimately depended on affordability (DME, 2003). Often poor households were unable to reap the benefits of being connected to the electricity grid since they could not afford even the minimum amount of electricity required for their basic needs. In addition, many poor people are being burdened with high arrears, electricity cut-offs and poor service quality (Karekezi & Majoro, 2004). Thus in Soweto, as a result of average income levels and the necessity to provide for other basic needs such as food, water etc., 89 percent of the households sampled by Fiil-Flynn and SECC in 2001 had electricity arrears. Thirty percent of them owed more than R10 000.00, an amount that was unpayable given the household incomes in the area (Egan & Wafer, 2004; Fiil-Flynn & SECC, 2001). This has resulted in protests and activist campaigns such as the Soweto Electricity Crisis Committee. This committee campaigned for better electricity service delivery and the introduction of more radical pro-poor policies.

2.4.2 The off-grid electrification programme (Solar Home Systems)

In order to install and maintain non-grid electricity technologies in allocated rural areas where grid electricity could not reach, the government pursued the Energy Service Company (ESCO) model with a fee-for-service approach. However, this has to date been only limited to the provision of Solar Home Systems (SHSs) rated at 50 W capacity which powers approximately four lights, a radio and a black-and-white TV estimated to consume about 6 kW/h per month (Davidson and Mwakasonda 2004).

For most beneficiaries of the SHS off-grid electrification, this meant that they could still not cook using electricity since the capacity of the SHSs was inappropriate to power a stove or hot-plate (Qase and Annecke, 1999). Although the benefits of improved lighting, radio and television were appreciated, consumers were unhappy with the fact that the system did not provide sufficient energy for cooking. This has produced dichotomy in consumer satisfaction with the SHS systems particularly with women who are traditionally responsible for the collection of firewood for cooking (ERC 2004). Hence, most SHS users have been using the system only as an interim solution (ERC 2004).

2.4.3 The Free Basic Electricity (FBE) policy

In order to solve the problem of affordability, the government decided to provide 50kW/h free basic electricity monthly to each qualifying poor household connected to the electrical grid. The off-grid users were to be subsidized by R40 which used to be paid directly to the service providers (ESCOs), leaving the users to pay only R18 as monthly fee towards installation cost (ERC, 2004).

Whereas the FBE subsidy paid to consumers has certainly contributed towards affordable electricity, there remain numerous problems related to the FBE policy. In the Ministerial foreword to the government notice introducing the FBE policy, the government claims that conventionally, the average poor household does not consume more than 50 kWh of electricity per month (foreword DME, 2003). This justifies why the allocation of free basic electricity was set at exactly that amount. However, the basic allocation has been contested by consumer and activist groups, who claim that the 50 kW/h is not sufficient to serve even the most basic needs of poor households (Fiil-Flynn & SECC 2001). Even for basic cooking and lighting, the 50 kW/h per month is insufficient, which in part explains why many people with access to free basic grid-electricity still use firewood or paraffin for cooking (Mapako and Prahad 2005). Table 2.2 shows the energy mix in spite of being connected to electricity.

Table 2.2 South African household fuels/uses. Units: 000 of households. (Source: Department of Minerals and Energy, 2002:36**).**

	Electricity	Coal	Wood	Paraffin	Gas	Candles	Batteries
Heating Water	3364	441	2358	2565	242	0	0
Heating dwellings	2437	753	2264	1548	121	0	0
Cooking	3346	783	2741	3370	673	0	0
Lighting	3812	0	0	1901	158	3245	125
Total	12959	1977	7363	9384	1194	3245	125

In the survey in Soweto by Fiil-Flynn and SECC referred to above, it was established that the average monthly usage in poor households is more than ten times that amount, sometimes up to 600kW/h. Much of this is due to insufficient insulation in poor people's houses, thus increasing electricity usage for heating in winter.

Another problem has been that the FBE allocation is made to all households without distinction, especially in most category A Municipalities (with adequate resources) (DME, 2003). This is due to the fact that it is difficult to determine a baseline as to who is poor and thus qualifies for the subsidy. From an operational perspective, it has been even more difficult to allocate the subsidy only to people who were identified as eligible beneficiaries, making the subsidy paid to all consumers regardless of their income levels (Fiil-Flynn & SECC, 2001; DME, 2003). This causes a significant amount of the overall budgetary allocation for FBE to be going to non-poor consumers and has not been having the expected poverty reduction effect. The lack of differentiation between household sizes meant that there has been effectively a disproportionately lower benefit for bigger households (Fiil-Flynn & SECC, 2001). Given the reality that larger households are mostly female headed and often by a pensioner with dependent grand-children who have lost their parents to HIV/AIDS related illnesses, this policy further disadvantages women and the poorest households (Egan & Wafer, 2004).

2.4.4 Household use of Paraffin

Like in most African countries, paraffin is seen in South Africa as a safer and modern fuel. As such it receives increasing government subsidy to serve about 30 percent (20 percent urban and 50 percent rural) of the population, primarily composed of the poor, still without access to electricity (Davidson and Mwakasonda 2004). However, the widespread use of paraffin in South Africa is reportedly costing the country an estimated R 104 billion per annum, poured into health and disaster relief through the regulation and enforcement of standards for both the resale of the fuel in pre-packed, child-resistant containers and enforcement of the minimum health and safety standards for the appliances (Kruger, 2005). In addition, its use as household fuel has an unacceptably high harmful incident rate of uncontrolled fires, respiratory illnesses and poisoning of children (Coetzee, 2003).

Kidsafe (2003) estimates that from 1996 to 2001, 80,000 children ingested paraffin every year resulting in 40,000 children developing chemical pneumonia per year. Markinor (2001) reported that 46,517 paraffin-related household fires occurred in 2000, 50,000 individuals suffered from paraffin related burns and 63 percent of those burns were the results of paraffin stoves exploding. Kruger, (2005) reports that a turnover of R2 100 million in paraffin sales creates a burden 50 times higher. Kruger (2005) further reports that the use of approximately 700 million litres of paraffin creates the cost of R104 564 million as follows: death R99 200 million, burns R5000 million and ingestions R364 million.

The other problem with the use of paraffin is the substandard paraffin appliances, particularly non-pressure varieties (Figures 2.3 & 2.4) which explode once the fuel in the container is hot. Leakage and poor stability of the unit further exacerbates the probability of fire (Markinor, 2001). The placement of the appliances often at the door due to the noxious emissions or on the floor in easy reach of small children is also a contributing factor (Palmer Development Consulting, 2004). This situation is worsened by the highly combustible materials such as wood and cardboard used to construct these homes.

Figure 2.3 A paraffin flame stove (Source: Cousins & Mahote, 2003)

Figure 2.4 Iron heated on a paraffin flame stove (Source: Cousins & Mahote, 2003)

The closeness of homes in the informal settlements usually with a single room for multi-purpose dwelling and often relying on each other for stability, lead to a single stove conflagration causing runaway fires such as that which resulted in 980 homes burnt to the ground (Figure 2.5) in only 2 hours at Joe Slovo in Cape Town in 2000 (Kruger, 2005).

Figure 2.5 Khayelitsha informal settlement fire in Cape Town showing both household materials and paraffin flame (Source: Cape Times, 2005).

Currently, paraffin and LPG like petroleum products have become as expensive as electricity due to the rise in oil prices and are in many cases unaffordable by low income households.

2.5 Renewable energy technologies in South Africa

South Africa is a party to the Johannesburg 2002 proposal at the World Summit for Sustainable Development where countries adopted a 10 percent target for energy supply from renewable energy sources (ITDG 2002a) by 2015. The proposal aims at averting the environmental, economic and social challenges faced by developing countries regarding energy access. The agreement was also based on the fact that reliance on imported oil based fuels by most developed and developing countries to meet their energy requirements imposes a heavy burden on the economy by greatly increasing the portion of the nation's energy expenditure (Sustainable Energy Africa, 2006).

However, South Africa has continued to rely almost completely on fossil fuels as a primary energy source (approximately 90 percent with coal providing 75 percent of the fossil fuel based energy supply (DME, 1999) and generating 91 percent of electricity (NER, 2000). The intensive use of fossil fuels such as coal and petroleum products has led to increased green house gas emissions, which have caused the country to be ranked as one of the highest emitters of carbon dioxide per capita in the world (Sustainable Energy Africa, 2006). This is of world wide concern because of global climate change resulting from the emissions released into the atmosphere.

As a response to the Johannesburg proposal (2002), the South African government has shown commitment to the promotion of renewable energy programs by publishing a White Paper on Renewable Energy that is aimed at integrated income generation for the pursuit of economic and agricultural development (delivering energy for a range of end uses including cooking and productive uses) (EDRC, 2003). This is planned to afford women and the poor masses a more qualitative and productive time and also encouraging investments.

However, greater concentration of government's efforts and international aid initiatives in the provision of renewable energy have been on solar home systems and specifically in rural areas in the formal sector. Unfortunately, the formal sector responsible for the SHS has failed to involve, reach and benefit the poor majority as energy development partners and has not solved the poor's problems of jobs, income and affordability of energy (SADC, 1997). In addition, the concentration on SHS only has neglected improvements in other non-conventional sources such as fuel-wood which is commonly used and could equally benefit the majority of poor people economically.

In general, the solar electrification programmes have been limited by the following general barriers (DME 2004, Quadir *et al,* 1995):

- Many technologies remain expensive on account of higher capital costs compared to non-conventional energy supplies for greater household energy supply though it still does not address the cooking needs of the poor.
- Implementation of the SHS technologies needs significant initial investment and may need support for relatively long periods before reaching profitability.
- There is a lack of consumer awareness on benefits and opportunities of SHS.
- Financial, legal, regulatory and organisational barriers in the implementation of SHS technologies and markets development.
- There is a lack of non-discriminatory open access to key energy infrastructure in SHS.

As a result of the above barriers, many solar home systems installed in rural areas in South Africa were by 2002 reported no longer working, as maintenance services were not available. Original equipment suppliers left the market and replacement components were unavailable (Martinot *et al,* 2002). This led to donor disillusionment and aid recipients viewed renewable energy technology as second class technologies that industrialized countries were unwilling to adopt themselves.

2.6 Improved Cook Stoves

2.6.1 Previous work on improved cook stoves (ICS)

In spite of the detrimental results of inefficient fuel-wood use, more positive impacts of improved cook stoves especially on the environment have been recognised since the oil crisis in the 1970's. However, recognition of improved cook stoves' benefits peaked in the wood energy crisis in the 1980s and continues to the present day (Matinga, 2004). The available evidence in fuel savings from ICS suggests decreased fuel-wood collected from the source, hence a decrease in deforestation and environmental degradation (Dutta, 2003).

Current ICS designs provide estimated fuel savings of between 25 percent and 40 percent of the fuel-wood normally consumed in traditional stoves and open fires. This means more savings are being realised by the transition from open fires to ICS due to the poor efficiency of open fires (Baldwin, 1986). In South Africa, the Yamampera and Simunye stoves tested at the University of KwaZulu-Natal by Green and Mabaso (2006) saved between 25 - 40 percent in cooking fuel. This further suggests decreased fuel-wood collection times and trips, hence a decrease in work burden for the fuel-wood collectors who are mostly women and children.

Studies on health dimension of users of biomass with regard to indoor air pollution (IAP) in Kenya, Sudan, Nepal, Guatemala and elsewhere have shown decreased indoor air pollution as well as decreased incidences of Acute Respiratory Infections (ARI) in households using ICS. In contrast, households using open fires, especially women and children are increasingly at risk with ARI (Ezzati & Kammen, 2002). According to the Global Environmental Facility (2000), improved wood stoves reduce carbon dioxide pollution by 42 - 54 percent. In Guatemala, improved wood-burning cook stoves (Plancha) had 87 percent fewer emissions during water boiling test and 99 percent fewer emissions during standard cooking tasks (McCracken & Smith, 1998). Furthermore, cultural benefits have improved the prospects of ICS programs. Unlike solar cookers, hay-box cookers and other pro-poor cooking technologies, cook stoves do not require (drastic) changes in cooking methods or food types. This makes the ICS more culturally acceptable in most poor countries and easily adopted compared to the aforementioned technologies.

In spite of the diverse benefits, ICS programs have not been a resounding success especially in Southern Africa. One of the major reasons has been that most of the earlier ICS designs lacked field testing which resulted in some stove openings not matching with the sizes of pots utilised by users (Quadir *et al*, 1995). Most stoves built in the early 70's were huge, fixed and of poor quality not appealing to the users. They were in some cases even less efficient than the three stone open fire.

However, a large number of ICS models have of late been designed and built based on the efficient rocket combustion chamber model (Figure 2.6) though using different construction materials, fuel and end use applications, and depending on local conditions.

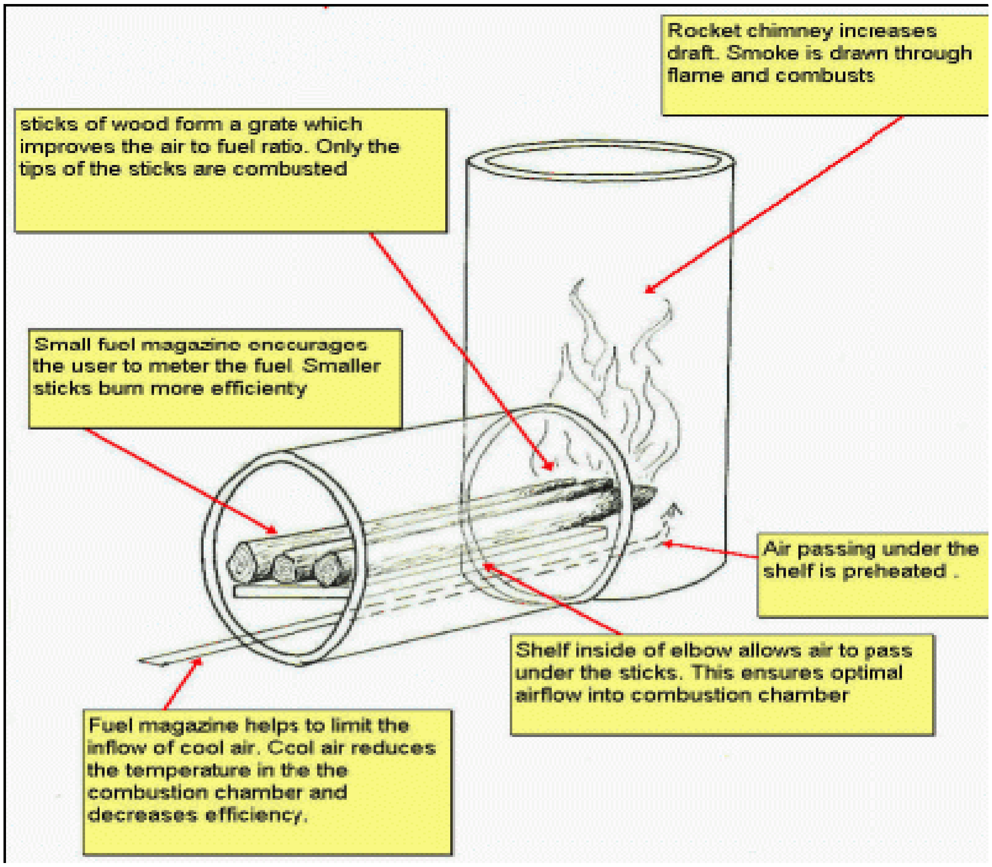

Figure 2.6 The Rocket combustion chamber model.
(Source: Design principles for wood burning stoves Still & Winiarski, 2001).

In spite of the better designs that gradually came about from mid 1980’s, another problem has been that few earlier ICS programmes in Africa have provided options that enabled users to diversify their stove use beyond household cooking to address the critical need of poverty and unemployment reduction. Other needs such as indoor heating in winter have not been considered due to the assumption that African winters are warm. Whilst this may be true in many cases, the question of whether an area or day is cold enough to warrant space heating is subjective and is often based on one's lifetime conditioning. Furthermore, in certain parts of Africa such as the highlands of South Africa, below-zero temperatures in winter (and sometimes spring), are not uncommon. Thus in winter, most households revert to inefficient stoves and open fires to enable simultaneous cooking and space heating. For some of these households, this reversion becomes permanent (Quadir, 1995).

Despite the fact that improved stoves have been introduced in many developing countries including Kenya, Uganda, Ethiopia etc, since late 1980s, much of available literature on the stoves has focussed on description of health benefits, reducing deforestaton and convenience of cooking stoves (DFID, 2000). However, knowledge about the socio-economic characteristics of stoves that would further promote their adoption is sparse. Moreover, empirical evidence on the effectiveness or fuel saving efficiency of the improved stoves, particularly wood stoves, is also extremely scanty and mixed. Green and Mabaso (2006) and Barnes *et al*. (1994) are some of the few in this respect. Green and Mabaso (2006) empirically analyzed the adoption of improved stoves especially by the low income earning casual workers from a technology substitution perspective, using data from Pietermaritzburg. Barnes *et al*. (1994) provided a general review of the conditions for success and failure of previous ICS programmes as instructive for the design of stove programs. Based on data from three villages in the rural Jiangxi Province of China (Smith, 1987), he found that improved stoves had a positive effect on fuel-wood consumption. This turned out to be central to the rationale behind the promotion of improved stoves.

Even though improving the income benefit of ICSs has currently been one way of working towards increased ICS adoption, there has been no such example in southern Africa. In Kenya, Uganda and Ethiopia, ICS programmes enabled cook stove users save cash as a result of reduced quantities of wood used because of improved efficiency of the stoves. (FAO Regional Wood Energy Programme, 2000). In Kenya and Ethiopia, stove manufacturers have been earning substantial income from sales of Kenya Ceramic Jiko (KCJ) and Lakech stoves, without subsidies (DFID, 2000). Both stoves have sold in millions, even after USAID and Kenya Ministry of Energy (in Kenya) and the World Bank and the Government of Ethiopia stopped supporting such projects (World Bank 2000). The success of the sales resulted in reduced price of each stove to 1/20th of their original (DFID, 2000). In addition, the stove users saved over 25 percent charcoal (cited by Green and Mabaso, 2006).

Even though the above findings show success, they fail to show whether the stoves were sold at a profit or not. The studies do not quantify the economic benefits such payback period, net benefit, rate of return, total annual costs of cooking with alternative energy sources achieved which would indicate the profitability of the technology. Payback period, net benefit, rate of return are crucial in informing policy makers to consider interacting improved woodstoves with existing energy initiatives for social and economic development during energy policies formulation (FAO Regional Wood Energy Programme in Asia, 1997). Even though the stoves saved 25 percent of charcoal, the findings do not show whether these stoves were economically efficient. The economic efficiency of the improved wood/charcoal stove can only be determined if the benefits derived from its utilisation are compared with other economic variables. Some of these variables are; (a) household's absolute fuel-wood/charcoal consumption, (b) fuel-wood savings achieved through use of the improved stove, (c) fuel-wood/charcoal price or the amount of time spent on collecting/purchasing fuel-wood/charcoal and preparing the meal, (d) price of improved stove in the household budget and (e) the expenditures that are required for the stove.

2.6.2 Improved cook stoves used in the study

All the stoves used in this research are portable and were built on the rocket combustion chamber model (Figure 2.6). Such a design is assumed to achieve almost complete combustion of wood, thus increasing the efficiency and decreasing indoor air pollution particularly by the emissions such as carbon monoxide (Scott *et al,* undated).

2.6.2.1 The Vesto

The Vesto is mostly made commercially from Stainless steel (Figure 2.7). The Fire Grate and its bottom where the fuel sits can be replaced separately (Figures 2.8 & 2.9). The stove uses wood, dung, charcoal, maize cobs and any biomass as fuel. When cooking, the heat to the pot can be controlled with the control lever to save fuel, reduce smoke and use the required heat output for specific purpose (Figure 2.10).

Figure 2.7 Vesto Stove made from Stainless Steel (ProBEC)

Figure 2.8 Vesto's replaceable bottom

Figure 2.9 Vesto's Fire grate

Figure 2.10 Vesto's heat control lever

The stove is industrially produced in Swaziland by New Dawn Engineering, mainly for urban household use. The standard size of each stove is 284 mm diameter, 450 mm height, 1.5kg mass and costs R250.00 (about US$35). The stove has a laboratory efficiency of 39 percent (PHU), a fuel saving of 30 – 60 percent from field tests and an evident time saving. The stoves are being disseminated using a commercial approach on a cash basis without any subsidy and have been in use in Johannesburg, Swaziland, Botswana and Namibia since 2004 replacing the Tsotso stove (ProBEC, 2007).

2.6.2.2 The Portable Household Rocket Stove

The Household Rocket (Figure 2.11) is a fuel-wood stove, originally from Malawi and is used in the urban areas in Malawi, Zimbabwe and Zambia. It is made by artisans using mild steel, 1.6 mm for body and skirt. The inside liner is made of cement mixed with sand and some white clay as insulation material. It has a diameter of 300 mm and is 450 mm high. It has a Laboratory efficiency of 35 percent (PHU) and a fuel saving of 25 – 40 percent (Field test). It costs R200.00 (about US$27). Like the Vesto, it is disseminated using a commercial approach purely on a cash basis without any subsidy (ProBEC, 2007).

Figure 2. 11 Portable Household Rocket Stove (ProBEC)

2.6.2.3 The Yamampera

The Yamampera stove (Figure 2.12) was designed by the researcher, adapted from Harsha Chulha (Figure 2.13) which has been in use since 1991 in India (RWEDPA, 1993). Like Chulha, Yamampera is a single pot portable metal stove but is different in that it is fitted with a moulded layer of clay, sawdust and cement in between the outer casing and the inner metal lining. The sawdust when burnt reduces the heat absorption by clay and heat escapes through conduction from the combustion chamber.

The stove is designed for small scale local industry. Production involves metal work which includes cutting, welding, grinding and punching of cut sheet metal. The stove has an aluminium lining of combustion chamber to reflect heat upwards to the pot bottom. The size of the stove is 260 mm width, 260 mm length and 300 mm height. The stove costs R60.00 (about US$9). It has a laboratory efficiency of 34 percent (ProBEC, 2007) and a fuel saving of 30 – 40 percent (Field test) (ProBEC, 2007) (Green & Mabaso, 2006). It is intended to be disseminated in both urban and rural areas through government agencies, NGOs, private industry etc through commercial approach.

Figure 2.12 Yamampera Stove
(Green & Mabaso, 2006)

Figure 2.13 Harsha Chulha
(FAO RWEDPA, 1993)

2.6.2.4 The Simunye Stove

Simunye (Figure 2.14) like Yamampera is a wood stove, locally designed by the researcher but adapted from Navjyoti Chulha (Figure 2.15) which is predominantly used in Maharashtra, Gujarat and Himachal Pradesh in India (RWEDPA, 1993). The Navjyoti is smaller in size and holds small size pots only. Simunye, unlike the Navjyoti has a cradle where burning wood in the combustion chamber rests. It allows air to flow under the wood to maintain oxygen flow into the combustion chamber (Figure 2.5) to increase complete combustion of wood.

Simunye is made of mild steel on the outside which is fitted on the inside with a ceramic pottery lining. The size of the stove is 280 mm by 280 mm at the top and 260 mm by 260 mm at the bottom with the height of 300 mm. The stove has a larger surface at the top to cater for bigger size pots. The stove costs R110.00 (about US$15). Like Yamampera, it is designed for small scale industry and pottery (Green & Mabaso, 2006).

According to Green and Mabaso (2006), Simunye has a laboratory efficiency of 24.8 percent (ProBEC, 2007) and a fuel saving of 23.3 percent (ProBEC, 2007). (Field test) and, like Yamampera, is intended to be disseminated in both rural and urban areas through government agencies, NGOs, private industry etc through commercial approach.

Figure 2.14 Simunye Stove (Green & Mabaso, 2006)

Figure 2.15 Navjyoti Stove (FAO RWEDPA, 1993**)**

2.6.2.5 The Three Stone Open Fire

The three stone open fire (Figures 2.16 & 2.17) is the commonest used technology by the majority of poor unelectrified households in developing countries. It is traditionally self-made, generally by women. The three stones are arranged in form of an equilateral triangle sometimes surrounded by walls of mud or pieces of sheet metal or pottery to protect fire from wind. The commonest fuel is wood. It has a laboratory efficiency of 5 – 15 percent (ProBEC, 2007) and is always used as reference for fuel saving.

