THE GREEN VILLAGE PROJECT

Improving socio-economic conditions of the Tsitsa river catchment and Okhombe communities through landscape greening and integrated green innovations

Volume 2: Improving socio-economic conditions of the Okhombe communities through integrated green innovations




Prepared by: Smith M.T., Everson T.M. and Zuma K.D.

WATER RESEARCH COMMISSION

TT 777/2/18

THE GREEN VILLAGE PROJECT

Improving socio-economic conditions of the Tsitsa River catchment and Okhombe communities through landscape greening and integrated green innovations

VOLUME 2:

Improving socio-economic conditions of the Okhombe communities through integrated green innovations

Report to the

WATER RESEARCH COMMISSION

Prepared by

M.T. Smith, T.M. Everson and K.D. Zuma

Project leaders: Prof. K.M. Rowntree (Rhodes University), Dr T.M. Everson (Aquamet)

WRC Repot No. TT 777/2/18

ISBN 978-0-6392-0071-2

January 2018

Obtainable from
Water Research Commission
Private Bag X03
GEZINA 0031

orders@wrc.org.za or download from www.wrc.org.za

This report forms part of a series of three volumes. The other volumes are *Improving socio-economic conditions through landscape greening, a case study from the Tsitsa River catchment, uMzimvubu basin* (**WRC Report No. TT 777/1/18)**;

Green Village Catchment Management: Guidelines and Training (in preparation).

EXECUTIVE SUMMARY

Introduction

With the increasing impacts of global climate change, depletion of natural resources and increased degradation of the world's environment there is a need for more sustainable development (Trier and Maiboroda, 2009). Sustainable development and growth can be achieved by improved management of ecosystems and a more strategic use of water, energy, land and other natural resources.

The Green Village concept, whereby people have sustainable and affordable access to quality food, water and energy within a well-managed and functioning ecosystem, poses a significant opportunity for researchers and government to investigate rural development alternatives for the provision of basic services in remote and impoverished areas of South Africa. The "green concept" is becoming even more relevant as the impacts of climate change are beginning to be felt in the entire value chain, but in particular in marginalized rural areas.

The two Green Village demonstration sites that were selected in this study were Mahlabathini and Sinxaku in the uThukela and Jo Gqabi district municipalities respectively. The research focus in Mahlabathini was specifically on green energy – piloted in a number of households in the village. In contrast, the Sinxaku research engaged with landscape rehabilitation so it was necessary to work at a broader scale. The detailed approaches and outcomes of the two projects are therefore reported in two separate volumes:

Volume 1.	Improving socio-economic conditions through landscape greening, a case study from the Tsitsa River catchment, uMzimvubu basin
Volume 2.	Improving socio-economic conditions of the Okhombe communities through integrated green innovations

The current project (Volume 2) investigated micro-scale renewable energy technologies and practical models that could be applied at a household with potential to upscale to a whole village. Potential models had to address the basic needs of marginalized communities and create opportunities to support household economies.

Renewable energy can play a fundamental role in addressing the impacts of climate change, environmental degradation and energy security (SANEDI, 2017). Policy support, funding and a regulatory framework are key factors for the growth of renewable energy use. In South Africa, the Department of Energy (DoE) is the main government department in charge of developing national energy legislation and promoting policy on the implementation of renewable energy programmes. The South Africa National Energy Development Institute (SANEDI) is the implementation agency for DoE policy and the approval agency for renewable energy projects. SANEDI promotes the optimal use of local resources that diversify energy production and create an environmentally sound energy sector. One of SANEDI's programmes is the Renewable Energy Centre of Research and Development (RECORD) which recognizes the importance of skills development in renewable energy technologies. The current project, which focused on building capacity of rural communities to use and implement renewable energy technologies, therefore falls under this programme. The project also addressed the following points in the National Department of Agriculture's discussion document on 'The policy on agriculture in sustainable development" (NDA, 2002):

- Decrease the depletion of non-renewable energy resources (i.e. oil, gas, coal) and promote methods extending their 'life' through recycling, using less or switching to renewable substitutes;
- Develop and implement programmes that would combine, more efficiently, and as appropriate, the use of traditional, renewable energy resources, and cleaner fossil fuel technologies, which could meet the growing need for energy services in the longer term to achieve sustainable development;
- Provide support for the development of safe low-cost technologies that provide or conserve fuel for cooking and water heating; and
- Intensify research and the development, diversification and conservation of energy, taking into account the need for efficient use and environmentally sound technology.

In South Africa the traditional use of energy sources in the form of fuelwood has resulted in substantial negative environmental impacts, particularly in catchment areas where the removal of indigenous biomass results in severe erosion and silting of dams. In addition, the use of fuelwood, coal and paraffin to meet people's basic needs for cooking, lighting and heating can result in significant health and safety hazards. One option to mitigate these adverse impacts is to switch to alternative sources of energy. A growing response to this challenge is the development of green energy technologies as an approach to improve livelihoods and health, generate jobs and reduce siltation of dams and risks posed by climate change. The project reported on in this document falls under the Water Research Commission's (WRC) Green Village Lighthouse. This is a long-term programme that is committed to demonstrating how the green economy can be achieved in marginalised areas of rural South Africa, improving human well-being while at the same time reducing environmental risks. A green economy is thus one which acknowledges the economic value of intact ecological infrastructure.

Aim and Objectives

The aim of this project was to investigate methods of improving socio-economic conditions of the Okhombe communities through integrated green innovations. The objectives of the project were:

1. Identify drivers of poverty, opportunities offered by natural ecosystem, and develop a community based vision of a Green Village using a bottom up approach.
2. Through integration of indigenous knowledge, green innovations, research, and technology, develop a tool box of green solutions that can address the impact of climate change and help communities or sectors to adapt to climate change.
3. Identify and develop a business (economic) framework that poor and local communities can use to improve their livelihoods without furthering land use degradation.
4. Develop and test practical and appropriate mechanisms, manuals and guidelines for landscape development and management that will protect the infrastructure and improve ecosystem services.
5. Train communities (mainly the youth) on appropriate skills/capacity necessary to sustain the businesses and ecosystem services that transform the poor community to be more self-sufficient.
6. Integrate the green solutions tool box and business framework with core line function government departments in order to ensure sustainability of the intervention and to forge partnerships with all key stakeholders.
7. Develop models on how to expand the green tool box of solutions and business framework utility, from household/village to the national or country-wide scale.

These objectives were applied in the upper Thukela catchment in KwaZulu-Natal. This area was considered to be most suitable for implementation because the communities living in these mountainous areas experience severe poverty, often with little access to basic amenities. They rely heavily on the natural resources for energy, crop and livestock production. Removal of fuelwood for energy and overgrazing has caused degradation of large parts of these areas, resulting in poor water infiltration, severe soil erosion and loss of grass and trees. Large quantities of silt have been deposited into the dams that make up the Thukela-

Vaal water transfer scheme (e.g. Woodstock Dam and Sterkfontein Dam). This silt not only reduces the capacity of the storage reservoirs, but is also expensive to remove. The use of alternative energy sources to fuelwood will therefore have a positive effect on South Africa's scarce water resources.

Energy poverty (i.e. poor or no energy security) is a further debilitating factor to the living standard of rural people, often impacting their health and economic livelihoods. Therefore, the implementation of integrated green innovations and technologies to create entrepreneurship/jobs that improve the economic conditions of the communities living in these marginalised rural areas is likely to have a positive impact on their livelihoods.

The first step in project implementation was obtaining approval of the project from the Tribal Council. This was followed by an innovative Android phone based survey whereby the project team interviewed 110 households to determine the demographics of the area, ascertain key data on energy and water use, as well as farming practices and the availability of land in rural areas. Mahlabathini village was selected as the study site because (i) it had a distinct boundary, (ii) it was one of the last areas to receive reticulated grid electricity with some households still having no access, (iii) it bordered the Khombe river – one of the main feeder rivers to the Woodstock dam which is in danger of silting up due to degradation, and (iv) its size lends itself to a pilot scale-up where alternative technologies could be installed throughout the village.