Figure 2.16 The Three Stone open fire. GTZ – (ProBEC, 2006)

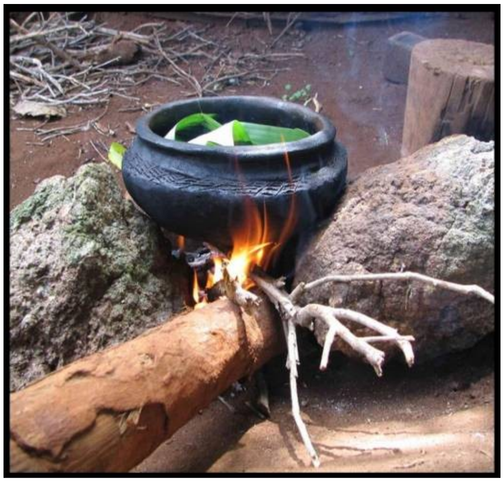

Figure 2.17 The Three Stone open fire. (Green & Mabaso, 2006**)**

2.7 Conclusion

Modern improved renewable energy technologies are already the government's priority but they still remain unavailable and unaffordable to the majority of the targeted poor urban users. This is primarily due to;

- unavailability of the technologies,
- targeted users' ignorance about the technologies,
- poverty, unemployment and health problems (HIV/AIDS).

The concentration of energy programmes in South Africa on large scale infrastructure projects does not address the peri-urban poor's basic need for cooking. This largely contributes to energy access problems at urban and peri-urban household level. As a result, there are important linkages with productivity, consumption and cross-sectoral applications that need to be addressed.

While lack of electricity remains a main constraint in addressing socio-economic problems that limit sustainable livelihoods, it is important not to ignore issues such as availability, affordability, sustainability and safety of energy in the context of the nature and standards of housing units used by urban poor. For example, extending an electricity grid to households in peri-urban informal settlements has been hampered by high initial costs, subsequent monthly payments and lack of awareness about technology protocol such as meter reading, or prepaying. As such, the over-emphasis on electricity has only been to the detriment of other energy sources that also alleviate energy-related socio-economic problems and has led to the vulnerability of users to shocks of price rises, unreliable supply trends and seasonal unavailability of fuels (i.e. during peak electricity consumption periods).

Despite the obvious disadvantages in terms of sustainable supply, collection efforts and household air pollution, fuel-wood has continued to be the primary cooking fuel for the poor. This is because alternatives such as electricity, LPG and paraffin are too expensive and in most cases difficult to supply to these congested poor areas. Worse, advances in efficiency of improved fuel-wood stove usage have been limited. As such, there is scant knowledge about the characteristics of stove adoption that is based on empirical evidence such as the economic effectiveness and fuel saving efficiency of the improved stoves. This negatively affects the achievement of the Millennium Development Goals which are aimed at improving the livelihood of the poor by halving poverty and hunger amongst other issues by provision of sustainable clean energy by 2015.

CHAPTER THREE

THE STUDY AREA

3.1 Introduction

The fieldwork for this research was done in Isnathing and Umsilinga in the Greater Edendale Area (Figure 3.1), Pietermaritzburg, South Africa between July and August 2006. Both areas are economically disadvantaged and form the greater parts of the populations of both Edendale (54614) and Raisethorpe (42850). To understand the importance of improved low cost household wood burning stoves in these areas, there is a need to understand and identify the historic, human and socio-economic dimensions of the areas. The aim of this chapter is to give a detailed background of the study area in the light of the above issues.

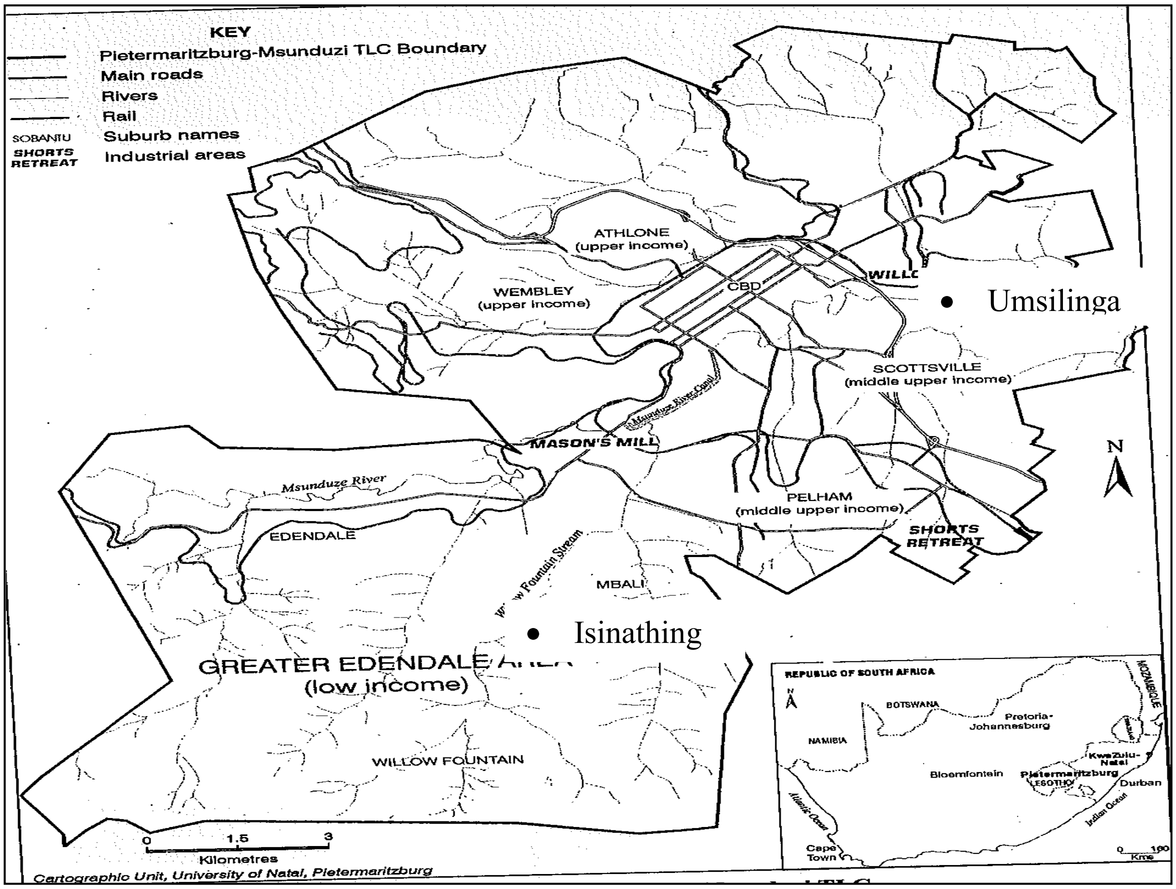

Figure 3.1 Study sites (Isnathing and Umsilinga) in the context of the Greater Edendale Area (GEA) in Pietermaritzburg, KwaZulu-Natal. (Source: Cartographic Unit, University of Natal, Pietermaritzburg).

3.2 Geographic location and climatic conditions

Isnathing is in outer Edendale between 30° 21' 0 E and 29° 37' 60 S. Umsilinga is near outer Raisethorpe between 30° 25' 0 E and 29° 34' 0 S. Both areas are characterized by undulating terrain (Figure 3.2) with an altitude of 731 metres for Isnathing and 646 metres above sea level for Umsilinga.

Figure 3.2: The undulating terrain of Isnathing with Eucalypts plantations vastly depleted. (Photo by the researcher. June, 2006**).**

The two areas experience extremely hot weather in summer and extremely cold and windy weather during winter (Statistics South Africa, 1997). The mean annual temperature is approximately 21.5°C for both Isnathing and Umsilinga. The mean annual rainfall is 821 mm per annum (Laband & Haswell, 1988; BESG, 2003) and is concentrated in the summer season from October to April. There is a steady increase in the mean annual rainfall total from less than 800 mm in Isnathing to above 1100 mm in Umsilinga because of the change in altitude between the two areas. Variations of rainfall across the area have also been observed across the city (Statistics South Africa, 1997). The mean annual rainfall (821 mm) and the temperature ranges shown on Table 3.3 look moderate and to a greater extent affect the species of trees grown in the area and the fastness of growth to reach harvestable sizes for sustainable fuel-wood use.

Table 3.1 Climate of Pietermaritzburg (PMB). (Source: Anonymous, Document of KwaZulu-Natal Department of Agriculture and Environmental Affairs)**.**

Mean annual rainfall (mm)	Temperature °C			Heat units (base)			Evaporation (mm)	Sunshine (Mean annual) (Hours)
	Mean	Max	Mini					
786	18.1	25	12	10	4.4C	5.0C	1723	6.9

The vegetation is broadly classified as semi-arid savannah and is characterised by a mixture of trees, shrubs and grasses. There is in each area a perennial stream originating from the hills.

In Isnathing, the terrain is covered with a thick layer of clay red soil. The area is characterized of semi – arid African savannah dominated by grassland which had been planted with eucalypts during the apartheid era by the white owners. The eucalypts are fast diminishing due to household over-utilisation as fuel and uncontrolled harvesting for house construction.

Umsilinga is characterized by a phonolite lava flow which is 100 – 200 m thick. It is covered with brown soil which has limited drainage both on the higher elevations and steeper slopes. The area is predominantly surrounded by the sugarcane plantations with scattered eucalypt plantations belonging to the sugarcane plantations.

3.3 Infrastructure

Isinathing has one primary and high school which is 3 kilometres away from the Edendale trading centre and children always walk to and from school regardless of bad weather. There is no clinic or trading centre in the area and people go to Edendale which is approximately 8 kilometres away for medication as well as household supplies including paraffin and food. The area has one gravel road and piped water along this road (Figure 3.3). However, most of the water taps are not functional due to damage by the cattle which are left to range freely.

Figure 3.3: The only existing road (gravel) in Isnathing which becomes badly affected and impassable in rainy season, limiting the movement of people to buy paraffin and gas from Edendale. (Photo by the researcher. June, 2006**)**

Umsilinga has one primary school only where children learn in classrooms made from wattle and daub construction. Like Isinathing, there is no health centre or trading centre and people access these services from Pietermaritzburg CBD which is 12 kilometres away. Unlike Isinathing, Umsilinga has no piped water and women walk approximately 5 kilometres to a water pump.

The Greater Edendale area has poor and fragmented infrastructure. There are no clinics, recreation areas, sports fields and a shortage of water and electricity. This was also observed by Built Environmental Support Group, (2003). It is beginning to be slightly improved now.

3.4 History of the study area

Many people and households in Isinathing and Umsilinga like the rest of the greater Edendale area came as refugees from political violence among the supporters of the African National Congress and Inkatha Freedom Party during the 1980s and the Seven Day War in the early 1990s. They originated from rural areas like Impendle and nearer urban and peri-urban areas like Howick around Pietermaritzburg to seek refuge in the inner city (personal communication with Mabena, 2006).

The conflict also involved the apartheid state security and the military's overt and covert operations. The political violence and apartheid policies have until this day made these areas economically, socially and politically complicated in the sense of hostilities between races and parties, unemployment, resource competition, crime, poverty and lack of land for Agriculture (Mabena & Madonda, 2006; Development Committee Leaders, personal communication).

A multi-cultural community of Blacks, Indians and Whites thrived in the area until the apartheid legislative intervention wreaked havoc among the communities. The Group Areas Act of 1950 effectively displaced the families that had come from the Lesotho and Qwa-Qwa areas during the 19th century. Currently, both places are black residential areas with no formal sector jobs. As a result, most of the population travels daily to Central Business District (CBD) and its surrounding industries, which is about 10 km from Umsilinga and 12 km from Isnathing (personal communication with Thandi Dlomo, July 2006).

The rural to urban influx continues to date with the bulk of the poor people moving into the inner city. This phenomenon has largely contributed to the development of the informal settlements in the two study areas with largely poor housing infrastructure which often become victims of accidental fires caused by inefficient paraffin panda stoves (Figure 3.4).

Figure 3.4: Informal housing infrastructure without electricity and water in Umsilinga. (Photo by the researcher. June, 2006**)**

There are fourteen municipal wards in the greater Edendale. Some of these wards include areas that are almost rural in character. Whilst some areas within the greater Edendale area have received attention in recent years, many other areas including Umsilinga and Isnathing have been deprived of access to services and resources such as piped water, electricity, etc due to land insecurity and complex tenure systems as the land was illegally occupied. This situation affects an estimated 90 000 people of the total population of 550 000 people. This figure translates to 40.91 percent of the total population. These areas are to be given priority focus within the special development programme, whilst attention will also be given to the facilitation of an integrated planning and development process for the entire area as a part of the statutory Integrated Development Plan (IDP) for the city.

3.5 The Human Settlement

3.5.1 Population

The Greater Edendale area (GEA) has a population of approximately 220 000 people in a city (Pietermaritzburg) of some 550 000 people. It contains the bulk of historically disadvantaged townships and informal settlements in the city. The most important source of quantitative evidence for the area is the 1996 census. Figures show the percentage of women in Edendale at 53.2 percent, slightly higher than the figure for Msunduzi as a whole. Most of the Edendale population is young, with 22.9 percent between 20 and 29 years old. This is significant because HIV/AIDS affects this group more than any other.

Human population densities range between 1200 for Isinathing and 1500 people per square kilometre for Umsilinga. Mean household size of people above five years is approximately six in Isinathing and seven in Umsilinga. According to the researcher’s observation, Isnathing and Umsilinga have relatively higher population densities than for Pietermaritzburg, including Willowfontain, Imbali and Edendale, where the population density falls by 51 to 500 persons per square kilometre. However, the population densities of Isnathing and Umsilinga are lower than those of Ntuzuma and Umlazi (5916 and 4804 persons per square kilometre) and Durban (1674 persons per square kilometre) (Krige & Scott, 1995).

In general the numbers of dwellings and population in the greater Edendale area are much higher in the lower income areas. Isnathing and Umsilinga are some of the places where the majority of the population of the GEA is categorised under the lower income levels. Table 3.2 provides an overview of the GEA within Pietermaritzburg.

Table 3.2 Dwelling units and population estimates by income levels in PMB- TLC 1998 (Source: Integrated Planning Service (PTY) LTD, 1998)

Income classification	No. of dwelling units	Percent of dwelling units	Population	Percent of population
Upper	5199	6	19913	4
Middle	14902	17	67776	14
Lower	66669	77	397593	82
Total	86770	100	485282	100

3.5.2 Settlement and Household Characteristics

The settlements are typical of overcrowded temporary informal mudded shelters often and predominantly made of salvaged iron sheets and timber (Figure 3.5). These structures are not often able to accommodate paraffin, gas and electricity due to expense and risk of accidental fires (Green & Mabaso, 2006).

Figure 3.5 Overcrowded informal shelters in lower Isnathing suggesting the difficulty of electrifying them all in the near future in spite of the electricty that passes over their area. (Photo by the researcher. June, 2006**).**

A clear indicator of relatively greater poverty is that Edendale has 25.3 percent of households with only one room, as compared to the Msunduzi average of 15.8 percent of single-room households. It is apparent that overcrowding is a serious problem in this area. According to Built Environmental Support Group (2003) study of income and expenditure in urban KwaZulu-Edendale-Imbali, the average household size of the study area was seven which was also supported by Laband and Haswell (1988).

Table 3.3 Settlement types and population of the GEA. (Source: Data World, Consultants to the Masakane Project, January 1998).

Total dwellings	Formal		Informal		Population
	Number	%	Number.	%	
39754	13439	34	26315	66	238524

3.5.3 Unemployment

It is estimated that 65 percent of the population is dependent on grants, cannot afford formal housing and are forced to build temporary accommodation in spontaneous overcrowded informal settlements (Table 3.2) (Green and Mabaso, 2006; Data World, 1998). Population growth, urbanisation, lack of land and lack of development policies of the past are believed to be the causes of the increasing numbers of informal settlers, many of whom have located to Umsilinga and Isnathing.

Unemployment Figures are estimated at 56.4 percent of the total population (Morodi, 2003) According to May and Peters (1984), a large percentage of the unemployed population in the GEA were women. The data also show that amongst the unemployed group, a greater proportion fell into the younger age group (15-34 years). Of those aged 15 to 34 years old (economically active age bracket), only 20.2 percent are employed, and 21.5 percent are unemployed and seeking work. 24.9 percent is not employed and is not looking for work. Together this represents 56.4 percent of the total population that is unemployed. Unemployment is more prone in the informal settlement areas than in the formal ones (May and Peters 1984).

Although it is estimated that the majority of the population in PMB area lives in the greater Edendale area, the employment areas are situated outside of this area. In this case, the Central Business District (CBD) which is about 5 kilometres away, provided the most jobs (25,000 or 56.8 percent) in 1998 followed by Willowton Industrial area (12000 or 27.3 percent). Camps drift /Mason's Mill and shorts Retreat provided very few jobs (4000 or 9.1 percent. and 3000 or 6.8 percent) (Figure 3.6).

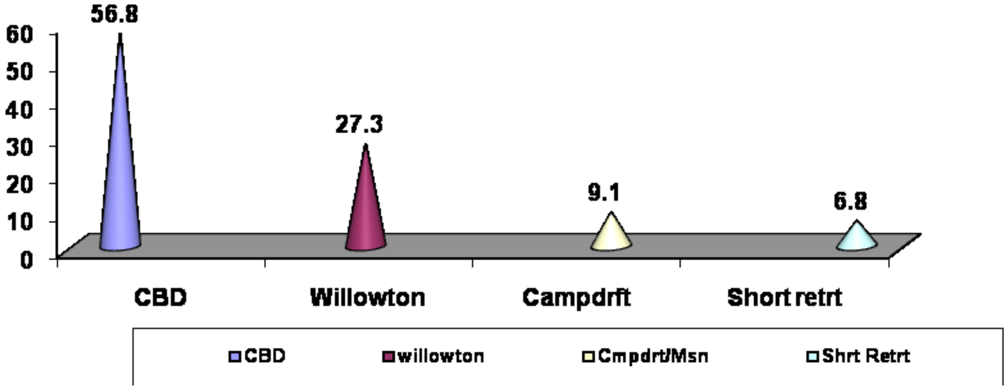

Figure 3.6 Employment areas and employment status in PMB - TLC in 1998
Source: Integrated Planning Service (PTY) LTD (1998:17).

3.6 Access to Energy

In the large greater Edendale area, electricity is largely provided by the Municipality in the city. Even though electricity passes through these areas and over some people's houses (Figure 3.5), the majority of households in both Isinathing and Umsilinga depend on firewood to perform the basic day to day tasks of cooking as 95 percent of their staple food needs cooking before it can be eaten (Mabena and Madonda, 2006, Development Committee Leaders, personal communication). They also use firewood to assist in the performance of income generating activities (IGAs) which are energy intensive, for example baking, beer brewing amongst others for wealth generation and improvement in their living conditions. Other fuel types used include paraffin, candles, liquid petroleum gas, batteries and to a lesser extent animal dung. No electricity is used as no connections have been made.

The over dependence of households activities on fuel-wood in these types of settlements affect the environment through destroying the forested areas for fuel-wood. This is largely because the informal housing structures are not often able to accommodate paraffin, gas and electricity due to the risk of accidental fires. Moreover the cost of such fuels like gas, paraffin and electricity are very high and in most cases unaffordable by lower income earners which encourage continuous use of inefficient traditional technologies with limited capabilities (Figure 3.7).

Figure 3.7 Traditional Tripod Stand used indoor showing wasteful and unsustainable use of fuel-wood in Isnathing. (Photo by the researcher. June, 2006**).**

In addition, collected fuel-wood accounts for a larger proportion of the total fuel-wood used in the area although some households do buy from local vendors. This often makes excess demands on access to fuel-wood and establishes a strong correlation between energy deficits and poverty where the existing energy resources (fuel-wood) are heavily relied upon and subsequently degraded because of demand.

3.7 Conclusion

This chapter discussed the background of the study area, which is mainly characterised by informal settlements. It generally houses a large influx of rural to urban unemployed and poor migrants escaping rural poverty. Their limited access to cleaner energy technologies due to low or unpredictable incomes often puts extreme pressure on surrounding natural resources. It also makes them purchase fuels as and when cash resources are available and in small amounts on a daily basis (an expensive option) which is not largely applicable to the available modern cleaner energies. Such unstable energy use patterns characterised by the use of several fuels for different end uses, clearly militate against the efficient and rational use of energy and make many of these poor people often pay more per unit of energy to get expected results than the better off.

However, the relative availability of fuel-wood in these areas needs to be considered in broader urban energy scenarios and interventions in order to effectively and sustainably utilise the limited resources. This would help address the current problems of poverty, unemployment, unequal distribution of resources, poor social services and facilities as well as environmental degradation and deforestation in the study area.

CHAPTER FOUR

METHODOLOGY

4.1 Introduction

This chapter addresses the methodology used in the collection of data for the study. The selection of the two study areas is presented as well as the comparative efficiency performance test of the stoves. The procedure followed in selecting households and community members for participation in the baseline study and focus groups, conducting the actual baseline survey and focus group discussions are also outlined.

This study was carried out with support from the University of KwaZulu-Natal, Community Resource Management, Programme for biomass conservation (ProBEC), and the traditional leaders in the study areas. The University of KwaZulu-Natal provided materials for the stoves, equipment for comparative efficiency testing, transport for the mobility of the researcher and testimony to the research as purely academic. ProBEC provided two types of stoves and some funding while traditional leaders in the study areas were responsible for overall moral support, partial supervision of responses from the community at large and the provision of community assistants to help during the baseline exercise.

4.2 Study design

The study design was both quantitative and qualitative (Table 4.1) so that the quantitative results could be explained by the qualitative data.

The physical testing for efficiency of the stoves and their fuel use was done in order to account for the influence or change caused by the different factors by controlling each factor at a time. This was done in order to provide representation, objectivity and correspondence in the results as promoted by Leedy and Ormrod (2001) and Terrre Blanche and Durrheim (2002).

Table 4.1 Summary of the Study design

Objective		Sample	Data collection tool	Data collected
1	Compare the efficiencies of the improved stoves with that of open fire	Four improved wood stoves and the three stone open fire	Water boiling test Water simmering test	Time used by each stove Wood saved by each stove Frequency of attending to the fire
2	Determine type of fuels and appliances used the study area	100 households, stratified random sampling	Baseline survey	Household heads, household sizes, gender. Employment status, level of education, income. Cooking fuel costs and cooking fuel situation before demonstration of stoves.
3	Determine benefits of stoves in households	Eight focus groups and an additional 24 households	Focus group discussions and observation	Consumer preferences in choosing the technology to use Perceived socio-economic benefits of stoves Comparative perception of the technologies used by participants

The baseline survey questionnaire was chosen in order to record data that came through observation and to probe data lying deep within the minds, attitudes, feelings or reactions of the respondents as promoted by Leedy and Ormrod (2001), Terrre Blanche and Durrheim (2002) and De Vos (1998).

Focus group discussions were used in order to obtain in-depth information on concepts, perceptions and ideas such as well-being and self-sufficiency in relation to the types of fuels used by groups. The method allowed members to talk freely and spontaneously about the topic which enabled the researcher to tap the analytical abilities of participants and understand their perceptions of concepts as promoted by Helitzer et al (1994).

4.3 Population and sample selection

The scope of the research required the study to be done in more than one area; where traditional multiple fuel use was prevalent. Other sample specifications were that the areas be high density peri-urban areas with high population density, high unemployment rate or low income and acute respiratory infections which are commonly associated with fuel-wood use. As such the selected areas were required to be in a province where there is more wood and predominant use of wood for domestic purposes. This was because the stoves used in the study were all wood burning and were compared with the three stone open fire which predominantly also uses wood.

According to Statistics South Africa (2001), KwaZulu-Natal was one the provinces in South Africa which had the highest poverty, HIV/AIDS related respiratory infections such as tuberculosis, volumes of wood and where wood is dominantly used for cooking. Pietermaritzburg was chosen because of its nature of being the capital of KwaZulu-Natal, lack of industries to absorb the increasing unemployed masses of people and the necessary links and networks the researcher had established before that would make going into these areas comparatively easy due to his previous fieldwork in its urban and rural areas. In addition, there were many significant stories in the city gathered by the researcher during his previous field work about houses being burnt down and people losing life due to paraffin use especially in the informal settlements.

Since the purpose of the study was to assess the potential socio-economic benefits of the stoves to the poor communities living in urban poverty, the first choice were sites closest to the city where households though within the electrified areas, do not enjoy the benefits of electricity. This required that the two peri-urban areas to be selected as study areas should have the majority of characteristics common to most peri-urban and informal settlements in South Africa.