Following the selection of Mahlabathini as the study site a Green Village community workshop was held which revealed that multiple energy use is already a reality in this community, with households using electricity, wood, paraffin, candles and dung as energy sources. However, it was apparent that there was little knowledge of modern technologies that focus on efficiency, reliability, affordability and renewable energy. An expert workshop involving private, government and SANEDI representatives was therefore held to obtain advice on best practice options for renewable energy, the most suitable technology options for the household scale and how to take the initiative through to government. The following selection of sustainable green energy technologies was identified through the expert workshop, market research and consultation with the community to form the Green Toolbox of options to be tested for rural areas:

- Basic solar photovoltaic (PV) lighting and charging kits.
- A more advanced solar PV back-up system (wired into a home).
- Two varieties of wood pellet / biomass stoves; (i) one fan driven with a small solar panel, charger and light, (ii) one non-fan driven Top Lit Up Draft stove.
- Low-tech solar geyser (coke bottle geyser).
- Low-tech 1 000 litre biodigester.
- Two types of solar cookers: (i) a bought parabolic dome cooker, (ii) a self-build solar oven box.
- LED lights.
- Wonderbags.

A second workshop was held in which the community selected the households that would be allocated specific technologies for implementation, testing and monitoring. Selection of the households was based on criteria such as poverty, ability to engage in the project and the final decision of which households to select was left entirely to the community members present – an important process that ensures community ownership of the research.

The capacity-building component of this project focused on training the community members on the theory and practice of using renewable energy. This involved interactive presentations on potential green energy technologies and training on how to build various low-tech alternative technologies to assist community members with heating of water and cooking.

As part of the capacity building process seven workshops were held to enable community members to share best practices and give their insights on their experiences. For example, the household testing the fixed dome biogas digester reported that the available biogas was not always sufficient for all their cooking needs, especially during winter months when biogas production decreased. One option to increase the temperature in the digester and thus increase potential biogas production in winter is to add warm water to the digester. However, heating twenty litres of water daily is not a financially viable solution for rural households. The current project addressed this issue through the development of a low cost renewable energy technology that harnessed ‘free’ energy from the sun to heat water. This solar water geyser could be made within the community using recycled two litre coke bottles and plastic piping to generate warm water which could be used to feed the biogas digester, and supply households with warm water for household use and cooking needs. It is therefore recommended that when upscaling to a green village that households with biodigesters should also operate a solar water geyser. This supports the notion that sustainable solutions should be developed with a combination of various, supporting technologies.

The Drakensberg area is typically devoid of suitable trees for fuelwood, and households are required to purchase 'bakkie' loads of wood – costing in the region of R600 to R800 per load, with research showing that this can sometimes last households only one month in winter. A green energy technology that was tested by the Mahlabathini community was a biomass wood pellet stove which is an efficient cooking stove that offers the ability to improve the efficiency of biomass based cooking with an alternative "high energy" fuel source (wood pellet). Although the two pellet stoves tested provided a much cleaner burning, efficient cooking and heating solution than wood fires the community feedback indicated that the technology was not preferred above electricity and but was appreciated and useful as a back-up energy when electricity was unavailable. Pellet consumption data, and pellet sales at the local Spaza Store, supported the fact that these technologies were used infrequently as back-up technology.

The household that tested the solar PV system indicated that the technology worked very well. The household did not have electricity which meant that the solar lighting was very beneficial especially as the quality of the light enabled household members to continue working on their craft work which was an important income generation activity.

Following the community feedback sessions, a business plan or concept was designed for relevant technologies to include local economic development, natural resource and environmental sustainability and a net export trade balance between the local community and the external surrounds. The business plans were designed so that they could be taken to funders and/or communities for implementation.

Four models were identified for increasing energy service from household/village to national and country-wide scale: (i) Market-based models, (ii) Government led models, (iii) Private company participation, and (iv) Subsidies. In the case of Okhombe (and many other similar, rural villages), it is likely to be best served by a hybrid model, which administers various support at different stages of development.