The selection of the two sites (Umsilinga and Isnathing) was further influenced by a related academic study in these areas by Ghebremicael (2000) which highlighted high poverty as well as unemployment levels. According to McDonald, (2002), the prevalence of the following;

- high population density,
- high poverty and unemployment levels,
- high levels of adult illiteracy,
- high deforestation rate,

- extensive dependence on fuel-wood as a major source for cooking,
- dominance of traditional housing which does not readily accommodate electricity connection because of the multiple dwelling form and temporary nature,

highly contribute towards the unlikelihood of using modern cleaner energies by most prevalent groups of poor people living in such places. Using the above characteristics, the two areas (Umsilinga and Isnathing) were selected and used as study areas.

4.3.1 The research sample

The sample was made up of 100 households, 50 in each area for practical purposes. Each study area was divided into sections called strata based on the number of households. A random number was selected as the starting point, and an appropriate sampling interval selected according to the study area and based on the number of households in each block and number of households required in the sample to ensure that each household had a chance to be selected (as recommended by de Vos, 2002 and Terre Blanche & Durrheim, 2002).

Each strata was assigned 10 households, then the researcher selected every 10th household counting from left to right in a clockwise direction in each strata to answer the baseline questionnaire. During this process, each selected household was assigned a random number. Selected households were then sorted by the assigned random numbers. Purposive systematic random sampling was done in order to have a sample that was representative of the population so that generalization of the results could be extended to the whole population in the study area.

Prior to the site visits, traditional leaders in the two study areas were consulted for their moral assistance in the mobilization and cooperation of communities during the baseline study, stoves demonstrations, focus group discussions and stoves placement later in the study. Subsequent meetings were arranged with the development committees' leadership to explain the purpose of the research, request households' participation in achieving the methodological objectives, as well as to answer any questions that the committees had about the study. During these meetings, the methodological objectives were explained to the committees which then allowed them give their permission to the researcher to conduct interviews during baseline and after stove placements in addition to letting the community participate in the focus group discussions.

4.4 Field work

The field work of this study was conducted by the researcher and four assistants with occasional cases of moral assistance from community leaders. The assistants used were provided by the development committees but approved by the researcher after interviewing them together with the development committees' leadership. The interview questions were based on their literacy level (matric) and knowledge of the area.

4.5 Tools used in the study

Three research tools were used in the study. The first was an experiment which compared four different types of stoves for efficiency that included fuel saving, speed of cooking, time saving and frequency of attending to the fire. As such, water boiling at high power and simmering tests were conducted on one prototype of all four different stoves under normal household conditions. These tests were based on the standards suggested by VITA and Baldwin (1986) and the Agricultural Research Council – Institute of for Agricultural Engineering (South Africa) (2000).

The second tool was a baseline survey questionnaire of fuels and appliances used by households in the study areas as well as general socio-economic background of those households participating in the survey. The baseline was used for benchmarking comparisons between improved wood stoves results during demonstrations and placement in households later in the study and the three stone open fire in order to determine how each of them affected the users socio-economically.

The above two tools were complemented by a questionnaire administered to the selected households where the stoves were placed later in the study to gauge users' opinion regarding stoves' performance, efficiency and other socio-economic benefits in comparison with other fuels and appliances existing and used for the same purpose. This questionnaire was also used to verify the driving and restraining factors influencing women cooks and households in choosing domestic fuels and appliances identified and prioritised during the focus group discussions.

The third tool was the focus group discussions conducted after the stoves demonstration and placements. This was done in order to determine the type of stove most preferred by the interviewees, reasons for its preference and possible terms of payment.

4.6 The comparative efficiency performance test

Four newly constructed prototypes of stoves were used in the comparative efficiency tests with the three stone open fire as a control. These were the Rocket stove from Malawi, Vesto stove from South Africa, Simunye and Yamampera locally manufactured by the researcher at the University of KwaZulu-Natal in South Africa (Figures 4.1, 4.2, 4.3 & 4.4).

The four stoves were used in this research because they are portable and can be moved and used inside or outside the house depending on the user's choice. The second reason is that all these stoves were built based on the rocket combustion chamber model (Chapter 2, Figure 2.5) which is assumed to achieve almost complete combustion of wood, thus increasing the efficiency and decreasing indoor air pollution particularly by the particulates and carbon monoxide. The three stone open fire was used as a control in order to ensure internal validity and that whatever change that resulted from the study was due to efficiency of the stoves or not.

Figure 4.1 Yamampera stove during demonstration

Figure 4.2 Simunye stove during demonstration

Figure 4.3 Rocket stove during demonstration

Figure 4.4 Vesto stove during demonstration

Stoves were tested using a Water Boiling (high power) and Simmering tests. The methodology used was adapted from VITA and Baldwin (1986) and the Agricultural Research Council - Institute for Agricultural Engineering (South Africa), (2000). The tests were done by using one of each type of stove on a rotation basis. All tests were done indoors using the same 26.5 centimetres diameter stainless steel pot in all tests in a space completely protected from the wind in order to emulate household kitchen conditions and ensure that there was no wind disturbance to the fire.

All stoves were used starting from cold and air temperature ranged from 29°C to 32°C, thus care was taken to test individual stoves at the same range of air temperatures one after another. All testing work was done over the weekend so that there was adequate space and sufficient time to conduct the tests without being disturbed by students and other scholarly experiments.

4.6.1 The equipment used in the water boiling and simmering tests

As recommended by VITA and Baldwin (1986) and the Agricultural Research Council-Institute for Agricultural Engineering (South Africa), (2000), the following equipment was used in the water boiling and simmering tests (Figure 4.5).

- One scale of 6 kg capacity and 1 gram accuracy

- Two heat resistant tiles to protect the scale while weighing the charcoal and wood after the water boiling test and charcoal after simmering.
- One thermometer, accurate to 1/10 of a degree, with thermocouple probe suitable for immersion in liquids
- One timer
- One standard aluminium pot 26.5 centimetres diameter and weighing 254 grams
- One clamp for holding the thermometer in water (Figure 4.5)
- 10 litres of clean water for each water boiling test in 5 litres containers (additional to compensate for spills while pouring the water into the pot to be used in the test)
- 100 millilitres, 500 millilitres and 1000 millilitres labelled clear glass jars to measure water before and after the tests
- Bundles of air-dried split fuel-wood (Wattle), each weighing 700 g
- One pair of heat resistant gloves
- One metal dust pan for transferring charcoal
- A pair of tongs for handling charcoal
- Small shovel/spatula to remove charcoal from stove

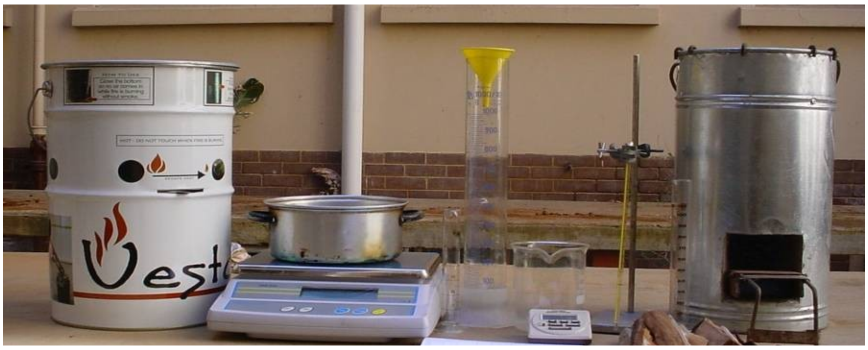

Figure 4.5 Equipment used in the water boiling and simmering tests

4.6.2 Pre-test procedure

Fuel and water were sourced ahead of time in order to ensure that there was an adequate supply of clean water and sizeable fuel-wood. All wood was wattle and was bought from the same source (Mndeni Meat Supermarket in Mkondeni). 5.0 kg of air-dried fuel-wood was procured for each stove in order to ensure that there was enough fuel to complete three tests for each stove.

In order to save time during testing, the researcher prepared enough bundles of wood in uniform split sizes which were weighed in equal measures (700 g). The average size of the split pieces of wood was 4.5 cm diameter by 22 cm long each. Sticks used to start the fire, were prepared ahead of time and were part of the pre-weighed bundles of fuel-wood.

One practice test was performed on each type of stove in order to become familiar with the testing procedure and with the characteristics of the stove. Two litres of water in the standard pot was brought to a rolling boil while ensuring that the stove's power output was high and the water was fully boiling. Using the same thermometer that was later used for testing, the boiling temperature was measured when the thermometer was positioned in the centre, 5 mm above the pot bottom. Care was taken to ensure that the thermometer did not touch the metal base of the pot in order to avoid its cracking.

The researcher recorded the temperature over a three minutes period using lead pencil on pre designed data forms (Appendix I) until full boil and noted the maximum temperatures observed during this period. The maximum temperatures were then averaged and the results were then recorded as the local boiling temperature on the data and calculation forms. This also provided an indication of how much fuel was required to boil two litres of water. The practice period was also used to determine the local boiling point of water. The local boiling point of water is the point at which the boiling water reached the rolling boiling and it varies according to latitude.

4.6.3 Water boiling test

Equal (700) grams of oven dried wood of the same species (Wattle) and uniform size of split pieces were used on each stove in each test. The pot was filled with 2 litres water and no lid was used (Figures 4.6 & 4.7). Water temperature was determined by reading the inserted thermometer suspended inside the pot by a clamp 5 mm from the base of the pot. All stoves were started at room temperature. Fire was started in reproducible manner. Water temperatures were recorded every three minutes as water was brought as rapidly as possible to a boil without being wasteful of heat. When the pot came to a boil, wood used and time taken were recorded. This was done three times on each stove.

Figure 4.6 Water boiling & simmering test on Yamampera

Figure 4.7 Water boiling & simmering test on Household Rocket

4.6.4 Water simmering test

The simmering test was done to determine the effectiveness of each stove regarding heat control which is greatly required by users in the preparation of their staple foods such as uPhuthu, uJeqe, etc. After the water boiling test, the remaining wood and water were used in the simmering test. The fire was maintained in such a way that the water temperature remained at the highest temperature above 80°C. This was done until the remainder of wood was not able to maintain temperatures at that range. Time was recorded as in the water boiling test above.

After the drop of temperature below 80°C, the pot was removed from stove and remaining water measured. The amount of charcoal left was weighed. Three tests were also done on each stove as in the Water Boiling Test above.

4.7 Household baseline survey

Vulnerable people in the peri-urban and urban informal areas in South Africa have to choose between food, clothing, shelter and fuel to survive the effects of the pro-rich economy. Statistics South Africa (2001) reported that between 1990 and 1995 real GDP fell by nearly 30 percent. Per capita GDP for 1997 was $1,593 (R11 151) and indications are that it dropped an additional 15 percent over two years later. Unemployment in KwaZulu-Natal among those able to work in 1998 was approximately 35 percent and was at the time of study believed to have reached 40 percent.

It was within this context that the questionnaire for the baseline survey was organised to provide a benchmark for comparison with the effects of the improved wood stoves under study regarding their influence on household expenditure on fuels, increase consumption of food. This is in addition to other social conditions such as savings of disposable income incurred by using the stoves and how this would affect entrepreneurial coping mechanisms within households in the study area.

4.7.1 Survey questionnaire organisation

The main instrument used in the survey was a comprehensive household questionnaire. The questionnaire was designed by the researcher but adapted from a similar study done in Zimbabwe by Mutamba and Gwata (2003). The questionnaire is attached as Annexure A. This questionnaire covered a wide range of topics but was not intended to provide exhaustive coverage of any single subject. In other words, it was an integrated questionnaire aimed at capturing a variety of aspects of living standards.

The topics covered included demography, household services, household expenditure, educational status and expenditure, remittances and marital maintenance, land access and use, employment and income, health status and expenditure. This questionnaire was available to households in isiZulu and English but was first pre-tested in Sweetwaters area which is another peri-urban township on the periphery of Pietermaritzburg but with similar characteristics to the study areas. The pre-test was done in order to test for clarity of questions. After the pre-test, minor adjustments were made on the questionnaire in terms of the wording before the actual survey was conducted.

A crucial concept in the questionnaire was the definition of the household. The household definition was drawn up in such a manner as to avoid double-counting of individuals who may live in more than one place. The definition of the household included only those members who had lived "under this roof for more than 15 days of the last 30 days". This definition was derived to eliminate double-counting of individuals. In addition, the purpose of this questionnaire was to elicit information on the energy supplies available to the community in each cluster.

Questions related primarily to the provision of energy, food, education, health and other socio-economic services. Furthermore there was a detailed section for the prices of a range of fuels commonly used in the city and purchased either from retail sources within the study area or from the bulk suppliers in town. The purpose of this section was to obtain a measure of price and expenditure variation between those purchasing small quantities from retail source and those buying large quantities. The prices were obtained from the interviewees but verified by the researcher from both sources. In all these questions, respondents were prominent members of the households such as household heads or the eldest in the household.

4.7.2 Baseline survey organization and administration.

The researcher provided a one-day training to the two assistants that he worked with in each study area. The training included a piloting exercise to test and adapt the questionnaire. All four assistants attended the training and debriefing after completion of the pilot study.

Houses which answered the baseline questionnaire were marked a day earlier by the researcher with the assistance of two local assistants resident in each area. From the 50 households selected during baseline study, 25 households were later, purposively selected by the researcher in each area, 5 households from each stratum for focus groups discussions. The later selection was based on the type of fuel used, household size, household income, responsibility for sourcing fuel as well as cooking and their willingness to use the improved stoves shown to them.

4.8 Stove demonstrations

Each of the four types of stoves was brought to the demonstration venue a day earlier and explanation of details regarding origin, cost, weight and how each stove worked was given before the start of stove performance demonstration (Figure 4.8). Fuel and water were supplied by participants. The stoves performance was demonstrated using the water boiling and simmering tests which were conducted by the assistants from the study area to avoid thinking that only specialised people could use the stoves.

The procedure followed was the same as the one described above (VITA & Baldwin, 2003) except that time was the factor measured during water boiling while wood time and wood balances were measured during simmering. Stove demonstrations were done to induce users' perceptions, attitudes, behavioural and cultural practices that underpin choice of cooking appliances. Focus group discussions followed immediately after the demonstrations.

Figure 4.8 Participants and stoves during focus group discussions

4.9 Focus group discussions

The true experts on any activity to empower poor people in each area are, in fact, the participants in these activities themselves. Participatory methods have enabled researchers to tap the analytical abilities of these participants, as well as to learn their understanding of concepts such as well-being and self-sufficiency. Drawing on these methods, this focus group discussion explored the types of fuels used in households, reasons for their choice and impacts of such fuels upon householders.

The discussion also gauged users' perception of the demonstrated and home placed stoves regarding performance, appearance, purpose and cost in addition to exploring the participants' understanding of possible benefits related to their empowerment from the demonstrated stoves that would positively impact on their well being. This qualitative part of the study was undertaken in order to complement the efficiency test and baseline survey done earlier in the study.

4.9.1 Selection of focus groups

Eight focus group discussions (FGDs) were held in the two study areas (Isnathing and Umsilinga) during normal weekly meeting times of already existing clubs and societies. This was done in order to maximise members' attendance and participation. At each study area, the researcher was given a contact person by the local development group, who scheduled the discussions, arranged for a facility, and in some cases, identified individuals to participate in the research discussion groups as moderators.

Focus group participants were randomly selected into a convenience sample from stratified local NGOs such as social clubs and societies' membership rolls (including Burial societies, Stokvels) and participation was voluntary. The groups had been selected by the researcher in consultation with the local development committee leadership in the study area because of their diversity of experience with such groups in both areas. The eight different focus groups were selected to cover the range of experiences existing among different groups as some of these groups were weak in comparison with other groups while others were stronger. Six of the groups were stokvels while two were burial societies.

All respondents were household heads or wives and in the absence of these, the one who was responsible for cooking and making the decision regarding choice of stove type participated in the discussions. The focus groups consisted of up to ten individuals and were divided according to gender and age. Focus group sessions were scheduled to last 90 minutes.

4.9.2 The research team

The research team included all the survey assistants from both study areas. This was aimed at enabling better facilitation of the discussions and recording of proceedings. The four assistants and one appointed discussion group moderator who were all Zulu speakers and from the study areas, facilitated the discussions by interacting with participants in ways that ensured that quieter participants spoke, and that more dominant participants were encouraged to share the analysis with others. The moderators were briefed twice (one week and one day before the discussion) of what they were required to do. The researcher moved freely among groups checking on the progress of the discussions.

4.9.3 How the discussions were conducted.

At the beginning of the discussion, the researcher explained the reasons for the discussion and stressed the confidentiality of the session and asked for everyone in the room to acknowledge that they both agreed to participate and to keep the contents of the discussion confidential. Participants were reassured that no one would be able to attribute comments to individuals or to specific households, that the session was voluntary and that they were welcome to leave or not to respond to any questions with which they were uncomfortable.

Participants were encouraged to share their ideas and were told that there were no wrong answers to the questions being asked. Participants were advised of "ground rules" for the discussion, which included the role of the moderator and what constituted appropriate participant behaviour. They were then reminded that they were being recorded.

To begin the discussion, participants introduced themselves to one another and to the moderator. They were then led through the research questions in the questionnaire. Each of the discussions was recorded on audio tapes for transcription later and participants' responses written on the flipchart placed in front of participants.

After starting with the discussion, questions concentrated upon the following issues: reasons for using the existing fuels and appliances, their desired household energy plans, their knowledge of alternative improved energy sources, perceptions and concerns about existing fuels and appliances in comparison with the demonstrated stoves. When a participant gave a response, it was further probed to see the number of others agreeing as recommended by TerreBlanche and Durrheim (2002). In addition, controls were effected in answering the questions to ensure full participation by all members and truthful responses. Responses to the follow-up questions were given by raising of hands which were then counted and recorded. By these probes, the research team wanted to understand the meaning that participants attached to their responses. The questionnaire used in the focus group discussions is attached in Annexure B.

4.10 The household performance test (HPT)

The Household Performance Test (HPT) was adopted from the work of Baldwin and VITA (1987 and 1985) with slight changes. The main goals of the Household Performance Test were: (1) to compare the performance of improved stove(s) to the common or traditional stoves or to other improved stoves used in the households of real families and (2) to identify qualitative aspects of stove performance through a simple survey. To meet these two aims, the Household Performance Test included both quantitative surveys of fuel consumption and qualitative surveys of stove performance and acceptability.

4.10.1 Household fuel consumption measurement

The survey about how people felt about the stove happened in two stages. The goal of the first stage of the survey was to identify basic social, economic and cooking information of community families. This was done during baseline survey earlier in the study (before the stoves were actually distributed) and provided important information.

The second stage of the qualitative survey was conducted for two weeks from the time the improved stoves were placed in the homes. The survey was done in households randomly selected from the list of households that were willing to use the improved stoves and participated in a detailed study of fuel consumption during the baseline survey. This was done in order to ensure that all households that showed willingness to use the stoves had equal probability of being selected for the survey. The survey avoided selecting families with only certain specific characteristics which other did not have using information previously obtained.

In each study area, the Household Performance Test (HPT) was conducted in two groups, with one group using the traditional stoves and the other group using the improved stoves for a week and exchanged in the following week. Cooks in the participating households were trained to use the placed improved stoves and on fuel-wood management procedure. This was done before the actual placement of the stoves in order to familiarise them with the operation of the stoves tested.

The researcher did not supply fuel-wood to the participating households but had an agreement with the families that they could gather fuel-wood. However, the assistants weighed wood into different measures ranging from 0.25 kg to 10.0 kilograms under the supervision of the researcher using a large capacity spring scale. All measures were then stacked as bundles in respective weights marks so that users could use each bundle at a time. This was initiated to ease up counting how much wood has been used. The decision not to supply wood was aimed at to avoiding participating families from adopting consumption patterns that they could not follow under normal circumstances. However, households that participated in the HPT were each offered a free stove and some cash at the end of the tests as token for the work done during the Household Performance Test (HPT).

Where the cooks were illiterate, they were asked to use their school going children to record the information. The unburned wood at the end of each cooking was removed from the fire and extinguished for re-use in the next cooking in the same day. After the day's cooking, the kept firewood was reweighed by assistants, subtracted from the total used in that day and added to the remaining supply.

Each participating family was taught to keep accurate accounting of fuel measures used in each day. Daily recordings of fuel-wood used, average time taken for each cooking ease of operation of the stove and comments on smoke were done on each stove by families using the stoves but were checked by the research assistants. Participating families were asked to only use the stove that was being tested throughout the entire week of testing. Visits to the households by the research team were made at roughly the same time each day, without being pushy on the families. These visits were also aimed at confirming that the stoves were operating properly.

With each daily visit, records of the number of people that ate their meals in the household since the last visit were kept according to gender and age of each person for the calculation the number of standard adult persons. After each visit, data was transferred from the household record sheet to the main data form that was used in the analysis. Weekends and holidays were not included in the test period because of the tendency of local events like market days that would influence average fuel consumption.

A comparison of the individual family's fuel use was then made between the old stove and the improved stove at the end of the testing period. This was done by calculating the average change observed in fuel consumption per person in each family before and after their switching to the improved stove.

4.11 Data treatment and analysis

The researcher analysed the data for the specific purpose of their research. The responses obtained from the structured and unstructured interviews in the baseline survey and information obtained from focus groups were presented, described and analysed qualitatively and quantitatively. In this case, manual and computer data analyses methods were used to analyse the quantitative and qualitative data, as the data was collected through qualitative and quantitative methods. The full coding system was developed manually with the help of counting sheets, and by keeping count of how many times each answer type was repeated. Based on this, tables were generated, while findings that did not require tables and charts were presented in the form of explanation.

Some quantitative data in the form of tables was also processed using computer packages from Microsoft office 2000. This software was used because it is possible to generate charts and graphs in full labelled forms and is relatively easy to use. Raw data was entered into the computer, from which fully labelled forms of charts were produced for discussion and for drawing conclusions. Tables, percentages, averages and graphs were some of the simple tools used for describing information, based on Babbie (1995) and Nicholls (1995).

Data analysed specifically for this research are parts of the household baseline survey, the results of focus group discussion and comparative efficiency stove tests. (refer to appendix 2 for code log and raw data). The findings from the three data collection tools will be presented in the following chapter.

CHAPTER FIVE

RESULTS OF THE STUDY

5.1 Introduction

The aim of this chapter is to present and describe the results obtained from the following:

1. the comparative performance of the improved wood stoves and the three stone open fire during the efficiency test which included the water boiling and simmering tests. The following were observed:
   - i time taken to boil and simmer two litres of water,
   - ii water evaporated,
   - iii heat generated,
   - iv. fuel-wood used,
   - v. heat control and frequency of attendance to the fire during simmering;
   - vi. implied comparative fuel savings between the improved wood stoves and the three stone open fire.
2. the outcome of a baseline survey which included
   - i the demographics of the sample (household heads, household sizes, and gender);
   - ii socio-economic characteristics of the sample which included employment status, level of education and income;
   - iii the households' cooking fuel situation before the demonstration of stoves.
3. the respondents perceived socio-economic benefits of the demonstrated and placed stoves which included:
   - i consumer preferences in the choice of types of the stove to be used;
   - ii the perceived socio-economic benefits of the demonstrated improved wood stoves from consumers point of view;
   - iii the consumers' perception of the placed improved wood stoves in homes in comparison with existing alternative energies and technologies in the study area.

5.2 The comparative stove efficiency performance test

The Water boiling and simmering tests were a simulation of actual cooking. All tests were carried out at similar air temperatures and humidity.

5.2.1 Water boiling test

5.2.1.1 Time taken to boil water

Water on the four stoves reached the boiling point of 98°C as follows (Figure 5.1);

- 9.0 minutes on the Rocket and Vesto,
- 14.6 minutes on Yamampera,
- 17.8 minutes on Simunye,
- 19.5 minutes on the three stone open fire respectively.