This hybrid model was developed within the South African rural context. The absence of private company financing and interest in the rural energy service arena means that government and/or aid agency subsidisation will be critical in (i) disseminating and deploying appropriate renewable energy technologies in people’s homes, and (ii) supporting the development of a service industry to operate and maintain a supportive network. It is unlikely that private companies will invest appropriately, effectively and to the scale that is required from mass roll-out of decentralised energy options. The hybrid model is summarised as follows:

- Research and development: to investigate the needs of rural populations and select the right products for those needs
- Subsidisation: of (i) research to select the right products, (ii) renewable energy technologies delivered to end-users, (iii) development and maintenance of rural energy service companies until such a point as they are profitably sustainable.
- Service: development of a service network to support the energy systems.
- Move to sustainability: by way of proving concepts, establishing good-practice operating environments and providing supportive regulation; the market can be opened and made attractive to private investment and companies.

With respect to energy security, it was clear that access to energy, the cost of energy and the reliability of energy are major challenges that people face each day. The lack of reliability of electricity supply was described clearly, with community members noting how it could become unavailable at any, unexpected time and could remain unavailable for days. The general energy security problems were highlighted by the fact that households tend to use multiple energies, largely due to changing levels of accessibility, cost and reliability.

Although the focus of the Okhombe research was predominantly centred on identifying various renewable and sustainable options for energy provision, the impacts of climate change were also taken into account in developing the Green Village concept. While climate change has undoubtedly constrained the livelihoods in Okhombe due to the critical shortage of water, it is apparent that poor governance is a key factor in affecting its accessibility. The dwindling support of uThukela District in maintaining the boreholes as well as the withdrawal of support to a local water committee project indicates lack of support from government institutions which is critical to ensure that the vulnerable social groups adapt to climate change.

In terms of opportunities to create small businesses from renewable energy technologies, it was apparent that extreme poverty, far distances to the nearest town and lack of resources (even 'waste products' like empty two litre coke bottles) will be a major constraint. Subsidization models may overcome these problems, but it was clear that small-business training and support mechanisms would be needed to develop sound, sustainable small medium and micro-enterprises (SMMEs) – and these SMMEs would likely provide additional, not primary, income.

The implementation of the project in Mahlabathini achieved the following outcomes in relation to the objectives of the project:

1. **Identify drivers of poverty, opportunities offered by natural ecosystems, and develop a community based vision of a Green Village using a bottom up approach.**

The baseline survey in which 110 community members in Mahlabathini were surveyed, identified limited employment opportunities, poor resources (especially water and firewood) and poor infrastructure as the main drivers of poverty.

Of the 40 community members who attended the workshop on "Community visioning of a green village in Mahlabathini", only one had heard of a green village concept. The participants collectively reached a consensus that "*Amadlelo Aluhlaza*" (greener pastures) best described how they envisioned the green village with the following**:**

- People had water that was piped to their households;
- The cattle were grazing the plentiful grass [sic];
- People were working in community gardens which produced enough food to eat and sell to make money;
- Fields were ploughed by livestock for crops;
- Erosion gullies were fixed;
- Trees were grown for firewood;
- There was enough firewood to be harvested by women for energy; and
- People were talking to each other indicating that they were happy.

2. **Through integration of indigenous knowledge, green innovations, research, and technology, develop a tool box of green solutions that can address the impact of climate change and help communities or sectors to adapt to climate change.**

This was the focus of the Okhombe project where a tool box of green solutions was developed and tested with the community to incorporate their personal experiences and indigenous knowledge.

3. **Identify and develop a business (economic) framework that poor and local communities can use to improve their livelihoods without furthering land use degradation.**

In Okhombe a set of concept projects and business plans were developed for each green energy technology for implementation in rural areas. The intention of these plans was to provide a means of local economic development, with an integral focus on sustainability – of both the job and/or business created, and of the natural resources and environmental nature housed within that venture**.**

4. **Develop and test practical and appropriate mechanisms, manuals and guidelines for landscape development and management that will protect the infrastructure and improve ecosystem services.**

Following the testing of eight green energy technologies, manuals and guidelines were developed for three technologies which could feasibly be made within the limitations of a rural community's resources: (i) Solar geyser using recycled coke bottles, (ii) Biogas digester (1000 litres) and (iii) Solar Oven (see Appendix 10.2)

5. **Train communities (mainly the youth) on appropriate skills/capacity necessary to sustain the businesses and ecosystem services that transform the poor community to be more self-sufficient.**

The capacity-building component of this green energy project gave training through seven workshops to community members on appropriate green energy technologies to grow business opportunities and promote the sustainable use of natural resources. In addition to the technical aspects of the training, community members were trained on monitoring, evaluation, reporting and data recording. The project also initiated the building of research capacity with two community members who showed potential to carry out experiments.