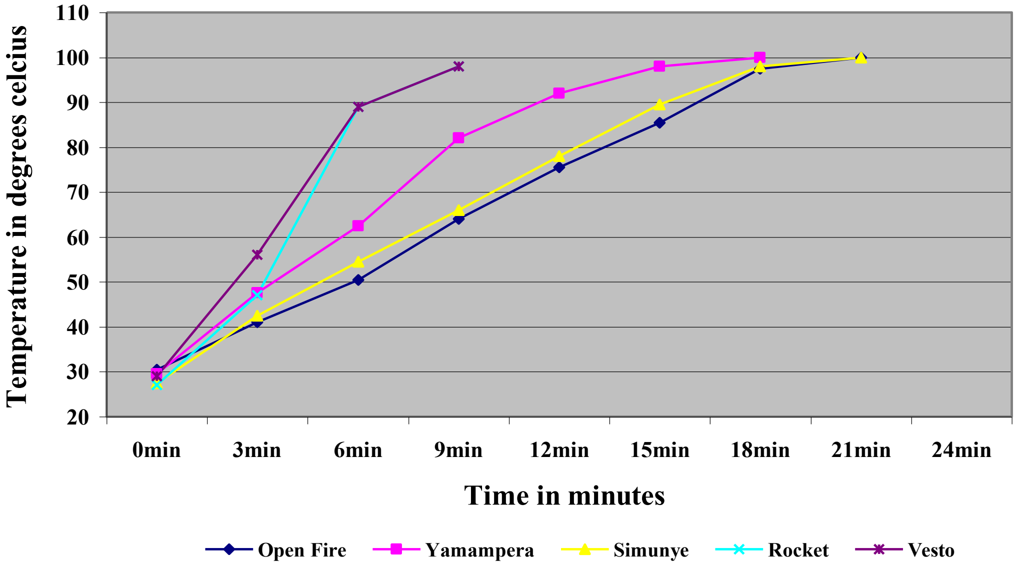

Figure 5.1 Time taken by each stove to raise water temperature to a boiling point (98°C)

5.2.1.2 Power output

The power output was determined by the following;

(a) Water temperature reached by each stove and the open fire at each specific time.

At the shortest boiling time (9 minutes) for the Rocket and Vesto stoves for example, the following were the temperatures reached by the other stoves and the three stone open fire (Figure 5.1);

- Vesto and Rocket (98°C),
- Yamampera reached (82°C),
- Simunye (66°C),
- The three stone open fire (64°C) respectively.

Based on the above temperatures, the four improved wood stoves had higher power output than the three stone open fire. The high power output of the stoves rapidly raised temperatures even after the first few minutes of lighting the stoves.

(b) The amount of water evaporated from the pot on each stove and the three stone open fire.

At each stove and the three stone open fire boiling points, the following were the percentages of water evaporated into steam (Figure 5.2);

- three stone open fire, 11.2 %
- Simunye, 14 %
- Yamampera, 28 %
- Rocket, 32 %,
- Vesto, 34 %

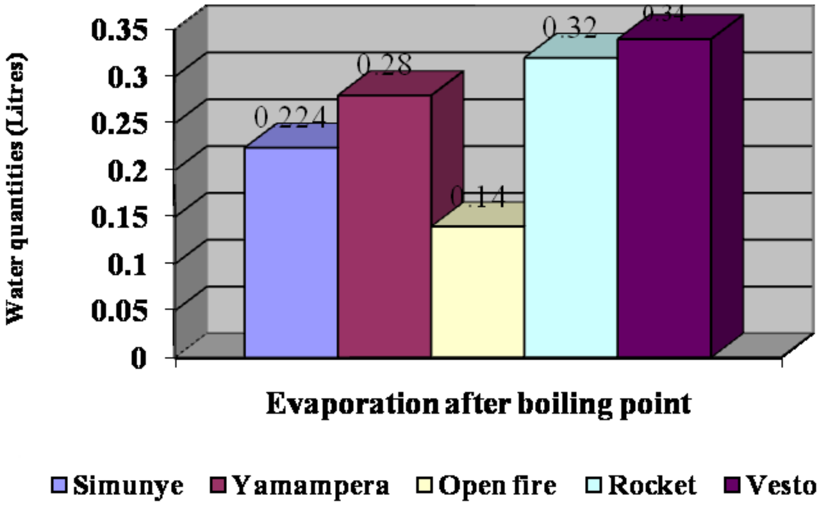

Figure 5.2 Quantities of water evaporated on each stove after boiling point

Higher percentages of water evaporation from the pot on the improved stoves compared to the three stone open fire signify higher power output of the stove. Heat intensity generated by each appliance correlates with the percentage of water evaporated.

5.2.1.3 Time saving

Time saving was determined by the ability of each stove and the three stone open fire to produce enough heat in the shortest time period to reach the desired outcome which was enabling water to reach boiling point as a simulation of preparation of tea. Table 5.1 shows time taken by each stove and the three stone open fire to reach boiling point. It also shows time saved by each stove compared with the three stone open fire. However, as a percentage, the following were the time savings (Table 5.1) in comparison with the three stone open fire;

- Vesto and Rocket, 53.8 %,
- Yamampera, 25.1 %,
- Simunye, 8.7 %.

Table 5.1 Time taken and saved by each stove to reach boiling temperature (98°C) compared to the three stone open fire

Name of Stove	Time taken by each stove	Total time saved	Time saved as a percentage
Vesto	9.0 minutes	10.5 minutes	53.8
Rocket	9.0 minutes	10.5 minutes	53.8
Yamampera	14.6 minutes	4.9 minutes	25.1
Simunye	17.8 minutes	1.7 minutes	8.7
Three stone open fire	19.5 minutes		

The improved wood stoves were able to transfer more heat to the base of the pot both by radiation and convection which raised water temperature and led to fast boiling of water. This was enhanced by the design of the combustion chamber.

As opposed to the three stone open fire, the fuel magazines on these stoves ensured optimal airflow into the combustion chamber. The air was then preheated as it passed under the shelf, enabling the smoke to be pushed through the flame and increased the combustion of unburnt particles. This effected more complete combustion which reduced emissions and increased heat output responsible for rapid temperature increases as also reported by Scott *et al* (undated).

5.2.1.4 Wood used and saved

The following quantities of wood had been used up on the four stoves and the three stone open fire at the boiling point of each;

- Rocket and Vesto (50 grams) each,
- Yamampera (142 grams),
- Simunye (160 grams)
- the three stone open fire (226 grams).

Figure 5.3 shows the wood balances at the boiling point of each of the stoves and the three stone open fire. As a percentage, Rocket and Vesto saved 90 percent of the fuel-wood, Yamampera 71.6, Simunye 68 and the three stone open fire 54.8 suggesting that Rocket and Vesto were at this time more efficient in fuel saving and the three stone open fire the least efficient.

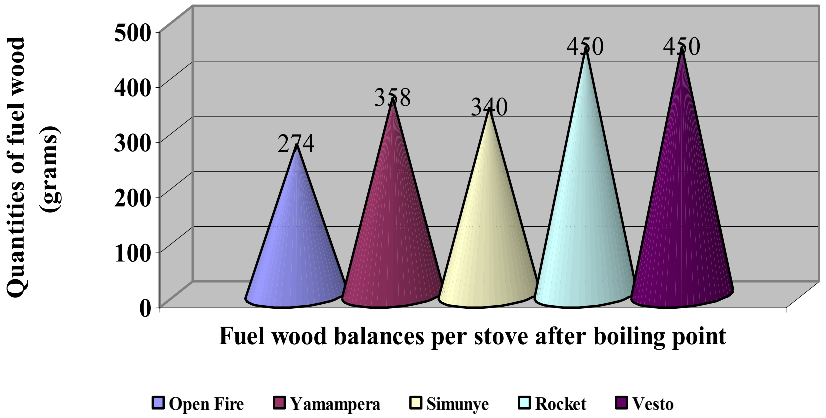

Figure 5.3 Comparative wood balances after the boiling point

5.2.2 Simmering test

5.2.2.1 Time taken and frequency of attention to the fire.

On simmering, the following were the stoves' performance (Figure 5.4);

- Yamampera maintained the highest temperature range above 80°C for 45 minutes with virtually no attention to the fire (perhaps once in every 15 minutes),
- Simunye maintained this position for 36 minutes but with a little more attention (1 – 2 movements) every 15 minutes,
- Rocket and Vesto maintained the same temperature (80°C) for 30 minutes with virtually no attention to the fire,
- The three stone open fire lasted for 24 minutes with continuous attention, about every 3 minutes until the wood was burnt out.

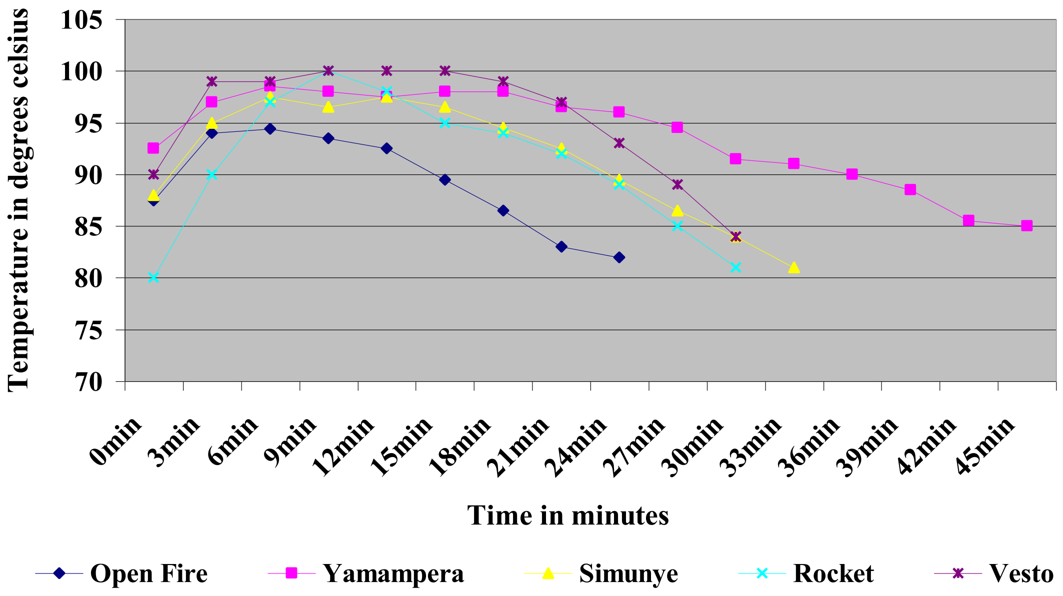

Figure 5.4 Comparative simmering temperature ranges and time taken by the four stoves and three stone open fire at 80°C minimum temperature

5.2.2.2 Power output

Figure 5.5 shows quantities of water evaporated on each of the stoves and the three stone open fire, once the minimum temperature of 80˚C had been reached. Even in the long run, the three stone open fire became less powerful in that it only caused 15 percent evaporation compared to 24 percent on Simunye, 38 percent on Rocket, 41 percent on Vesto and 42.5 percent on Yamampera (Figure 5.5).

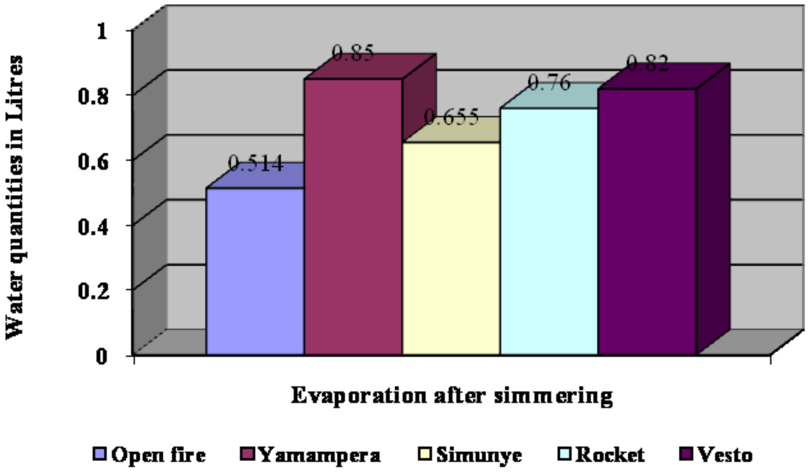

Figure 5.5 Quantities of water evaporated on each stove after simmering

5.2.2.3 Combustion efficiency

Combustion efficiency is the capability of the appliance to effectively burn wood and convert it into heat energy. After reaching minimum simmering temperatures of 80°C, the following quantities remained as charcoal and ash (Figure 5.6);

- 12 grams on Yamampera,
- 30 grams on Simunye,
- 35 grams on Vesto,
- 45 grams on Rocket
- 62 grams on the three stone open fire.

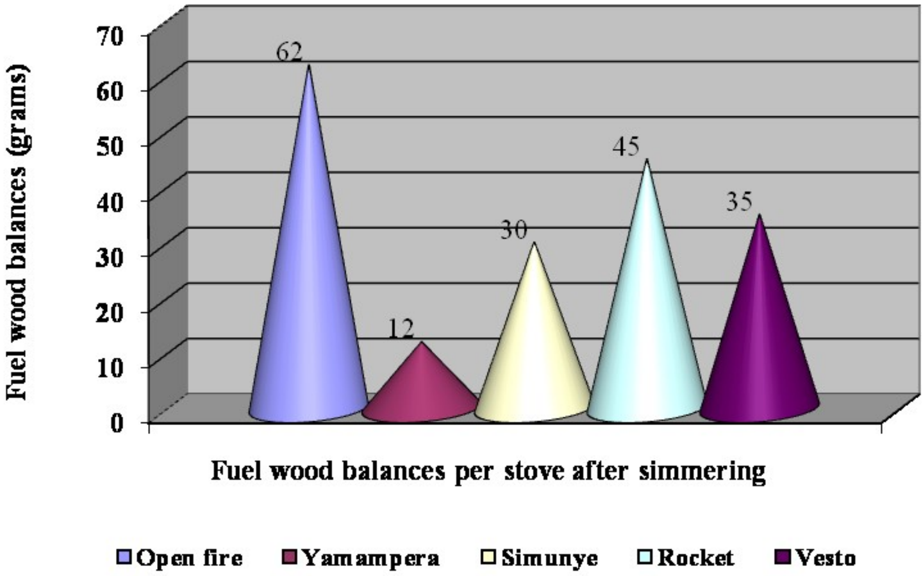

Figure 5.6 Comparative ash balances after wood burnt out.

Figure 5.6 shows that Yamampera effectively used 97.6 percent of the fuel-wood which remained as ash while Simunye, Vesto and Rocket effectively used 94 percent 93 percent and 91 percent. The three stone open fire only converted 88 percent of the fuel-wood used.

The poor combustion efficiency on the three stone open fire was largely because some of the heat on the three stone open fire was being diverted away from the bottom of the pot even with very little wind. On the improved stoves, almost all heat was directed by the combustion chamber to the bottom of the pot causing constant temperature rise of water in the pot.

This poor combustion efficiency of fuel-wood by the three stone open fire means that the technology needs much more fuel-wood to produce matching results from the improved cook stoves. In addition, the poor conversion of unburnt gases on the open fires as observed in the literature review is greatly related to high emission of particulate matter such as carbon monoxide (DFID, 2000) responsible for Acute Respiratory infections (ARI).

5.3 General descriptive data of those interviewed during baseline survey

5.3.1 Household size

100 households were interviewed in both areas. The average household size was 6.5 (Table 5.2). However, 88 households had an average of 7.4 members per household while 12 households had 3.3 members. Household members included mother, father, children and often grandparents and other close family members.

Table 5.2 Households interviewed and average household (n=100)

Sample characteristics	All households
Households interviewed	100
Average household size	6.5

5.3.2 Gender and education of household heads

Most (81 percent) of the households interviewed were headed by women while 19 percent were headed by men (Table 5.3). Some (23 percent) of the household heads interviewed had an education background ranging from junior primary school and below while 77 percent had their education background ranging from senior primary school level (Grade seven) and above. This suggested better literacy levels of the study area.

Table 5.3 Gender of household head (n=100)

Gender of Household head	Percentage of households
Male headed households	19
Female headed households	81

5.3.3 Employment status, income and expenditure

Most (69 percent) of household heads interviewed were employed (Table 5.4) and had an average monthly income of R1669.00 (Table 5.5) which was about R200 per capita per month.

Table 5.4 Employment status of household heads (n=100)

Employment status of household head	Percentage of households
Employed household heads	69
Unemployed household heads	31

Table 5.5 Income, general expenditure and expenditure on energy(n=100)

Employment status of household head	Monthly income (Ave.)	Monthly expenditure (Ave)	Monthly energy expenditure (Ave)	Energy expenditure as % of total expenditure
Employed	R1669.00	R1013.00	R299.00	29.5
Unemployed	R674.00	R1122.00	R265.00	23.6

This Figure (R200 per capita per month) is significantly below the poverty datum line of R650 in South Africa (Bhorat *et al,* 2001) and is exacerbated by the fact that the averages are skewed by only twenty seven of the 100 households that had a large income ranging from R3 000.00 to R5 300.00 per month (Figure 5.7).

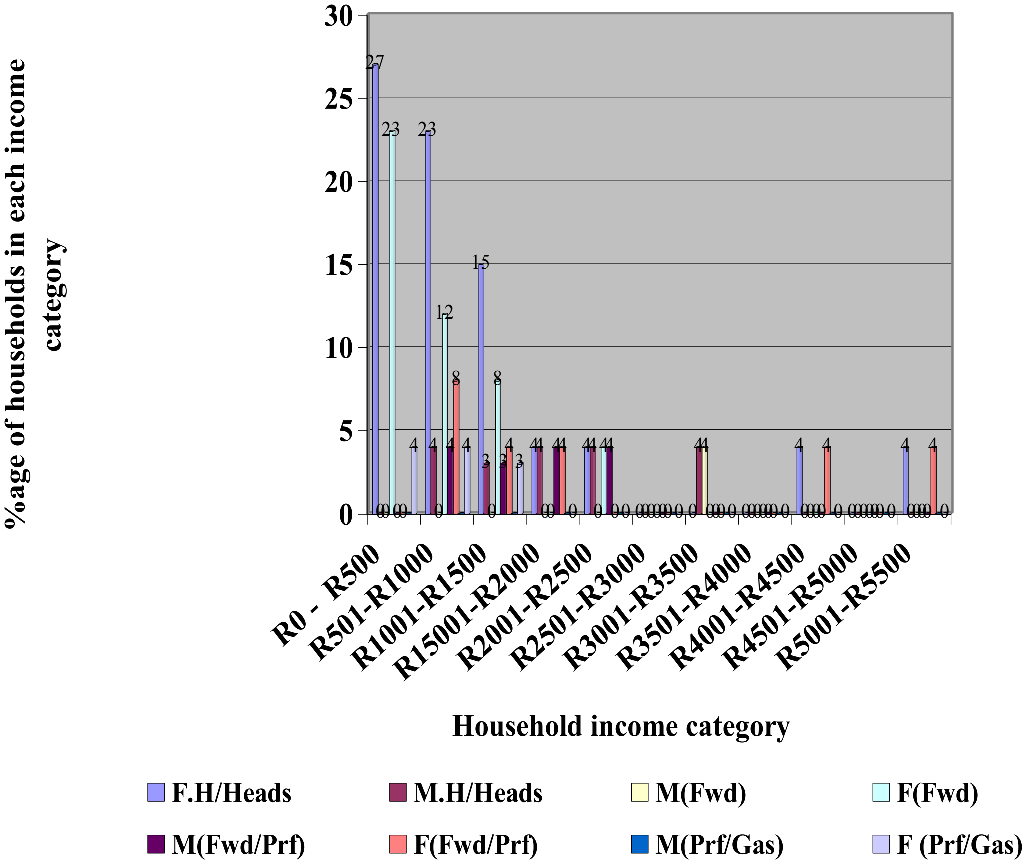

Figure 5.7 Household income and number of households in each income category

The average monthly expenditure of households with employed household heads was R1013.00 with an average of R299.00 spent on energy (therefore 29 percent of expenditure).

About a third (31 percent) of the household heads interviewed were unemployed (Table 5.4) but had an average monthly household income of R674.00 and an average monthly expenditure of R1122.00 where an average of R265.00 (23.6 percent) was spent on energy (Table 5.5). This is an anomaly because the shortfall in income must have come from somewhere, perhaps casual irregular income. The energy expenditure of those employed formed 29.5 percent of their total expenditure while that of the unemployed formed 23.6 percent.

Those with employment worked as domestic workers, casual labourers, gardeners, street vendors, taxi drivers, and clerks, earning between R100 and R5300.00 a month. Other important economic activities were vegetable growing and small scale subsistence poultry keeping which provided irregular incomes.

5.3.4 Household asset ownership

All the interviewed households had their own accommodation and none were renting. However, the average size of dwelling units was one room and the average number of dwelling units per household was two. The commonest assets were beds (42 households), wardrobes (27 households), and cupboards (23 households). However, the most desired assets were electric stoves (62 households), fridges (58 households) beds (42 households), televisions (42 households) and radios (35 households).

To a large extent the acquisition and sustainable use of the desired electrical assets were limited by the prevailing households' economic constraints. This shows the vital need for socio-economic capacitating of the poor households to achieve improved quality of life which is related to improved income. Improved energy initiatives such as improved wood stoves production and use would thus be central in catalysing income generating which would be an alternative form of employment. Figure 5.8 below shows household assets priority and ownership.

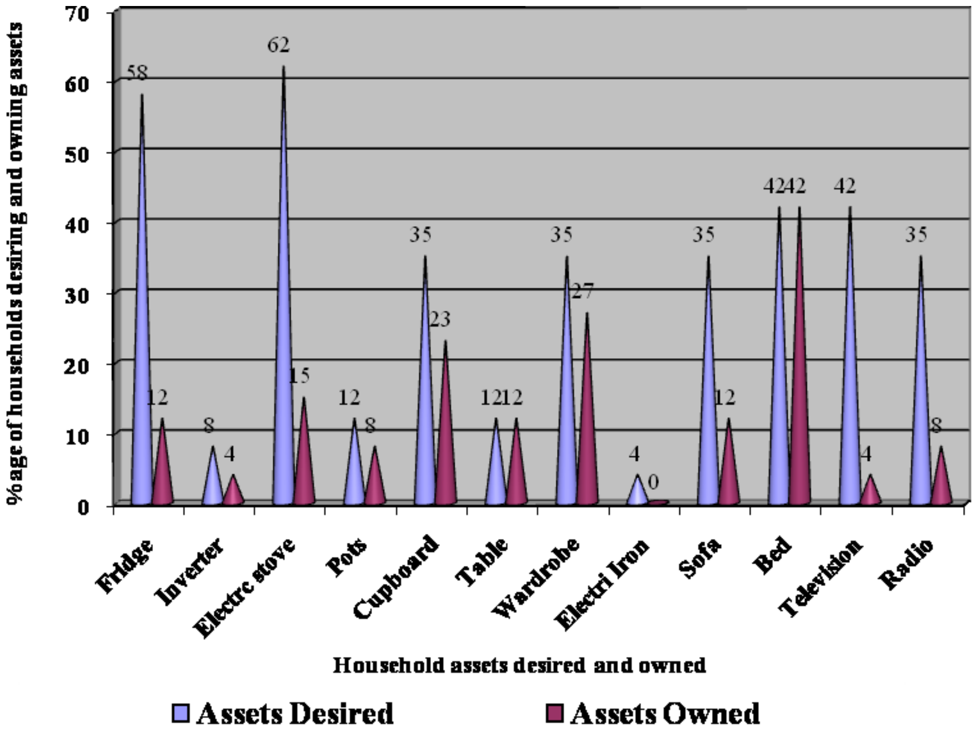

Figure 5.8 Households assets owned and desired

5.3.5 Types of fuel used

In the two study areas, wood was the main household cooking fuel which was predominantly used on the open fire. The two other main fuels used to supplement fuel-wood were LPG and paraffin (Table 5.6). The existing fuel use pattern was a mix of paraffin and wood, paraffin and gas and wood only. No households used electricity for cooking and the electric stove in Figure 5.8 was being used as a cupboard because the area was not electrified.

Table 5.6 Household fuel use (n=100)

Employment status of household head	Households proportions and percentages by fuel use		
	Using Fuel-wood and Paraffin	Using Gas and Paraffin	Only using Fuel-wood
Employed household heads	46	8	15
Unemployed household heads	4	4	23

5.3.6 Households' uses of available fuels

All 100 households interviewed used the fuels for cooking while 23 households used them for house warming, 65 households for ironing, 46 households for water heating and 12 households for baking (Figure 5.9).

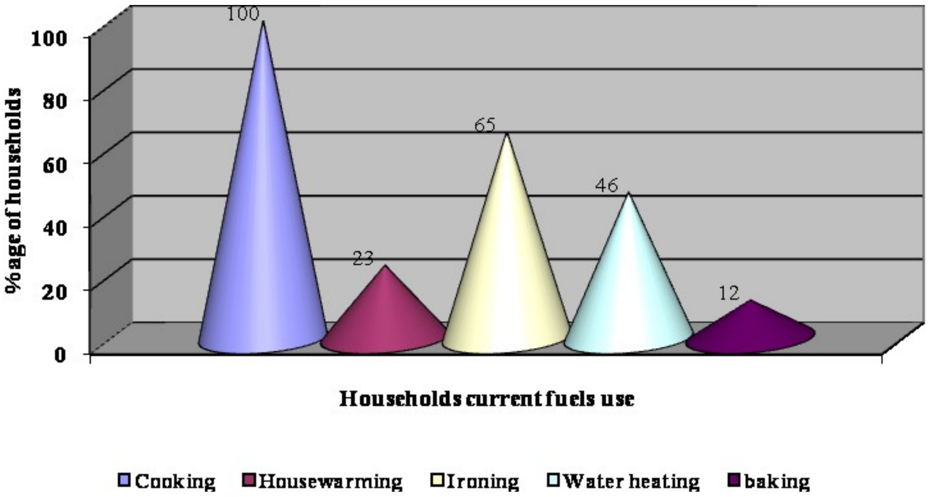

Figure 5.9 Households and current uses of fuel

However, over 80 percent of the households interviewed said they still used the three stone open fire mainly for cooking hard foods such as uJeqe and uPhuthu which are traditionally their staple foods, cooking large quantities of food on special occasions and for heating homes.

5.3.7 Household perception of the fuels used

Even though households used the three fuel types, they did so because they had no other choice. This was seen in the fact that 50 households in the sample did not like the fuels they were using because they were smoky, 15 felt the fuels were sourced very far, 31 described the fuels as dirtying their houses, furniture and clothes, and 23 believed the fuels to be very expensive. Four households did not like the fuels because they did not last and four said they were exposed to danger from thugs in the forest while collecting wood. The wood that was collected took about four hours round trip which is equivalent to half day's work. Twenty households had health challenges whereas 12 noted breathing problems, 4 poisoning of children and 4 eye problems (Figure 5.10).

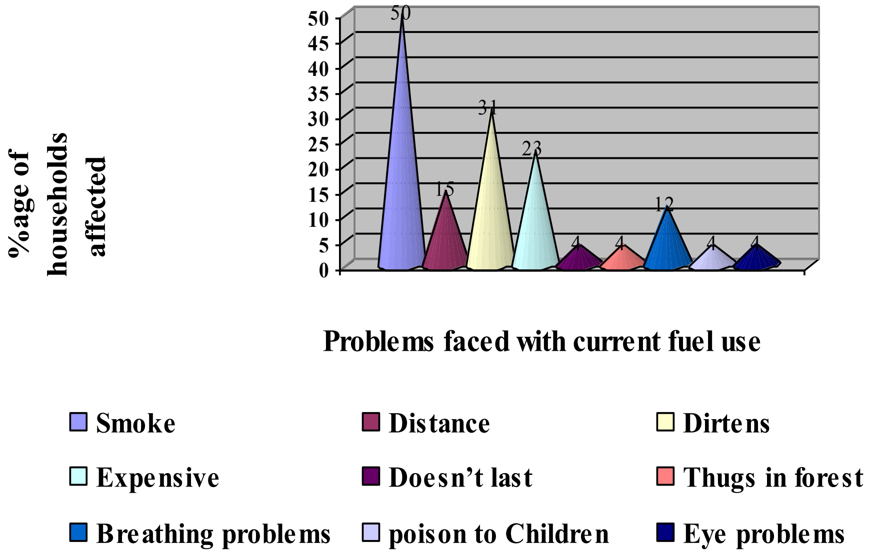

Figure 5.10 Households and their problems experienced with current fuels

5.3.8 Types of food cooked and fuels used

The most regularly cooked foods in a month in order of frequency were porridge (28), uphuthu (13.2), vegetables (11.8), rice (10.6), Irish potato (9.1), beans (6.4), stamp (5.1), ujeqe (4.9), and meat (3) (Figure 5.11). This agrees with what has been presented in chapter 2 that most poor households need fuel mainly for cooking because 95 percent of their food requires cooking before it can be eaten.

Figure 5.11 below shows a graphical presentation of foods cooked in the two study areas and the cooking frequencies. This means that households would fore go their most desired foods if they are energy intensive and opt for less energy intensive ones even though they might be less nutritive values in order to save fuel.

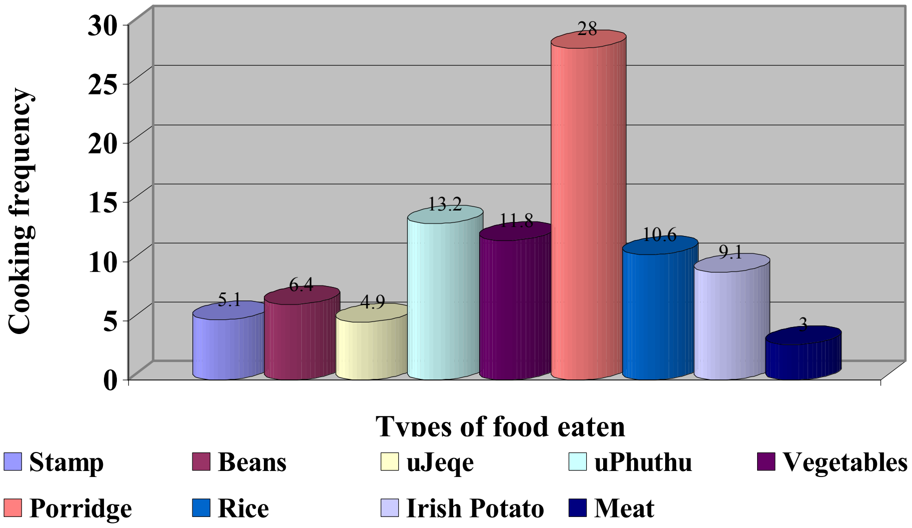

Figure 5.11 Average monthly frequencies of food cooked

5.3.9 Household size and type of fuel used

In addition, the fuel type used by a household was a direct result of the household size. For example, bigger households above 6 people used either a mix of paraffin and wood or wood only while smaller households (3.3 people) used a mix of paraffin and gas (Table 5.7). Households with less opportunity to gather their own fuel-wood because they were employed used greater amounts of complementary fuels such as paraffin and gas.

Table 5.7 Average household size and fuel use in both study areas.

Sample characteristics	Households proportions and percentages by fuel use		
	Using Fuel-wood and Paraffin	Using Gas and Paraffin	Only using Fuel-wood
Average household size	7.7	3.3	6.7

The use of a mix of paraffin and fuel-wood as well as fuel-wood only increased with household size up to 9 members after which it decreased drastically (Figure 5.12). The use of a mix of gas and paraffin was constant for the first two quartiles and also decreased as household sizes increased. This suggested that paraffin and fuel-wood were perceived as expensive for smaller and biggest households and affordable for the average household sizes. A mixture of gas and paraffin seemed economical with smaller household sizes and unaffordable as household sizes grew.

In general, fuel use conformed to the usual patterns of limited paraffin and gas use, usually confined to small thermal applications such as single pot primus stoves for cooking light meals, ironing and sometimes water heating while cooking the rest of their food with firewood.

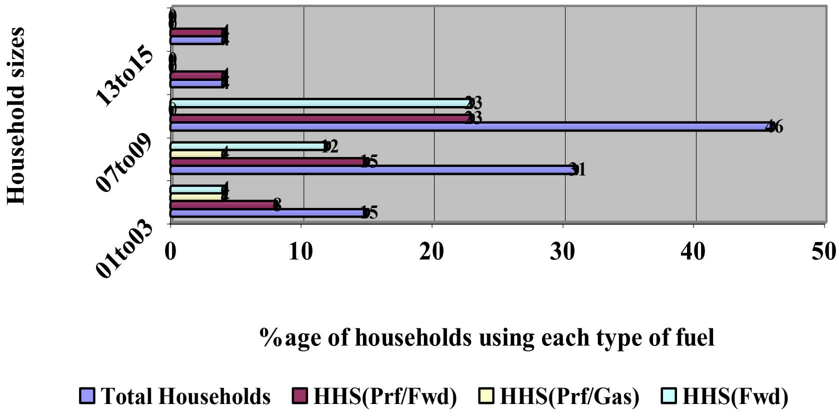

Figure 5.12 Household size and fuels used

5.3.10 Type of fuel used and expenditure

Households that used a mix of wood and paraffin spent an average of R342.00 while those that used paraffin and gas spent R152.00 and those that used wood only spent R240.00 per month on fuel respectively (Table 5.8). The average percentage energy expenditure for those using a mix of wood and paraffin was 30.9 percent of expenditure while those that used gas and paraffin was 9 percent and those that used wood only was 18.7 percent of the monthly total household expenditure (Table 5.8).

Even though wood was cheap costing R20.00 per head load weighing about 20kgs, the average expenditure was greater than that of paraffin and gas. This was mainly because of the poor efficiency of the three stone open fire used by households which needed more fuel-wood to properly cook the meal. Other factors included number of households using fuel-wood compared to those using paraffin and gas and household sizes as bigger households were compelled to use fuel-wood due to the high prices of the alternatives and used more quantities which were expensive in the end (Table 5.7).

Table 5.8 Type of fuel used and amount spent on fuel

Households expenditure	Households proportions and percentages by fuel use		
	Fuel-wood and Paraffin	Gas and Paraffin	Fuel -wood only
Average monthly expenditure	R1108.00	R1658.00	R1284.00
Average monthly energy expenditure	R342.00	R152.00	R240.00
Monthly energy expenditure as a percentage of total monthly expenditure	30.9 %	9 %	18.7 %

5.3.11 Income, gender of household head and fuel use

A third (33 percent) of the households headed by females had a monthly income in the lowest income bracket (R0 – R500.00 per month) and 28 percent in the second lowest (R501 – R1000.00) compared to no male in the lowest income bracket and only 4 (21 percent) in the second lowest bracket (Figure 5.5). This was to a greater extent due to higher chances of men taking up multiple piece works in a week than women. This situation limited such households from using paraffin and gas although it was available within their vicinity (mainly paraffin).

Although household incomes suggested that a number of women in both areas were poorer than men, women had bigger households and more responsibilities at home than men. Women were more responsible for the upkeep of children, buying school uniforms and stationery for children on top of fuel acquisition than men.

In spite of their limited income which predominantly came from social welfare grants (41 percent average) as pensions, disability and child support, most female headed households were forced to buy fuel-wood instead of freely collecting it. This was because fuel-wood, though scarce and collected further away from homes (about 3 – 5 hours return trip), was cheaper in smaller quantities and lasted them sometime before the next purchase compared with the alternative fuels. Fuel-wood collection was not considered by many women because of the fear of being mugged and raped in the forests areas where wood was collected.

5.3.12 Age of household head and type of fuel used

Most (78.9 percent) of the households headed by younger household heads used a mix of wood and paraffin and not a mix of paraffin and gas compared to 46 percent of the households headed by older household heads. Age of the household head here directly influenced the choice and use of fuel possibly due to insufficient income as suggested in some literature.

Table 5.9 Age of household head and household fuel used

Age of Household head	Households proportions and percentages by fuel use		
	Using Fuel-wood and Paraffin	Using Gas and Paraffin	Only using Fuel-wood
Householders aged 29 years and below	15	0	4
Householders aged 30 years and above	38	12	31

5.3.13 Education of household head and type of fuel used

None of the households headed by household heads with education background ranging from junior primary school and below used a mix of paraffin and gas while 11 households (14.3 percent) headed by those with an education background ranging from senior primary and above used a mix of gas and paraffin (Table 5.10).

Households with less education and without school going children frequently cooked hard to cook food that required more fuel and time for cooking. This meant more money spent for buying the fuel or more time for collection of fuel-wood.

Education here seemed to influence the choice and use of fuel. Both fuel use and expenditure in general were to a greater extent influenced by the type of food frequently cooked by the household and the size of household as already seen above.

Table 5.10 Education status and type of fuel use

Education status of Household head	Households proportions and percentages by fuel use		
	Using Fuel-wood and Paraffin	Using Gas and Paraffin	Only using Fuel-wood
Junior Primary and below	19	0	4
Senior Primary and above	31	11	35

5.3.14 Household perceptions of improved wood stoves

In response to the willingness to use improved wood stoves shown during executing the baseline questionnaire, 92 percent of households said that they would use the stoves (Figure 5.13).

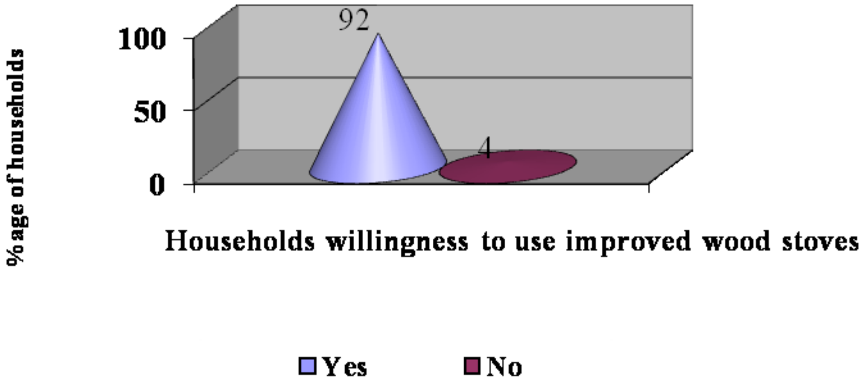

Figure 5.13 Households and the willingness to use of shown Wood Stoves

Most of them felt that the improved cook stoves would make women's lives easier and would change the future energy-use patterns where the majority would turn away from paraffin stoves because of the main of reasons given in Figure 5.10. About a third (31) of households believed they would save fuel, 15 households liked the stoves because they could be used for dual purposes; both cooking and house warming when it was cold with the same fuel-wood. Fifteen others said paraffin was expensive and the other 15 said the stoves were safe. Twelve households said the stoves were clean Eight households mentioned fast cooking and 8 others liked them for smokelessness. Four households felt the stoves were cheap and another 4 liked them for portability respectively (Figure 5.14).

However, four households disagreed that improved stoves would be a solution to their energy related problems. In their opinion, even wood was becoming more scarce and expensive compared to 2-3 years ago.

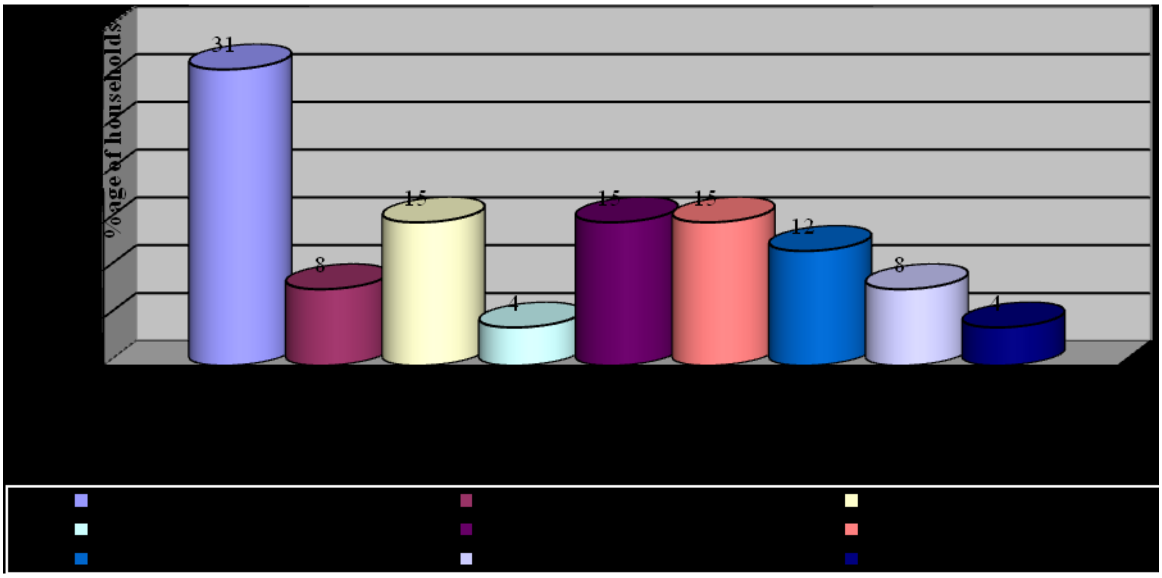

Figure 5.14 Households reasons for willingness to use shown improved wood stoves

5.4 Consumer perception of improved wood stoves

5.4.1 Focus group discussions after demonstration.

The sample population that participated in the focus group discussions was composed of 31 percent male and 69 percent female in Umsilinga and 23 percent male and 77 percent female in Isnathing a similar distribution. The total number was 69 people with 37 people from Umsilinga and 32 people from Isnathing.

Participants in the focus group discussions chose improved stoves for various reasons. In particular, they expressed very high satisfaction with them due to advantages they saw in cooking speed, safety, convenience, durability, quality of food produced, aesthetic appeal, and reduction in smoke (Table 5.11). Participants also acknowledged the fuel savings achievable with the improved stoves as another significant reason why they appreciated them.

Approximately 80 percent of the participants ranked aesthetic appeal and appearance, fuel saving and use for informal food preparation and selling as the most important benefits of using an improved stove. Around 70 percent of the participants considered the increase in speed of cooking and small size of the stove to be key reasons for choosing the improved stoves. Fifty five percent of the participants felt that reduced levels of smoke, cheaper prices and safety of handling the stove during cooking were determining factors (Figure 5.15).

Table 5.11 Consumer's choice of stove according to benefits (focus group results) n= 69

Benefits and number of consumers choosing the stove		Type of stove and cost price			
		Rocket R200	Simunye R50	Vesto R250	Yamampera R80
	Safety	X		X	
	Health	X			
	Aesthetic appeal	X	X	X	X
	Speed of cooking	X		X	X
	Fuel saving	X	X	X	X
	Price		X		X
	Less smoke	X			X
	Small size		X	X	X
	Informal food vending	X	X	X	X

As Table 5.11 shows, health did not rank in the top benefits cited by consumers as only 30 percent mentioned it. This supports previous work (ESD, 2000) that health and environment are not seen as the primary driver for consumers to purchase improved stoves.

All participants were prepared to cook meals on such stoves while 50 percent would also use them to boil water and heat houses. Most participants felt that they would use the stoves themselves because paraffin and gas were very expensive though only two used gas for additional cooking.

Most participants felt that the stoves were more suitable for domestic use while 65 percent felt that street vendors would be the suitable market for purchasing such stoves. Some felt that selling cooked food from these stoves would be a good way of generating an income with only one prepared to be an agent. Most (71 percent) were prepared to manufacture and sell the stoves to increase employment.

Most (77 percent) of the respondents preferred the Yamampera stove because of its light weight, wood saving and the shape that was nice and beautiful. About half (55 percent) preferred Simunye stove because it was good, beautiful, the fire box mouth was small and the pot rests were close enough to properly hold the pot when cooking. Average costs of R60 and

R80 were seen as affordable by all participants who felt the use of these stoves would bring them a sigh of relief from high paraffin costs.

On the bigger stoves, 77 percent of the participants chose the Rocket and 66 percent Vesto. The main opinion on the Rocket Stove was that although it was very heavy and expensive, it was more stable. The Vesto was seen as clean, easy to control heat while cooking but dangerous as one needs to remove the pot to refill the wood which might cause burns. The prices of R200 and R250 were considered high but participants suggested paying by installment for two months. Figure 5.15 below shows the percentages of people choosing each stove while Table 5.11 shows the consumer priorities in evaluating the stoves after demonstration.

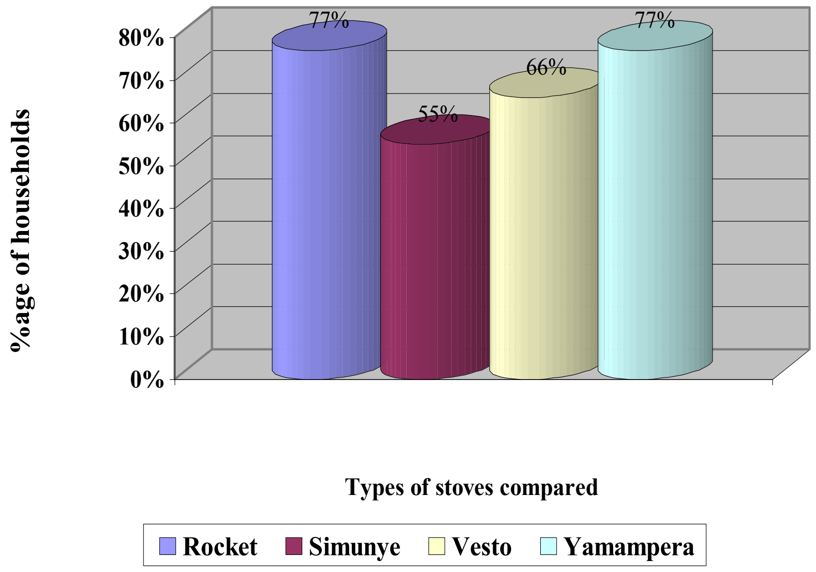

Figure 5.15 Consumer's choice of stove according to type (n=69)

5.5 Focus group discussions after stove placement in homes

5.5.1 Improved wood stove use

Twenty four households in both study areas participated in the household performance test. Each household spent one week under observation using their normally used technologies. Thereafter each household spent 1 week cooking on each stove type sequentially so that after 5 weeks reports were made from each household about their experiences of the normal cooking in comparison with to each of the 4 stoves that they had used. Most households expressed their satisfaction with the performance and fuel efficiency of the stoves. It was revealed after the placement period that the average user rate (over 7 days) for the Vesto stove was 70 percent, Simunye 75 percent, Yamampera and Household Rocket 80 percent (Figure 5.16). Vesto stove was difficult to refill with fuel-wood because it needed very short and small pieces of wood which were not always readily available. In addition, it required the pot to be removed first to refill fuel-wood. This exposed the cooks to extremely high heat which caused some burns to the cooks. In contrast to the Vesto, the other three stoves were easy to refill because additional fuel-wood was fed from the side which was similar to the three stone open fire.

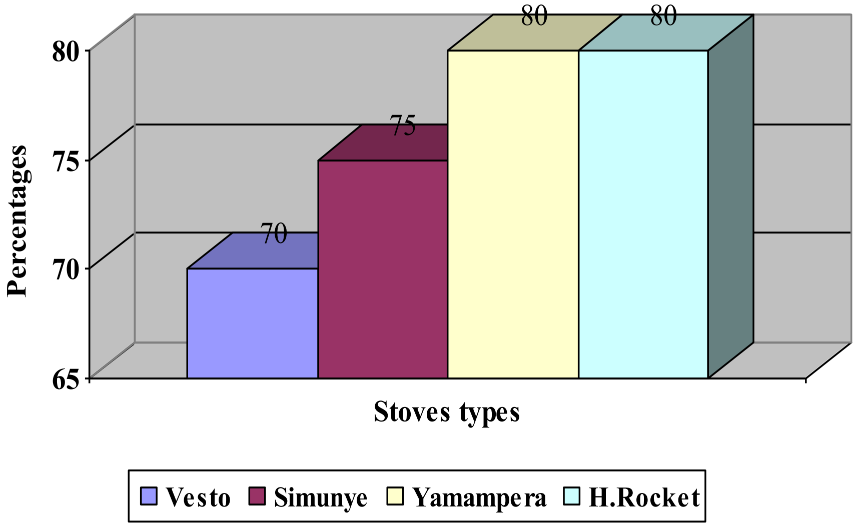

Figure 5.16 Improved stove user rate (n=24)

5.5.2 Speed of cooking, fuel and cost saving

More than half of the participating households expressed satisfaction in the cooking speed of improved stoves and ease of cleaning and maintenance. Almost all (88 percent) of the participants indicated that the speed of the improved stoves in general definitely reduced fuel-wood consumption and household energy expenditure.

The rate of fuel saving from the improved stoves was quite significant in comparison with the traditional three stone open fire used earlier by households. On average, a family saved around 45 percent of fuel-wood per week using Simunye and Vesto and around 50 percent with Yamampera and Household Rocket. Further details are given in Table 5.12 below. In terms of normal expenditure on fuel, this was quite a significant amount for an average low and middle income peri-urban family. The savings could allow for a relatively quick recovery of the initial cost of the stove, which makes the technology economically affordable and socially desirable.

Table 5.12 Fuel savings by types of stoves compared to the three stone open fire

Type of stove	Number of households	Quantity of fuel and amount of money used		Average fuel and money savings/stove	
		kgs	Rand	kg	Rand
Vesto	12	30	48.00	12.6	20.16
Household rocket	12	21	33.60	10.7	17.12
Yamampera	12	19	30.40	7.5	12.00
Simunye	12	16	25.60	6.7	10.75

However, an average of 29 percent continued to use their daily technologies because they were not very familiar with the improved wood stoves. In addition, these usual technologies helped when they needed to cook large quantities of food that did not fit on the improved stoves although paraffin and gas were rarely used and mainly for preparing foods that cooked quickly, reheating food, or making tea.

5.6 Conclusion

The comparison of energy consumption patterns between different peri-urban poor households, age groups, gender of householders and sizes of households in this chapter demonstrates various characteristics. Fuel-wood constitutes more than half of the total household energy use followed by paraffin and LPG. It is the low and middle income groups in these areas that are the main users of fuel-wood and paraffin because of their availability and no or low-cost. The consequence of such utilisation is the serious health hazard of inhaling the smoke from fuels used for cooking, environmental degradation and accidental fires to households in case of paraffin. This inefficiency of utilisation is also the result of poor education, bad health care, poverty and hardship imposed upon women.

However, with the improvement in the combustion efficiency of the energy carriers like the improved wood stoves used in the efficiency tests, household energy use and expenditure can be reduced by about 50 to 80 per cent. This is possible because these stove designs are geared at maximising the following:

- Fuel combustion by keeping the temperature high and ensuring the presence of sufficient oxygen,

- Radiative heat transfer from the fire to the pot by keeping the pot as close to the flame as possible,

- Convection from the fire to the pot by passing as much of the hot gases over to the pot as possible and reducing draft,

- Conduction to the pot by using insulation materials so that the heat is retained and concentrated near the pot,

The above factors increase user satisfaction and make the stoves convenient to use with local fuels, cooking pots and utensils, and prepare local dishes easily and well, in addition to increasing energy supply on a per unit of energy basis.

The declining share of total household expenditure on energy as a result of improved combustion efficiency of the stoves through fuel saving and real income means that the urban poor would be less vulnerable to unanticipated changes in prices of individual energies. Households would also have greater cash available for productive investment such as artisan produced stoves rather than on direct basic fuel and other needs.

Since fuel-wood will remain the most important and commonly used source of energy for the future decades (as observed from the prevailing energy consumption patterns), the use of these stoves would thus address energy development, poverty, social justice against women and children thereby contributing towards sustainable livelihoods. However, it is the incorporation of users' determining factors in choosing the type of stove to buy and be used such as fuel economy, price, speed of cooking, user friendliness, dual use and smokelessness of the appliances would bring about the increased acceptability and adoption.

CHAPTER 6

DISCUSSION OF THE RESULTS

6.1 Introduction

In the theoretical framework in chapter one, it was observed that energy technologies are not useful for the sake of technologies. It is their utility, which lies in facilitating human development through income generation, avoiding pollution, preserving natural resources, and empowering women and children through preservation of culture and heritage. In this perspective, the results of the performance efficiency test, baseline and consumer perceptions surveys in chapter 5.2, 5.3 and 5.4 of this thesis have shown that the use of all four improved wood stoves used in the study would yield better social, economic and environmental benefit to the households than the three stone open fire.

It is the improved efficiency performance of the improved wood stoves that yielded substantial savings in wood used by the four improved wood stoves and would further reduce household time spent on attending to the fire, collecting fuel-wood, lessens environmental degradation and reduces household expenditure on fuel. The reduced time spent while cooking on these stoves minimises household members' exposure to emissions, reduces the risks of burns and enables households to engage in more social and economic activities.

The wood and time saving effects of these improved wood stoves places the technology as a cleaner energy technology substitute for the three stone open fire, dangerous paraffin panda stoves and expensive LPG burners. The improved wood stoves would be more valuable to the 65 percent of the sample population in the study area which is currently relying on fuel-wood for cooking especially hard-to-cook foods with 80 percent of these households cooking on the three stone open fire (Chapter 5 of this Thesis). This supports the United Nations concept that energy efficiency and the development of new and energy efficient technologies has a significant role to play in facilitating human development by improving the livelihood of the urban poor as outlined in the Millennium Development Goals (MDGs) 1, 2, 3 and 7 (Chapter 2.1 of this Thesis).

This chapter discusses the detailed socio-economic efficacy of using the four improved wood stoves used in the study in comparison with the three stone open fire and to some extent, the paraffin panda stoves and the LPG burners as alternative technologies. It focuses on the following;

- existing fuel use pattern,
- efficiency performance of the stoves,
- the economic benefits of using the four improved stoves in relation to the existing negative social and economic impacts hindering the urban poor's sustainable livelihoods in the study area, and
- how the outlined consumer preferences in the study area affect household decisions over the stove adoption.

6.2 Multiple Fuel use

From the study findings, peri-urban households use multiple fuels but fuel-wood is the principal energy source for household cooking. Although paraffin is also a common cooking fuel in both areas, it is mainly used by high-income and some middle-income households. As a cooking fuel, it is rarely used for the main cooking tasks. It is mainly used for lighting and occasionally for short cooking tasks, such as preparing tea, vegetables, porridge or milk. Besides its high cost, other factors, such as the erratic supply of fuel due to lack of established retailers in the area, family size, cooking habits, explosive nature of paraffin panda stoves causing fires to the housing structures and their low power output, were mentioned as making paraffin inaccessible or unacceptable to the majority.

Many socio-economic factors influence household energy use strategies at a given time. In this study, respondents mentioned purchasing power of the households, the availability and reliability of the fuel supplies, fuel prices, high capital costs required for utilizing LPG, family size and cooking habits as major limiting or influencing factors. Households use more than one fuel but use one fuel as the primary energy source and others as secondary used to supplement, substitute or complement the primary fuel. Fuel mix is used in order to minimize uncertainties of modern fuels and hence to have fuel security. This pattern is more apparent than fuel switching. The switch from fuel-wood to modern fuels such as Paraffin and LPG as household income increases is not automatic. Therefore the proposition of an energy ladder is not concurrent with the energy use patterns in the study area. The problem of uncertainty of supply is a factor in this regard.

Households in the study can be defined in terms of groups, or classes of people with different income and assets. Households in these two areas fall into two categories: purchasers and gathers though both incur costs either in cash or time spent in gathering. It is this diversity that influences their energy use patterns, while family size determines quantities of energy used. These results also suggest that fuel consumption is positively related to household size. As the household size increases by one member up to 9, fuel consumption increases while the per capita fuel consumption decreases. On the other hand, per capita fuel consumption is negatively correlated to household size. This suggests that from the household economic point of view, large families are more efficient in energy use than small families. Moreover, the findings suggest that household fuel consumption here is correlated to household size and household income. However, it is household size that is more important in predicting household fuel consumption than household income.

6.3 Efficiency of the four improved wood stoves used in the study versus that of the three stone open fire.

6.3.1 Summary of efficiency results

The findings of the efficiency test results (Chapter 5.2) which are summarised in Table 6.1 below indicate that the improved wood stoves performed better in combustion of wood and heat output to the pot than the three stone open fire.

Table 6.1 Summary of the efficiency performance test results

(A) At the shortest comparable boiling point of 12.6 minutes		**Improved stoves**	**3 stone open fire**
1	Average power output	86°C	66°C
2	Average water evaporation	27%	11%
3	Average time saved	35.35%	control
4	Average wood saved	79.9%	54.8%
(B) After Simmering			
1	Average frequency of attending to fire in every 15 min	0.6 times	5 times
2	Average evaporation	36.38%	15%
3	Time taken to maintain high power temperature over 80°C	35.25minutes	24 minutes
4	Combustion efficiency	93.9%	88%

It is the effective combustion and heat output of these stoves (an average 86°C) that resulted into an average 79.9 percent (399.5 grams) wood saved at boiling point compared to only 54.8 percent (274 grams) on the three stone open fire.

In like manner, the improved combustion efficiency on these wood stoves maintained the high power temperature over 80°C for 35.25 minutes during simmering which enabled complete combustion of 93.9 percent of the wood and charcoal, leaving a final balance of 30.5 grammes as pure ash. On the other hand, the poor combustion efficiency on the three stone open fire managed to maintain the high temperatures above 80°C only for 24 minutes and ineffectively burnt only 88 percent of the wood, leaving a final balance of 62 grammes mainly as charcoal. The final mass and nature of wood balances after simmering reflect the higher comparative technological effectiveness of the improved wood stoves to the three stone open fire which is further demonstrated by almost no attention to the fire on the stoves and continuous attention in every three minutes on the three stone open fire during the whole simmering period.

It is clear from the summary test results above that the three stone open fire had flaws that prevented effective heat transfer from the wood to the pot as on the improved wood stoves. The two aspects to the transfer of heat from the wood to the pot are the combustion process, which releases heat and the second is the transfer of the heat to the pot and the overall efficiency which is the product of the efficiency of the first process (Nominal Combustion Efficiency) and the second (Heat Transfer Efficiency). It is the high combustion efficiency on the improved wood stoves that reduced frequency of attending to the fire and lengthened the time taken by the stoves to maintain high temperature range up to 35.25 minutes as opposed to 24 minutes on the three stone open fire. This combustion efficiency also has the added benefit of reducing emissions, whether to the kitchen or the outside environment.

Furthermore, the performance of the three stone open fire was less effective compared to all the improved wood stoves used in the tests because of the lower burning temperatures it achieved and the length of time it took to reach boiling point temperatures. The cool air in contact with the flames on the three stone open fire, conducted heat away quickly (Still and Winiarski, 2001), resulting in flames not burning efficiently and some of the (burnable) carbon within the wood escaping as unburned and wasted energy in the form of smoke. This contributed to the formation of excess charcoal which was also an indication of insufficient air access to the base of the fire to push the hot flue gases upwards thereby causing incomplete combustion.

On the other hand, the improved wood stoves achieved more complete combustion as the fire burnt hot and clean. The insulation around the firebox shielded the flames from contact with cool outside air, and the rocket shape of the combustion chamber (Figure 6.1) allowed enough oxygen to participate in the reaction. In addition, the extension of an insulated firebox upwards into the combustion chamber, created a draught, which helped to suck air in. The air then went through the fuel magazine, under the fuel, which rested on a shelf, enabling the warming of the fuel magazine and heating of the air before it reached the fire. The fire itself burnt the tips of the firewood pieces as they entered the firebox as shown in the “rocket elbow” (Figure 6:1). The firewood in the improved wood stoves is spaced above on the shelf in order to allow air to flow around them. Smoke (uncombusted material) that moves up the inner combustion chamber gets burnt before reaching the pot resulting in fewer emissions released and less charcoal left but more heat reaching the base of the pot.

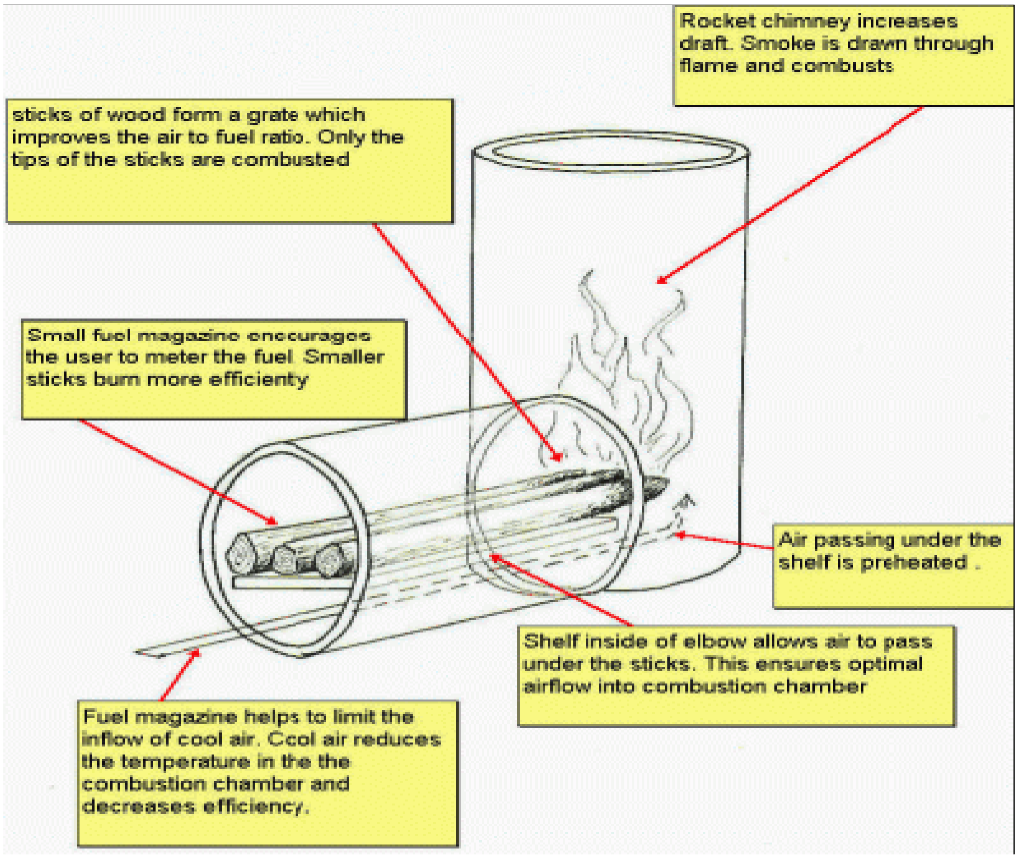

Figure 6.1 The Rocket combustion chamber model.
(Source: Design principles for wood burning stoves, Still & Winiarski, 2001)

The failure of the three stone open fire to consolidate heat in a short time basis effecting only 5 percent water evaporation in 18 minutes compared to an average of 21 percent on the improved wood stoves (Figure 6.2) signify that the three stone open fire would be less effective in properly cooking the commonest foods in the areas mainly in the light of scarce fuel-wood supplies. Since the percentage of evaporation from the cooking pot is directly related to the intensity of heat released by the stove under the pot from the burning fire, it therefore follows that the improved stoves conversion and conservation of more heat can effectively be used on the commonest foods of the rural and urban poor in KwaZulu-Natal like beans, uJeqe and home made bread that need long cooking times and intensive heat. This supports McCall and Witherden's (2002) views on energy in their study in KwaZulu-Natal.

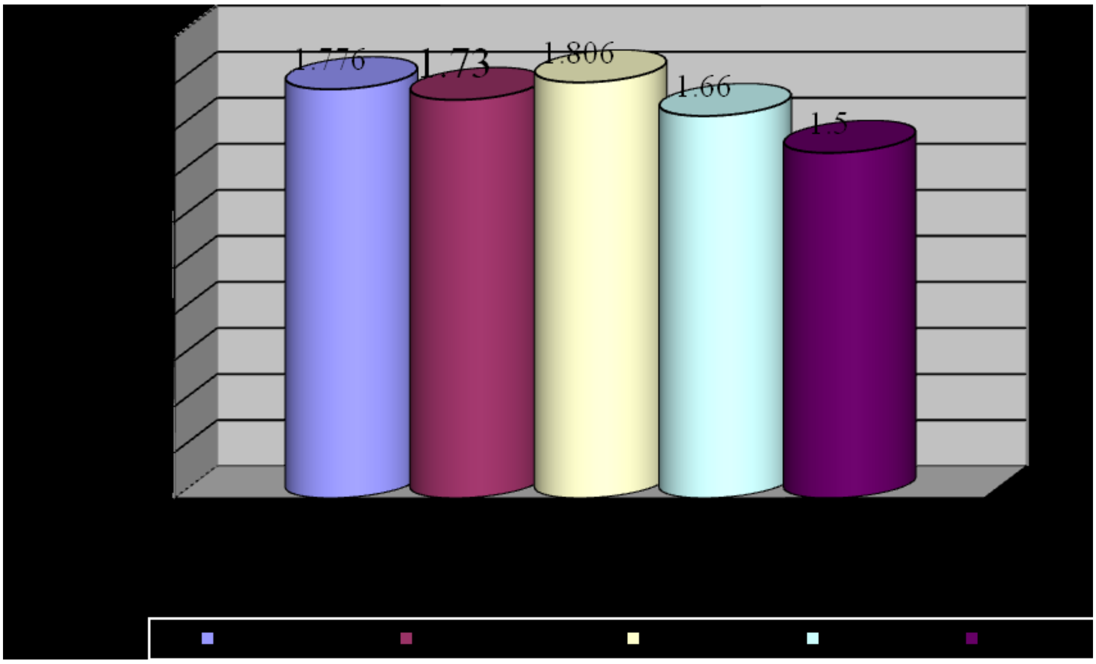

Figure 6.2 Comparative water balances after the boiling point

6.3.2 Time saving

The fact that the four stoves tested for efficiency reached boiling point from 6 – 16 minutes, giving an average time of 9.75 minutes for water boiling compared to the 19.5 minutes on the three stone open fires (Table 6.2) shows that the improved stoves were on average, 59 percent faster in cooking and their use would enable the households save an average 59 percent of the normal cooking time taken on the three stone open fires. This agrees with the findings in

Uganda (GTZ undated) where each household saved almost one hour per day in cooking time and collecting firewood on average

Table 6.2 Comparative cooking time saved by improved wood stoves and the three stone open fire

Stove	Time (Minutes) taken to reach boiling point	Percentage of time saved
Three stone open fire	19.5	Control
Yamampera	14.6	25.1
Simunye	17.8	8.7
Vesto	6.0	69.2
Household Rocket	6.0	69.2

The strong dependence on wood for main domestic applications such as cooking and space heating on the three stone open fire in the study area suggests that households spend even longer time collecting fuel-wood and preparing the meal with constant attention to fire to keep it burning properly (Table 6.1). This makes cooking drudgery, time consuming and limiting for other social functions and productive activities such as gardening and small skills jobs that would earn them some income as observed in the literature review (chapter 2).

The reduction in cooking time when using improved stoves as observed in this study means that women could have freed time to do other productive things such as attending social functions and government free trainings on empowerment and poverty reduction where they could identify income generating opportunities existing in their areas. Women could spend more time doing urban agriculture (growing vegetables using the ashes from the stoves as fertiliser), mat weaving, hair plaiting, beading which are potential non energy income generating activities for the area. Children especially girls, who are forced to accompany their parents to fuel collection/ purchase points and absented from school, could spend more time learning.

The speed of cooking and reduction in cooking time on these improved stoves would as well limit the morning rush to prepare breakfast and boil bathing water as householders prepare for work and school.

The agreement of the findings in this study with those of Barnes (1993) in Niamey and Niger, where the use of improved wood stoves realised 42.8 percent wood savings over the traditional stove and offered a total family savings of 335 kilograms of wood valued at just over $15 per a year, strengthens the argument about the efficacy of using household improved wood stoves. Also in agreement with the results of this study are those of the Rwanda study by GTZ (undated) where households that adopted improved charcoal stoves saved about 394 kilograms of charcoal worth $84. It equally follows that if families adopted and began using the improved wood stoves in the two study areas where average energy expenditure per household are as high as 29.5 percent for the employed and 23.6 percent for the unemployed (chapter 5.3), the dissemination of these improved wood stoves would save these peri-urban poor households higher percentages of income currently spent on energy and hundreds of tonnes of wood per year.

6.4 Economic quantification of the fuel-wood saving benefits of the improved wood Stoves and the three stone open fire used in the study.

Economic and financial contributions of improved wood stoves to the household go beyond just comparing the costs and benefits. As it has been observed in the baseline study and stoves placement in homes that fuel-wood is both bought and collected in both urban areas under this study (5.5.7; 5.3.10), fuel-wood and time savings are thus the main economic benefits for households using the improved stoves. Where fuel-wood has to be purchased, the savings in fuel-wood results in lower fuel-wood expenses, and where it is collected, the savings mean shorter collection times.

However, fuel and time savings alone cannot convey how relevant these benefits are for the household nor whether the use of improved wood stoves is indeed economic. For example, if the savings in the fuel-wood expenditure during the whole period of stove utilisation did not add up to the amount of money invested in the stove, it would not be economically sensible for the household to purchase the improved stove but to continue cooking with the traditional open fire.

However, the economic benefit varies from one household or place to another. For example, the amount of fuel-wood saved and the savings in fuel-wood expenditure or in time it took for the people in Isnathing and Umsilinga to gather/buy wood and cook the meal (chapter 5.4), not only depended on the technical performance of the improved stove but also on a number of other factors as well. In households with twelve people in both Umsilinga and Isnathing, for example, fuel-wood savings of 30 percent represented a larger quantity of fuel-wood saved than in a small household with four people because larger households consumed more fuel-wood in absolute terms. Thus the monetary savings in absolute terms in small households at the existing price of R20 per bundle of 20kg for example, was only half as high as if fuel-wood cost was R40 per bundle of 20kgs. For this reason, it is important to bear in mind that the economic efficiency of the improved wood stove can only be determined if the benefits derived from its utilisation are compared with other economic variables in the household budget and the expenditures that are required for the stove. Four key variables in this respect that determine the economic efficiency of fuel-wood saving stoves are:

- A household's absolute fuel-wood consumption,
- The fuel-wood savings achieved through use of the improved stove,
- The fuel-wood price or the amount of time spent on collecting fuel-wood and preparing the meal,
- The price of improved stove.

While the above variables clearly determine the economic profitability of using improved stoves for the household, the quantification of economic profitability is done using specific economic ratios. In this study, the quantification of economic benefits has specifically been calculated using the following economic ratios;

- Payback period,
- Net benefit,
- Rate of return,
- The net benefit as a share of the various items in the household budget (income of the household, minimum wage, household's daily expenditure for food and fuel-wood or alternative fuel),
- Total annual costs of cooking with alternative energy sources.

Each of the calculated economic ratios describes a different set of economic factor and is of course highly relevant as an indicator on its own of the net benefit derived by users of improved wood stoves in the study. See Annexure III.

6.4.1 The payback period

The pay back period of the improved wood stove in this respect is the length of time in days, months or years that would take the household to recover the initial investment costs on the stove through savings in fuel-wood expenditure achieved through the use of the stove. The length of the payback period is determined by the following three parameters:

- the price of the stove,
- the fuel-wood savings (as a percentage) through the use of improved wood stove and
- the price of fuel-wood or the length of collection time.

The amount of money the household spends on purchasing the stove is regarded as an investment by the household and the savings in fuel expenses are household earnings generated by this investment. As such, the shorter the payback period, the higher the profitability will be. In addition, if the improved wood stove does not pay for itself within this period of utilisation, the fuel-wood savings do not represent an economic benefit for the household.

However, as the pay back period of each improved wood stove declines, the risk associated with the monetary expenditure for the stove declines as well. In this case, there is less probability that the stove will not function properly before it is paid off or that it will stop being used because of lack of acceptance. This further makes it easier for the woman or her husband to decide to purchase the improved stove.

The payback period is used to;

- estimate the risk related to the amount of money spent to purchase the improved wood stove,
- assess the length of time during which an investment must be made in the stove before the costs are offset by savings or benefits.

In Table 6.1, the payback period for using the four improved wood stoves used in the study ranges from 14.7 days for Yamampera to 28.3 days for Simunye, 38.9 days for the household rocket and 48.6 days for the Vesto. The calculations in the table are according to the following formula;

$PpN = c/St$

Where PpN: Payback period for a new investment

c: Purchase cost of the improved woodstove

St: Savings in expenditure for fuel-wood during period t

Table 6.3 Payback period of the improved wood stoves

Stove	Purchase Price	Savings in expenditure for Fuel-wood (Monthly)	Savings in expenditure for Fuel-wood (Daily)	Payback Period
Yamampera	R60.00	R122.64	R4.09	14.7 days
Simunye	R110.00	R116.64	R3.89	28.3 days
Vesto	R250.00	R154.32	R5.14	48.6 days
Household Rocket	R200.00	R154.32	R5.14	38.9 days

Although all of the four improved wood stoves are likely to pay for themselves within their lifespan (i.e. generate benefits that are equal to or surpassing the required investment), households are likely to benefit more from the use of Yamampera because of the meaningful benefits that could be realized sooner rather than later. Improved wood stove users would be attracted by the shorter payback periods because of fewer risks of problems that might prevent the recovery of investment costs like in electricity, LPG and farming where benefits only come several months after the initial investment.

6.4.2 Net benefit

The net benefit during the life of the improved stove is the sum of household savings in fuel-wood expenditure during the lifespan of the stove less the costs incurred for the stove during the same period of time. Although net benefits of improved stoves come soon after the investment, these benefits need to be compared with the related costs if one is to tell whether the household is better off with the new investment or not. Net benefit indicates net savings after taking into account the costs of the purchasing and using the stove.

In Table 6.2, the possible calculated total net benefit of using the improved wood stoves during their respective life span ranges from R2689.36 for Simunye to R2883.36 for Yamampera, R3503.68 for the household Rocket and R5305.52 for the Vesto. This is calculated according to the following formula;

$Nt = St – Ct$

Where t: Life span of the stove

Nt: Net benefit for time period t

St: Savings in expenditure for fuel-wood during life span of the stove

Ct: Cost of Stove

Table 6.4 Net benefit of the improved wood stoves

Stove	Purchase Price	Lifespan	Stove's savings in expenditure for fuel-wood during its life span	Net benefit for the life span of the stove
Yamampera	R60.00	2 years	R2943.36	R2883.36
Simunye	R110.00	2 Years	R2799.46	R2689.36
Vesto	R250.00	3 Years	R5555.52	R5305.52
Household Rocket	R200.00	2 Years	R3703.68	R3503.68

Although little can be said about net benefit in isolation, it is clear that the use of Vesto, Household Rocket, Yamampera and Simunye would have a high and positive net benefit, like in a study cited by Clancy (2004) where urban households using improved fuel-wood stoves in Pakistan realised savings of up to 38 percent of fuel bills and those in the urban areas of Madagascar, an annual household fuel saving equivalent to the minimum monthly salary of approximately US$ 24. This means that poor peri-urban households in the study area and many other peri-urban areas in South Africa currently relying on fuel-wood and using the three stone open fire for cooking and other household chores would greatly increase their household's meagre disposable income. This would be so because the net benefits of using these improved wood stoves exceed the costs associated with their purchase and use.

In addition, the determination by 71 percent of both women and men who had stoves placed in their homes (chapter 5.4.1) to participate in the production, sale and use of improved stoves, means that there would be a high possibility of jobs and small businesses generation including informal food vending which would also increase households disposable income. Household members would thus begin to accumulate assets that would reduce poverty, hunger and environmental degradation. In addition, the saved income could be used to finance informal micro-enterprises as suggested by focus groups participants in the study. To those who are unemployed, the saved time could be used for seeking work, or doing other productive work like gardening and poultry keeping earning them some income as enterprises.

6.4.3 Rate of return

The rate of return expressed as a percentage, is a description of the economic efficiency of the improved stove during its life span. It is the accumulated net benefit as a percentage of the purchase costs throughout the utilisation life of the stove and of all relevant stove costs incurred during this period. It indicates by what factor the net benefit exceeds the expenses for the stoves.

In Table 6.3 for example, the calculated rate of return of all four improved wood stoves during their respective life span ranges from 1751.84 percent for Household Rocket to 2122.21 percent for the Vesto, 2444.87 percent for Simunye and 4805.6 percent for Yamampera according to the following formula;

R = Nt/Ct × 100

Where R: Rate of Return

Nt: Net benefit of improved stove during its lifespan

Ct: Cost of stove during its life span

Table 6.5 Rate of return of the improved wood stoves

Stove	Cost of Stove	Stove's net benefit for its life span	Rate of Return
Yamampera	R60.00	R2883.36	4805.60 %
Simunye	R110.00	R2689.36	2444.87 %
Vesto	R250.00	R5305.52	2122.21 %
Household Rocket	R200.00	R3503.68	1751.84 %

This means that the net benefit from using these stoves in their lifespan is expected to range between 8 and 80 times the total costs of purchasing and using the stoves. This implies that by using these improved stoves, a household would sustainably make much good use of available energy resources when the resources they utilize are considered.

However, the rate of return does not present any indication of the relative value of the net benefit for the household. If the stove price is low, for instance, and the net benefit only represents an amount which is negligible for the stove using household, a high rate of return on the stove would essentially be irrelevant for the household.

6.4.4 Ratio of net benefit to other household budget items

The economic value of the net benefit for the household is determined when the net benefit is compared with various items in the household budget. The level to which the use of fuel-wood saving stoves improves the living conditions of the households is assessed in terms of:

1. the Income side;

- The average income of the household in the income brackets to which the household using the improved stoves belong
- The legal minimum wage

2. the Expenditure side:

- The expenditure on food bought every day or every week (with or without fuel-wood expenditures)
- Miscellaneous expenditures in an average household.

When analysed within the context of the household economy, net benefit ratio provides additional information. As portrayed earlier in this chapter, the economic value of the each of the four improved wood stoves used in the study to the household wellbeing would be determined when the net benefit is compared with other items on which the household spends its income. Purchase of food items together with other groceries usually takes up a sizeable proportion of cash resources for most urban households as observed in chapter 5.3.

However, comparing the expenditures of the current energy and technologies such as paraffin and LPG used in the study area with other budget items, households gain only small proportion of net benefit from them because of the expenditure on them which is much higher than other budget items (chapter 5.3). These energy and technologies are therefore unlikely to make any meaningful contribution to household wellbeing. This is unlike the improved stoves used in the study which have high net benefit as a percentage of related budget items as shown in table 6.4 below.

Table 6.6 The ratio of net benefit from the improved wood stoves to other household budget items.

Stove	Stove's net benefit for one year	Household average income in one year	Net benefit as a percentage of household budget in one year
Yamampera	R1441.68	R16356.00	8.8 %
Simunye	R1344.68	R16356.00	8.2 %
Vesto	R1768.51	R16356.00	10.8 %
Household Rocket	R1751.84	R16356.00	10.7 %

In Table 6.4, the ratio of net benefit of the four improved wood stoves to the expenditure on food and groceries ranges from 8.2 percent as lowest for Simunye to 8.8 percent for Yamampera, 10.7 percent for the household rocket and 10.8 percent as highest for the Vesto. This is calculated according to the following formula;

$Hrt = Nt/Czt \times 100$

Where Nt: Net benefit within period t

Hrt: Net benefit as a percentage of household budget related to period t

Czt: Household average income in period t

As such, net savings that would be realised from the use of these improved wood stoves would be quite significant compared to household expenditure on food and other groceries. Because of this, gains from the use of these improved stoves would be quite substantial in the household's livelihood portfolio. Households would therefore likely to perceive these benefits as important to household welfare.

6.4.5 Total annual costs of alternative fuel for cooking

The total annual costs of cooking with alternative fuels indicate whether there is a cheaper alternative for households than cooking with improved wood stoves. They also show the cost intervals between cooking with alternative fuels such as paraffin, LPG and even solar where possible and cooking with improved wood stove.

While the use of paraffin would produce even faster cooking, the fuel has become unaffordable to the majority of poor households needing energy mainly to cook their energy intensive foods. As observed in the results, most of the households with larger household sizes are mainly headed by children, the use of paraffin would thus make these households unable to cook enough meals due to lack of enough money for food and also to buy paraffin. This suggests a situation where these households would sleep on an empty stomach while the food is there due to lack of fuel. In addition, as most houses in the area are single roomed and made of temporary materials such as wood and to some extent plastics, all activities including cooking (in case of paraffin) are done indoor. However, with the volatile nature of paraffin when lighting and turning off the stoves, this exposes more households to incidents of houses burnt down causing loss of property in most peri-urban areas. This on its own is an unaffordable cost as in most cases it is associated with loss of life.

The unaffordability of fuels that are used for cooking as alternative to fuel-wood in the study areas, quantification of cost of using these alternatives and possibility of their use is important in order to determine the annual cost of alternative fuel required and the amount of annual depreciation of the stove as well as other utensils used with the alternative fuel. In this analysis the cost of using paraffin and liquid petroleum gas (LPG) for cooking is quantified because some households in the study area use these fuels. This would help households determine whether paraffin and LPG could provide a viable alternative to fuel-wood for their cooking purposes.

While the annual cost of cooking with paraffin and LPG is assumed to consume about 9 percent of the monthly income (Table 5.8), this cost as said earlier in this chapter is quite high compared to other household budget items and is likely to be beyond the reach of most peri-urban poor households. The costs of buying the paraffin and LPG stoves, buying the required fuel and repairing the damages caused by fires from these fuels represent substantial expenditure costs that could be prohibitive for most urban poor households. It is therefore unlikely that Paraffin and LPG would be viable alternatives to fuel-wood as cooking energy in the peri-urban poor households in the near future.

6.4.6 Net present value

The economic ratios calculated above mainly assume that the value households get from using improved wood stoves does not depend on when these benefits accrue. This is because they assume that the utility value of a given amount of money today is the same as the utility value of that amount even if received after three years. This is in contrast to the utility value of a given sum of money which is lower in the future than it is at the present time. As such, households intending to invest in these improved wood stoves would prefer to do so in types of stoves that will let them have money sooner rather than later. Stove investments that will only yield most of its benefits much later into its lifespan would thus not be attractive enough to the household. However, for households to get the value of future benefits sooner, the benefits have to be discounted using a discount rate, which usually is the prevailing rate of interest. Net present value of using the improved wood stoves would thus compare the discounted costs and benefits.

Based on the above economic ratios, the net present value of using the improved wood stoves is higher than the paraffin stove and LPG burner and positively compares to the use of paraffin stove and gas burner. However, the net present values of each of the stoves are much lower than the undiscounted ratios (the net benefit ratio). Net present value better estimates net benefit or incentive to the household as it considers when the costs and benefits of an investment accrue.

6.4.7 Summary of economic benefits

It has been known and will continue to be implicitly believed that the use of improved stoves has economic benefits for households and women and that family members are directly affected by them. However, this will not always be the case if especially the woman's husband for example, budgets the money which is saved from lower fuel-wood expenses and does not spend it for the family's benefit or if the woman spends the money on herself.

6.5 Social Benefits

6.5.1 Health benefits

In the efficiency performance discussion above, it has been observed that the three stone open fire functioned poorly in both combustion and heat transfer which resulted into excess smoke escaping as unburnt energy. Soot produced when cooking with traditional three stone fires and paraffin creates unhealthy amounts of indoor air particulates that result in respiratory and breathing problems which are common among HIV/AIDS patients. In addition, when using the improved wood stoves, there are substantially reduced levels of burns caused by sparks from open fire and naked flames because of the enclosure of the fire in the combustion chamber.

It is the efficient fuel combustion and heat transfer capabilities of improved stoves as seen in efficiency analysis above that enables less unburnt energy in the form of smoke and less emission of particulate matter (PM) in the form of carbon monoxide to be released from the fire. The fuel combustion efficiency improve the indoor air quality which has social and health benefits for those using the stoves especially women and children.

In a study done in Kenya, households that were using the improved wood stove had the following reduction in the incidence of ARI and conjunctivitis (GTZ, undated):

ARI in children under age 5: 36 %
Conjunctivitis in children under age 5: 29 %
ARI in mothers: 25 %
Conjunctivitis in mothers: 8 %

The above findings agree with the Global Environmental Facility (2000) findings referred to in chapter 2, where improved wood stoves reduced carbon dioxide pollution by 42 - 54 percent. McCracken and Smith (1998) also observed that the use of improved wood stoves in Guatemala in 1990 reduced emissions by 87 percent which significantly reduced the acute respiratory infections (ARI) by 35 percent of general mortality and infant morbidity by 48.1 percent.

Less frequent attention to the fire when cooking on the improved wood stoves reduces exposure by the users to even fewer emissions from the improved wood stove. This further reduces the risks of indoor pollution, the risk of contracting acute respiratory diseases and eye infections resulting from indoor pollution significantly.

A reduction in respiratory and eye infections means fewer expenses for the household on medication and doctors visits. In addition, absences from work due to illnesses or poor health among economically active household members could be reduced, thereby contributing to higher income for the affected households. Moreover, a generally better state of health among household members due to avoidance of chronic respiratory and eyes or the gastro-intestinal diseases is in itself a benefit which could have a monetary value.

6.5.2 Role of Women

Even though the majority of respondents in the baseline survey were employed (46 %) and were currently using a mix of paraffin and wood (50 %) and mixed fuels of paraffin and gas (8 %), their preference to buy and use the improved wood stoves for their personal cooking of household meals was contrary to what has been written on this subject. However this shows that in spite of modernisation, people will always choose the type of fuel and technology to use depending on the cost and users' income.

Since a large portion of the respondents' salary (between 9 and 30.9 percent) the majority of who were female (81 percent) was spent on fuel purchases (Table 5.1), users were therefore prepared to opt for a cheaper fuel that would do the same job effectively but save them money. This principle is relevant to the current situation in South Africa where people mainly the low income earners buy goods such as shoes, clothes and even food based on the affordability to pay though such goods may not be of high quality

The introduction of improved wood stoves would also have an added advantage creating possible employment for housewives in the area. 42 percent of the respondents (all women) felt that they would participate in the improved wood stoves as a business for street food processing and vending thereby creating informal jobs for women and addressing the 31 percent unemployment rate. However, working capital has in most cases been the limiting factor for such micro enterprises. Access to loans from commercial banks by the peri-urban poor has been one of the major limiting factors for business start ups due lack of collateral and registered physical address. However, the choice by 42 percent of women to bank their money saved from fuel purchases and later to invest it in the stove business means the stoves would help reduce the burden of lack of capital since women would get credit based on their savings with such commercial banks. The savings could later be used as surety to the banks for loans to start up and grow their small businesses. This would help involved women gain financial freedom, self-confidence and improve their status in the community.

In addition, the choice by 33 percent of the participants to use the saved money from fuel purchases on food for the household and by 8 percent to use it on household purposes such as transport to work means a possibility of some economic freedom and upliftment. This is very consistent with the DFID (2000) findings from stove entrepreneurs in Uganda, Kenya and Ethiopia referred to in chapter two where after taking up their stove business, food situations (food intake and ability to afford better nutrition) improved as follows; Uganda 65 percent, Kenya 76 percent and Ethiopia 52 percent. 45.8 percent of the stove entrepreneurs in Kenya and 52 percent in Ethiopia were able to gain financial security and independence.

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The willingness by women during focus group discussions to actively participate in the energy technology as entrepreneurs (stove manufacturers and retailers) showed that they were willing to be active stakeholders in energy delivery that is key to development. This meant that the issue of stove promotion would be the issue of everybody willingly as opposed to what is currently happening where this is looked at as the government role only.

The preferences of the aesthetic appeal, fuel saving, speed of cooking and small size which were the characteristics of all the four stoves by users who had stoves placed in their homes agree with the assumption of this study that irrespective of being poor, poor people need good looking things which would improve their status if they own them. In addition, this shows that poor people would always want energy technologies that would meet the complementaries and trade-offs shown in the theoretical framework in chapter 1, because these would help them easily achieve the social, economic and environmental benefits.

As it has been observed in the baseline study, the majority of the people in the two lowest income segments were women, agreeing with literature that in poor communities, women are the most disempowered through lack of productive assets and resources. In fact they are over represented among those living in poverty for a considerable period of time (the chronically poor) that need to be halved by the year 2015 according to the Millennium Development Goals (MDGs) projections. By being involved in producing and selling of improved stoves, the disempowered South African peri-urban poor women would attain financial freedom like their Kenyan and Ethiopian counterparts who through stove entrepreneurship would earn 2-3 times better earnings compared to an average employee in the unskilled and semi-skilled factory jobs today.

6.6 Environmental benefits

The use of improved wood stoves in the peri-urban areas as seen from preceding sections of this chapter would contribute significantly to the reduction of quantities of fuel-wood used which would lead to environmental rehabilitation in terms of tree regeneration and soil fertility.

In table 6.7 below, the use of each of the four improved wood stoves tested in the study would have annual savings of fuel-wood as follows based on the following formula;

Yearly savings
Wood weight / m^3 × Annual increment

- One Yamampera stove, 1417.68 kilograms which is equivalent to 1.89 hectares of local woodlands
- One Simunye stove, 1399.68 kilograms which is equivalent to 1.87 hectares of local woodlands

- One Vesto stove and Household Rocket, 1851.84 each which is equivalent to 2.47 hectares of local woodlands
- One Household Rocket stove, 1851.84 each which is equivalent to 2.47 hectares of local woodlands.

Table 6.7 The Forest area equivalent to the fuel-wood saved in a year through the use of improved wood stoves.

Stove	Percentage savings of each stove	Yearly amount of Fuel-wood saved by each type of stove	Number of hectares saved by each stove in a year
Yamampera	51.1	1417.68 kg	1.89
Simunye	48.6	1399.68 kg	1.87
Vesto	64.3	1851.84 kg	2.47
Household Rocket	64.3	1851.84 kg	2.47

NB: Average yearly household firewood use is 2880 kg without improved stove
Average annual increment of a natural forest: $1m^3/ha$ (GTZ, undated)
Average wood weight of a solid cubic metre: $750kg/m^3$ (GTZ, undated).

With 80 percent of people using fuel-wood in the study area, there would be an overall annual saving of about 150,000 hectares at an average of two hectares per stove per year. However, since the use of improved stoves is a new cooking concept, the savings would be somehow less in the early days though significant enough based on the diffusion rate of the stoves but annual savings in wood used would greatly increase with people's awareness of good fire management and using a lid when cooking.

Although it is true that when household income increases beyond a certain level, fuel-wood consumption generally declines since clean and modern fuels such as paraffin and LPG are considered as symbols of high status and are therefore preferred to be used for cooking instead of wood, as seen in the study where 8 percent of the employed household used a mix of paraffin and LPG compared to only 4 percent of unemployed households, average per capita fuel-wood consumption often varied from one household and part of town to another. For example, in Umsilinga, fuel-wood consumption increased irrespective of income increases because of a limitation of alternative fuels. This is in agreement with the study conducted in Niamey in 1987 (Dechambre,1988) where the daily per capita fuel-wood consumption figures for various parts of town increased between 492 and 687 grammes irrespective of income increases.

Likewise, although fuel-wood consumption tests to date have taken a general assumption that the composition of a household has an influence on a household's level of fuel-wood consumption i.e. households with large number of women and children use less fuel-wood compared to households with large numbers of men. This is based on the supposition that the lower calorific intake by women and children which means a lower consumption of fuel-wood, is not supported by results in this study. Contrary, it was households with large number of children that had higher percentage of per capita consumption of fuel-wood (78.9) compared to 46 percent for households with large number of men (chapter 5.3.12). This is possibly due to the fact that the youth are more able to collect fuel-wood as they have few serious engagements.

6.7 Conclusion

Traditional biomass (fuel-wood) constitutes major sources of fuel for household cooking in both samples in the study area, while paraffin and LPG are mainly used for light meals and water heating. However, household cooking on the inefficient appliances is one of the menial and time consuming household task that needs to be addressed. The clean burning of improved wood stoves would drive energy transition that is rooted in the desire to reduce over expenditure on energy and free time for tasks other than gathering fuel, tending fires and facing the adverse health effects of traditional three stone open fires by the poor peri-urban households.

Although results of this study show that LPG and paraffin are substitutes (interchangeable) and wood and paraffin are also interchangeable, price elasticities and demands for these fuels were found to be relatively price inelastic. The cross-price elasticities related to firewood, paraffin, and LPG were also important in terms of explaining the quantity demanded of the respective fuel goods. Income elasticities for all the fuel goods were found to be positive, suggesting that none of the fuels considered are inferior goods. Moreover, household income or expenditure and other household characteristics such as family size, age and education level of head of the family significantly affected the probability of the household adopting the stoves used in the study.

Even though Arnold *et al*. (2006) concluded that fuel-wood remains the main source of domestic energy for the rural poor whereas charcoal remains a major source for the urban poor, evidence in this thesis reveal that even the urban poor greatly rely on fuel-wood particularly because of unaffordability of available modern fuels (Chapter 5). In fact, relative prices, income and local conditions are the important factors that determine the type of fuel (energy source) the urban poor mainly rely on. The conclusion that charcoal remains a major source for the urban poor also presupposes that charcoal and fuel-wood are always available simultaneously and are substitutes that are perfectly interchangeable.

Such generalization based on aggregate data fails to recognize the diversity of lifestyles and end-uses (purposes) for which these fuels are used in different local circumstances. For example, in countries like South Africa where *uJeqe* baking, uPhuthu and beans cooking are the main typical end uses as far as urban poor cooking energy consumption is concerned (Chapter 5), no charcoal is used for cooking, and the generalisation does not apply. In addition, the cooking appliances or stove technologies used are also quite different and can inhibit the ease of substitution. Evidence in this thesis also suggests a growing need for improved wood stoves particularly in the study areas. This does not completely support the *energy ladder* hypothesis (Figure 2.2) which always assumes people will always go for paraffin, LPG and electricity and never go back to using fuel-wood. The above strange situation could be because South Africa has high percentage of wealth owned by few, leaving the poor majority at the bottom of the energy ladder who would be happy with a fuel efficient wood burning stove. On the other hand, the great desirability of electric stoves in Figure 5.8 does support the energy ladder theory.

By looking at unemployment figures in these areas, stove interventions would on the one hand generate employment through manufacture, sales and street food sales. In addition households would acquire more assets that they wished to have, thereby improving the sustainability of their livelihoods. As women would be the majority of the stove initiators, this means that many barriers they face such as abuse by their marriage partners because their total dependence on their income would be reduced.

In conclusion, results in this thesis (chapter 5) show that addressing the urban fuel problem cannot be seen in isolation from broader energy development policies aiming at raising the levels of income, protecting the environment and reduction of poverty at household level. In addition to prices of related goods, household income or expenditure and other household characteristics such as family size, age and education level of the head of the family were significant factors explaining a household's decision to consume a particular fuel.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATIONS

7.1 Introduction

The study has shown that the use of the four improved wood stoves used in the study would help in meeting the suppressed energy demand in peri-urban and urban informal areas. These stoves would bring substantial benefits in the form of savings in fuel, income and time for peri-urban households. This would also help in the energy security by boosting local resource availability and diversifying energy portfolios and suppliers.

7.2 Conclusions of the study

The advantages of using the four improved wood stoves according to the study results when compared to the use of alternatives (paraffin stoves, LPG burners and the three stone open fire) are as follows;

- The technological performance of these stoves (Chapter 5, sections 5.1 & 5.2) is reasonably satisfactory and appropriate in terms of efficiency and acceptability among the sample consumers in the two study areas (Chapter 5, sections 5.14 – 6.1). Women in all the focus groups and during demonstration were more impressed with the fuel saving followed by speed of cooking, safety and clean burning.
- The technology is very effective in fuel saving, reasonably affordable to the majority of users in the lower income category and could be a good replacement of paraffin stoves and LPG burners (Chapter 5, section 5.14). This is because the construction materials for these stoves are easily available at low or no cost. Some of these improved wood stoves can be produced cheaply and locally from scrap metal. Due to the affordability of raw materials i.e. sheet metal which can easily be salvaged from demolished urban houses and scrapyards, the possibility of making different sizes of stoves to accommodate different pot sizes, if tailor-made stoves are impractical, would be much higher.
- The stoves are safe, simple and easy both to replicate and to be used even by women and children who are in most cases the main sufferers of energy poverty.
- As they are small, portable and do not emit more smoke, these stoves can be used indoors as well as outdoors depending on the user's choice.

- These stoves are economically beneficial to users through savings in fuel costs, cooking speed and through possibility of manufacturing, retailing and use in street food vending.

As such, it is concluded that the use of the four stoves used in this study would have profound socio-economic and environmental benefits to the peri-urban poor. They would feasibly address energy related challenges of affordability, accessibility, efficiency and environmental degradation due to deforestation which are often faced by many peri-urban and urban poor in the unelectrified areas of South Africa. This calls for the new approach where improved stove technologies are introduced as a new step in the energy ladder between traditional biomass stoves and the modern fuels and appliances. This approach would be appropriate in the many parts of the peri-urban poor areas where modern fuels like electricity are not available or will not be affordable in the near future so that peri-urban poor households continue to rely on traditional fuels. This would reduce pressure on biomass resources if improved wood stoves were adopted and used on a large enough scale in such settings. Although this would deliberately slow down transition to modern fuels like electricity, it might sometimes be warranted like in China, where many rural households moved up the energy ladder to coal because it was widely available in many areas that did not have official supplies modern energy (ESMAP, 2003).

The effective mass dissemination of the stoves would carry significant importance for protecting the overstressed biomass resources in the study area and bring sustainability in the energy supply among the peri-urban poor. In this respect, the introduction of fuel efficient cook stoves to influence switching from traditional three stone open fire, paraffin and LPG to these new and efficient wood stoves is an urgent need of national importance to the country. However, further penetration of these stoves would require a strong framework and clear guidance in addition to proper organizational mechanism and adequate networks for field level dissemination and marketing. In this regard, the extension of these improved stoves would be more effectively done if not left to public agencies only because public agencies have proved not to be effective mechanisms for mass scale dissemination or marketing of such technologies (chapter 2). Public agencies lack organizational mechanisms which results in poor coordination between district level supervisors, field workers, prospective technology users, especially poor households and other social organisations.

A reliable and effective network of these improved wood stoves needs to be developed preferably in the private sector to provide information and technical services as well as supplies of required materials needed for acquiring the technology. Appropriate mechanisms for dissemination and or marketing the wood stoves to the consumers in peri-urban households and small scale businesses need to be developed and encouraged. Organised follow-up research and continued research and development on the development of wood stoves with higher efficiency can further strengthen and encourage the adaptation of the technology by the peri-urban users.

The paradigm for the tested household wood stoves would call for a focus on poverty and livelihood issues, including income-generating use of energy activities with adequate access to financing. This is because an important factor associated with the continued inefficient use of non-electric fuels is unemployment and poverty. In addition, most household energy users who are women have gendered division of labour which traditionally means that they are a disempowered class responsible for managing household resources (i.e. fuel-wood collection) and cooking in the home using inefficient appliances in most cases. Unless they are breadwinners and command power in the household by virtue of holding an income earning position, they will remain poor and disempowered.

Small expenditure savings from households' use of these wood stoves can thus be used to finance the development of commercial activities in these underdeveloped areas, usually beginning with small businesses and micro-enterprises, such as production and sale of wood stoves, energy and related products, shops, street food vending and agro-industrial activity. As seen earlier (chapter 2), these micro-enterprises are a crucial factor in the economic empowerment of the urban poor. This is so because the development of commercial activities provides efficient but affordable services and employment for people living in such underdeveloped areas with underemployment.

In general, household cooking energy should not just be about electricity because electricity is not always the most appropriate cost effective energy source for all needs. Biomass, kerosene and other sources can play a role too. Moreover, demand for energy is a derived demand and people do not want energy in itself but the energy service it provides such as cooking, lighting, heating, water pumping, transport, etc (United Nations, 2005). As such, household domestic energy needs should be considered within the overall context of community life, and energy policies and projects integrated in a holistic way with other improvement efforts relating to health, education, agriculture and job creation as portrayed earlier in the theoretical framework.

Improved wood stove projects should start from an assessment of people's needs rather than a plan to promote a particular technology. Thus a full menu of options should be considered for providing improved energy services to the poor. The focus should be on the perspective of socio-economic upliftment of the user which could greatly contribute to the reduction of severe constraints on energy transition to cleaner fuels, sustainable economic, social and human development in these poor areas.

Meeting the needs of the poor for sustainable household cooking energy should thus mean finding affordable technological and institutional innovations that lower the costs of obtaining and using energy services, and tailoring these services to the requirements of low-income households and communities. The benefits of improved wood stoves need to be balanced against the benefits that other technologies can provide. However, this is the importance of the results in this study which provide some knowledge of how people currently obtain services and the nature of their demand for improved services to reduce substantial barriers that would prevent them from gaining access to modern energy services. This is important because it eases the effects of moving from traditional to improved, efficient and affordable energy technologies that would otherwise be very difficult.

As such, energy policymakers should establish an environment which has strong incentives for innovation in delivering energy services that meet the demands of poor users. Energy services for poverty reduction should be less about technology and more about understanding the role that energy plays in people's lives and responding to the constraints in improving livelihoods. New generation and distribution of technologies should have easily replicable models for community demonstration, incentives essential to improving services for the poor, and should be developed in a friendly institutional environment.

Knowledge of which fuels a household could potentially use as well as which fuels the household actually chooses to use revealed in this study is very relevant from a policy point of view, because this helps to understand to what extent observed patterns of energy usage reflect demand decisions or supply constraints. This would provide the energy policymakers and those who advise them with reliable and more consistent data on the poor's current energy consumption, demand for improved energy services and the markets in which people actually access and use energy services to avoid distortion of incentives.

Finally, as governments try to open opportunities for pro-poor energy innovations such as improved wood stoves, they should include choices about market structure and ownership (where and how competition and entry will be allowed and supported), regulation (what the prerequisites for, and mode of, regulatory intervention will be), and pricing (interventions in tax structures, and fuel taxation).

7.3 Contribution of the study

This study contributes to the existing literature in the following four important respects;

- it provides comparative insight into the possible range of efficiency performance of the four different types of improved wood stoves used in the study with the traditional open fire commonly used in the peri-urban poor areas,
- it describes the relevance of the efficiency of each of the stoves in reducing poverty, unemployment, hunger, indoor pollution, deforestation etc. affecting the sustainable livelihood of the peri-urban poor which is scanty in literature about improved wood stoves as observed in the conclusion of chapter 2,
- it reveals the existing energy use pattern of mass rural migrants settling in peri-urban areas in South Africa and the growing challenge of supplying modern clean and affordable cooking energy to meeting the United Nations Millennium Development Goals (MDGs), and
- it highlights the important factors that influenced households in their choice of fuel and the type of wood stove which are vital when planning any energy technology dissemination aimed at serving the peri-urban poor households.

Further importance of this study is that it has shown that local production of improved wood stoves using local materials could considerably reduce the initial investment cost and enhance widespread adoption. In addition, it has also shown that standard comparisons of fuel-savings efficiency can be made across all the improved wood stoves. However, enhanced stove research and development efforts turn out to be quite essential. Four lines of stove improvement (Research and Development) efforts are strongly recommended:

- stove R&D to increase the efficiency of the improved wood stoves, for example, doubling the current level of efficiency of the four stoves used in the study;
- least cost, or less expensive, material searching for stoves like the Vesto;
- concerted R&D effort to identify and encourage the local production of improved wood stoves using local materials; and,
- continuous testing and standardization of stove technologies.

7.3.1 Distinguishing between short- and long-term options

The policy implications drawn from the analyses cannot and need not be put into action all at the same time. It appears quite important to distinguish between short and long term options. With respect to dissemination of improved wood stoves for reducing poverty, hunger, indoor pollution, deforestation, etc, two issues are apparent:

- firstly, commercially disseminating the improved wood stoves among households by local producers as an SME investment which is still viable even at the initial investment cost,
- secondly, a concerted Research and Development effort to identify and encourage local production of improved wood stoves using local materials for the widespread adoption of the innovation.

The first issue could be looked into or considered as a short-term option. Whereas in the case of the second, quite some time will be taken up searching and testing local material for the local production of improved wood stoves, and this should therefore be regarded as a long term option.

As regards addressing prevalence of poverty indoor pollution and hunger of peri-urban households, two solutions that emerged from the analysis are:

- the widespread dissemination of wood stoves such as Yamampera and Household Rocket and
- encouraging local production of all four stoves at various levels of operation to meet different user categories.

The diffusion of all the four types of wood stoves used in the study and tackling bottlenecks affecting the diffusion of these stoves could be envisaged as a short-term option. While encouraging local production of all four stoves at various levels of operation could be seen as a long-term option.

7.4 Recommendations for further research

This thesis was essentially based on micro-economic analysis of household survey data. The analysis is partial in the sense that it looked at specific effects of change in exogenous variables on the endogenous variables in question. The analyses presented in this thesis are also unchanging, with no time dimension. There are a number of questions left open which suggest the following issues for further research.

7.4.1 Dynamic analysis

The analyses presented in the foregoing chapters are apparently static, with no time dimension. Nevertheless, firstly, household characteristics such as family size and composition change over time. Likewise, households generally tend to 'smooth' their consumption patterns through borrowing and lending and through some insurance mechanisms or social networking when their income flow overtime fails to correspond with their desired consumption pattern, or when their income fluctuates due to external shocks. Moreover, current fuel and technology use decisions are influenced by the desired pattern of consumption. But, more importantly, the activities such as technological change or technology adoption, and entrepreneurship for that matter, are dynamic decision issues involving long-term investment and decision-making. All these are best suited for or analysed in an inter-temporal dynamic optimization framework.

Secondly, although such static analyses are obviously the simplest possible case to begin with, they imply a serious gap in information. For instance, in static or comparative static analysis, it is often assumed that the process of economic adjustment inevitably leads to equilibrium. However, this might not necessarily be the case. Thirdly, stove production employment opportunities might induce a shift in household fuel preferences through its effect on household time allocation, choice of activity and households assets acquired. It is not clear, however, whether such labour market integration and involvement in wood stove production and distribution work would really induce the household to differentiate into fuel buying, be it fuel-wood or more sophisticated modern fuels such as paraffin, LPG or Solar. Therefore, it is proposed that further research into the dynamics of fuel demand be conducted.

7.4.2 Optimal stove efficiency, threshold rate of spread and forest resources dynamics

The foregoing empirical chapters were concerned with specific issues and the analyses that involved investigating the effect of a single measure or intervention such as the relevance of the efficiency of the tested wood stoves in reducing fuel consumption, indoor pollution, expenditure on fuel or whether household and community use of improved wood stoves contribute to addressing the fuel problem. It did not look into the interaction of the various aspects considered such as the interaction among rate of spread of technology, fuel demand, and existing forest resource stock.

It was evident that diffusion and adoption of improved fuel-saving or fuel-efficient stoves would result in less wood being used for cooking purposes. It was also quite apparent that two things should hold for the stove technologies to have a real effect on the rehabilitation of local forest areas. Firstly, the technology must be widely used in the economy beyond minimum threshold level. Secondly, stove technologies particularly the improved wood stoves should be significant in terms of fuel saving. However, it is not clear what the minimum threshold rate of spread or diffusion should be as this might partly depend on stove efficiency and price (Rogers, 2003). In addition, it is not clear what the optimal or target level of stove efficiency should be. In fact, all these are quite important for practical and policy purposes. For example, stove efficiency improvement programs might be interested in the optimal or target level stove efficiency that need to be aspired to. Therefore, it would be more insightful to put them all into context; stove efficiency, diffusion rate, fuel demand and forest resources stock, to analyze the interaction and determine the optimal outcome for sustainability. This could be done in an optimal control theory framework.

7.4.3 Economy-wide analysis

It is obvious that the problems such as energy poverty (or fuel problem) have broader economic consequences. However, as explained earlier, the analyses presented in this thesis are partial and did not look into the wider economic implications. This thesis has also shown that the use of improved stove technology results in less wood and expenditure being used for fuel. It is not clear, however, whether this results in increased demand for fuel-wood due to gains in real income upon the use of more efficient appliances. Moreover, it did not deal with the general equilibrium feedback effects of income changes. Therefore, it is suggested that a broader economy-wide analysis of the implications and their feedback effects be carried out.

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APPENDICES:

APPENDIX I: IMPROVED WOOD STOVES AND THE THREE STONE OPEN FIRE COMPARATIVE EFFICIENCY TEST RECORD SHEET.

Time in (Minutes)	**Rocket Stove (Temperature in °C)**		**Vesto Stove (Temperature in °C)**		**Three Stone open Fire (Temperature in °C)**		**Yamampera Stove (Temperature in °C)**		**Simunye Stove (Temperature in °C)**	
	Water boiling	Water Simmering	Water boiling	Water Simmering	Water boiling	Water Simmering	Water boiling	Water Simmering	Water boiling	Water Simmering
0										
3										
6										
9										
12										
15										
18										
21										
24										
27										
30										
33										
36										
39										
42										
45										
48										
51										
54										
57										
60										
Boiling point time										
Simmering time over 80°C										

APPENDIX II: LIST AND SIGNATURES OF PARTICIPANTS FOR VOLUNTARY PARTICIPATION IN THE STUDY.

Study area:...

Facilitators: 1...
2...
3...

I the participant, acknowledge that I have been clearly informed by the Researcher that the study is purely academic and I am participating in it on voluntary basis. I am free to withdraw at anytime I feel so without any ill consequence on me.

Name and Surname of Participant	Signature	Date of Participation
1.		
2.		
3.		
4.		
5.		
6.		
7.		
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30.		

ANNEXURE A: HOUSEHOLD FUEL AND TECHNOLOGY USE QUESTIONNAIRE FOR FEASIBILITY STUDY.

1) Household social characteristics.

<table>
<tr><td colspan="4">Household Number =
Total Number of Members =</td><td colspan="2">Household Education Level by Gender</td><td colspan="2">Particulars of Interviewee</td><td colspan="7">Household Assets ownership</td></tr>
<tr><td colspan="4">Males</td><td colspan="2">Males</td><td colspan="2">Gender</td><td colspan="7">Land</td></tr>
<tr><td>Total number</td><td>Ages</td><td>No School going</td><td>No out of School</td><td>Highest level</td><td>Lowest level</td><td></td><td></td><td>Yes</td><td>No</td><td>Size</td><td colspan="4">Mode of acquisition</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>Gift</td><td colspan="3">Bought</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Price</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Cash</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td><td></td><td colspan="2">Credit</td><td></td></tr>
<tr><td colspan="4">Females</td><td colspan="2">Females</td><td colspan="2">Household position</td><td colspan="7">Household Assets</td></tr>
<tr><td>Total number</td><td>Ages</td><td>No School going</td><td>No out of School</td><td>Highest level</td><td>Lowest level</td><td colspan="2"></td><td colspan="3">Considered important to own</td><td colspan="2">Currently owned</td><td colspan="2">Affects by assets not owned</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td><td colspan="3"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2">Age</td><td colspan="3"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td><td colspan="3"></td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

2) Household Economic Analysis.

Household Spending				Household Income				
Items	Expenditure (ZAR)				Sources of Income			
	Weekly	Monthly	Yearly					
1. Food				Amount (ZAR)	Work	Small Businesses	Grants	Other Sources
2. Groceries								
3. Clothing				Monthly				
4. Housing								
5. Transport				Yearly				
6. Gas								
7. Paraffin								
8. Paraffin Stoves								
9. (a) Firewood (b) Firewood collection time				No of members involved				
10. School fees								
11. Stationery								
12. Health								
13. Furniture				Places where sourced				
14. Debt payment								
15. Cellphone								
16. (a) Water (b) Water collection time								
17. Others								
Total								

3) Fuel Use.

Type of food cooked	Frequency of cooking				Reason for the frequency	Fuel type used	Quantity of fuel used				Appliance used	If using current, reason for change
	Per day		Per week				Per day		Per week			
	Summer	Winter	Summer	Winter			Summer	Winter	Summer	Winter		
1.												
2.												
3.												
4.												
5.												
6.												
7.												
8.												
9.												
10.												
11.												
Other uses	Frequency of use				Reason for the frequency	Fuel type used	Quantity of fuel used				Appliance used	If using current, reason for change
	Per day		Per week				Per day		Per week			
	Summer	Winter	Summer	Winter			Summer	Winter	Summer	Winter		
1.												
2.												
3.												
4.												
5.												
6.												

4) Fuel acquisition, effects of use and willingness to replace current appliance.

Type of fuel used	Fuel source	Distance to fuel source	Frequency per week	Quantities bought per trip	Effects of fuel use	Willingness to replace current appliance with displayed stove		Reasons
						Yes	No	

ANNEX B. IMPROVED WOODSTOVES QUESTIONNAIRE FOR DEMONSTRATIONS AND FOCUS GROUPS DISCUSSIONS

Study area…………………………………………………………………………

Demonstration	
Focus Group discussions	
Total members present	
Males	
Females	

1. What form of energy do you use for cooking in your households?
   a) Paraffin
   b) Gas
   c) Electricity
   d) Firewood

2. If firewood,
   a) Where do you get it……………………………………………………….
   b) How far is the Source?..

3. Why did you have to choose the energy form you are currently using?
   …………………………………………………………………………………
   …………………………………………………………………………………
   …………………………………………………………………………………

4. How much does it cost to use your current form of energy;
   a) On a weekly basis?..
   b) On a monthly basis?..

5. In your opinion, is the cost of the form of energy you are currently using for cooking;
   a) Cheap?...
   b) Affordable?..
   c) Expensive?..
   d) Very expensive?..

6. Are there any problems with the form of energy you are currently using?
   a) Yes…………………………………………………………………………
   b) No…………………………………………………………………………
   c) If yes, list down the problems being encountered:
      ………………………………………………………………………………
      ………………………………………………………………………………
      ………………………………………………………………………………

7.a) Of the energy forms in question 1 above, which one is your best preference to use in your life regardless of reasons stated in question 2 above?...............................

b) What would be the advantage of using this form of energy?
… ……………………………………………………………………………
…………………………………………………………………………….....
…………………………………………………………………………….

c) Currently, what prevents you from accessing this form of energy?
…………………………………………………………………………….
…………………………………………………………………………….
…………………………………………………………………………….

8. How much income do your households get from the following sources in the specified periods below?

a) Full time work	Weekly…………….	Monthly…………
b) Part-time work	Weekly……………..	Monthly…………
c) Casual work	Weekly……………..	Monthly…………
d) Grants	Weekly……………..	Monthly………

9. a) How many Household members are ;
   i. On full time work?...
   ii. On part time work?...
   iii. On casual work?..

b) How many Household members receive grants?
……………………………………………………………………………

c) What are the types of grants received?
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………

10. Based on the stoves demonstrated today, which of the following would you prefer to use in your household?
a) Open fire…………………………………………………………
b) Vesto……………………………………………………………..
c) Simunye…………………………………………………………
d) Rocket…………………………………………………………..
e) Yamampera……………………………………………………..

11. If you preferred on of the stoves in question 10 above;
    a) What was particular in the stove of your choice? Give reasons in order of importance.
       …………………………………………………………………………………
       …………………………………………………………………………………
       …………………………………………………………………………………
    b) Would you buy it?..
    c) If yes, how much would you be prepared to pay for it?.....................................
    d) How would you pay for the stove?
       i. Cash…………………………………………………………………..
       ii. Installment……………………………………………………………
    e) Who would make the decision to buy the stove?...
    f) Why?...
       …………………………………………………………………………………
       …………………………………………………………………………………

12. Which of the following would you use the preferred stove in question 10 above?
    a) Boiling water…………………………………………………………………
    b) Cooking meals………………………………………………………………..
    c) For space heating (warmth during cold days)……………………………………..
    d) All the above………………………………………………………………....
    e) Others (Specify)…………………………………………………………......

13. Would you use the Stove you have chosen to replace your current appliance?
    a) Yes……………………………………………………………………………
    b) No…………………………………………………………………………
    c) Why?...
       ……………………………………………………………………………......
       ……………………………………………………………………………......

14. What is it that did not appeal to you in the other stoves you did not prefer? List the facts of your dislike in order of importance.
    a) Open fire…………………………………………………………………
       ……………………………………………………………………………....
    b) Vesto……………………………………………………………………………
       ……………………………………………………………………………….
    c) Rocket…………………………………………………………………………..
       ……………………………………………………………………………….
    d) Simunye…………………………………………………………………….
       ………………………………………………………………………………
    e) Yamampera………………………………………………………………….
       ………………………………………………………………………………

15. How do you rate the following stoves demonstrated today according to the following characteristics (on the scale of 1 -5, 1 for the worst and 5 for the best)?

Stove type	Characteristics					
	Appearance	Emissions	Fuel use	Time use	Affordability	Ease of operation	Stability
Open fire							
Vesto							
Rocket							
Simunye							
Yamampera							

16. If you were to use the improved stove you have preferred above and discovered that you had some savings on cooking time, fuel and money, what would you use;

a) The saved money for?...
………………………………………………………………………………......
b) The saved time for?..
………………………………………………………………………………..
c) In what other way would your households benefit from the Stoves you have chosen above?
………………………………………………………………………………
……………………………………………………………………………......

17. Which of the following would best apply to you regarding improved stoves chosen as an income generating activity in your neighbourhood?

a) As an agent: selling the Stoves for someone on commission only……………
b) As an Entrepreneur: Buying and selling the Stoves……………………………
c) As a Manufacturer: Making and selling the stoves……………………………
d) Any other (Specify)……………………………………………………………
e) Why would you want to be involved as above?...
………………………………………………………………………………

18. In your opinion, which of the following groups of people would benefit more from the improved Stoves you have just seen demonstrated to you?

a) House wives using the Stoves for domestic purposes………………………………………………………………………
b) Informal traders cooking and selling foods in the streets………………………………………………………………………
c) Street Vendors selling stoves………………………………………………………………………
d) Others (Specify)……………………………………………………………..
e) Why do you think that the chosen group would best benefit from these stoves?
………………………………………………………………………………
………………………………………………………………………………

ANNEX C: COMPARATIVE USE OF IMPROVED WOOD STOVES AND USUAL APPLIANCES DURING STOVES PLACEMENT IN HOMES.

Appliance	Quantity of fuel used per week	Cost of fuel used per week	Time taken to cook a meal	Problems encountered	Alternative appliances used	Reasons for using alternative appliances
Improved Wood stoves						
Open fire						
Paraffin Stove						
LPG						

APPENDIX III: FUELWOOD USAGE AND BENEFIT

1. Amount of fuelwood saved in a year through the use of improved wood stoves

Stove	Percentage savings of each stove	Yearly amount of Fuelwood saved by each type of stove	Number of hectares saved by each stove in a year
Yamampera	51.1	1417.68 kgs	1.89
Simunye	48.6	1399.68 kgs	1.87
Vesto	64.3	1851.84 kgs	2.47
Household Rocket	64.3	1851.84 kgs	2.47

NB: Average yearly household firewood use is 2880kgs without improved stove
Average annual increment of a natural forest: $1 m^3/ha$
Average wood weight of a solid cubic metre: $750 kg/m^3$

Yearly savings
Wood weight / m^3 × Annual increment

2. Formula for calculating Pay Back period

$PpN = c/St$
PpN: Payback period for a new investment
PpR: Purchase cost of the improved stove
St: Savings in expenditure for fuelwood during period t

Stove	Purchase Price	Savings in expenditure for Fuelwood (Monthly)	Savings in expenditure for Fuelwood (Daily)	Payback Period
Yamampera	R60.00	R122.64	R4.09	14.7 days
Simunye	R110.00	R116.64	R3.89	28.3 days
Vesto	R250.00	R154.32	R5.14	48.6 days
Household Rocket	R200.00	R154.32	R5.14	38.9 days

$PpN = c/St$
R60.00/R4.09 per day = 14.7 days
R110.00/R3.89 per day = 28.3 days
R250.00/R5.14 per day = 48.6 days
R200.00/R5.14 per day = 38.9 days

3. Formula for calculating Net Benefit

$Nt = St – Ct$
t: Life span of the stove
Nt: Net benefit for period t
St: Savings in expenditure for fuelwood during life span of the stove
Ct: Cost of Stove

Stove	**Lifespan**	**Stove’s savings in expenditure for fuelwood during its life span**	**Net benefit for the life span of the stove**
Yamampera	2 years	R2943.36	R2883.36
Simunye	2 Years	R2799.46	R2689.36
Vesto	3 Years	R5555.52	R5305.52
Household Rocket	2 Years	R3703.68	R3503.68

4. Formula for calculating Rate of Return

R = Nt/Ct × 100
R: Rate of Return
Nt: Net benefit during the lifespan of improved stove
Ct: Cost of stove during its life span

Stove	Cost of Stove	Stove’s net benefit for its life span	Rate of Return
Yamampera	R60.00	R2883.36	4805.6 %
Simunye	R110.00	R2689.36	2444.87 %
Vesto	R250.00	R5305.52	2122.21 %
Household Rocket	R200.00	R3503.68	1751.84 %

5. Formula for calculating Ratio of net benefit to the household income

Hrt = Nt/Czt × 100

Nt: Net benefit in period t
Hrt: Net benefit as a percentage of household budget related to period t
Czt: Household average income in period t

Stove	**Stove’s net benefit for 1 year**	**Average Household income in 1 year**	**Net benefit as a percentage of household budget in 1year**
Yamampera	R1441.68	R16356.00	8.8 %
Simunye	R1344.68	R16356.00	8.2 %
Vesto	R1768.51	R16356.00	10.8 %
Household Rocket	R1751.84	R16356.00	10.7 %

Hrt = Nt/Czt × 100