6. **Integrate the green solutions tool box and business framework with core line function government departments in order to ensure sustainability of the intervention and to forge partnerships with all key stakeholders.**

For the green energy project an expert workshop was held with industry experts and government representatives to gain professional insight into the range of available technological options for testing, how best to implement and test these technologies, and how to mitigate any potential risks with the community based research. The project identified existing government initiatives that can be used to forge partnerships for upscaling the project. The identified partnerships are with the following: Department of Public Works**,** Comprehensive Sustainable Green Economy Programme**,** Department of Energy and the Department of Environmental Affairs.

7. **Develop models on how to expand the green tool box of solutions and business framework utility, from household/village to the national or country-wide scale.**

In Okhombe, four models were identified for increasing energy service from household/village to national and country-wide scale: (i) Market-based models, (ii) Government led models, (iii) Private company participation, and (iv) Subsidies. These different models are applicable to, and have varied success rates at different scales – and it is therefore important to understand the local setting before choosing and rolling out a model. Following the results of this study a hybrid model was recommended which included aspects of all four models.

The business and economic analysis reviewed a variety of projects and business models that could aid in improving community livelihoods in poor rural areas. The aim of these business models was to:

- Achieve the development goals of green technology deployment and rehabilitation of degraded land,
- Create jobs,
- Develop and sustain small, medium and micro enterprises (SMMEs) in rural areas.

The business models proposed for Mahlabathini village targeted the local manufacture and servicing of the Green Technology solutions that were tested in the village which included:

- Low-tech, community made renewable technologies from recycled materials
- Biomass pellet stoves
- Low-tech biogas manufacturing and service industry
- Sale of support of various renewable energy technologies in rural villages.

Key findings of both the surveys and workshops in the study area showed that energy, water and food security are of real concern for the people of Mahlabathini. It is clear that poor governance with respect to access to water will be a major challenge in the implementation of a Green Village. If the water, energy food nexus approach is adopted using the technologies tested in this project there is potential to improve the livelihoods of people living in these villages.

In general, it was clear from the results of both the community survey and the community workshops that the community was interested in and supportive of developing a Green Village. Much of the interest and excitement in the topic was founded in the belief that renewable energy could provide an alternative means to strengthening energy security and alleviating the cost of living. Specifically, it became clear that 'off-grid' options for energy would alleviate pressure by providing alternatives to electricity (which has proven to be unreliable), wood and other fuels (which are both expensive and often inaccessible). Although the community's support of and interest in alternative options was apparent, the research identified that it was directed at identifying secondary or back-up options and was neither considered nor used at the research households as a primary option. Electricity remained the preferred primary energy at all research households, and it was evident that the implemented technologies, although extremely useful and appreciated during electricity outages, were sub-ordinate in their ability to serve peoples' advancing needs and chosen secondarily even where monetary savings had been experienced. While alternative and low-tech options serve a purpose, especially where no grid electricity is available, the technologies tested were not capable of meeting all the peoples' energy needs, and therefore, more advanced off-grid and/or mini-grid electricity options need to be further investigated.

LIST OF ACRONYMS

CSI	Corporate Social Investment
DAFF	Department of Agriculture, Forestry and Fisheries
DC	Direct Current
DEA	Department of Environment Affairs
DoE	Department of Energy
DWS	Department of Water and Sanitation
IAP	Indoor air pollution
IDP	Integrated Development Plan
KZN	KwaZulu-Natal
NAP	National Action Programme
PV	Photovoltaic
RECORD	Renewable Energy Centre of Research and Development
RESCO	Rural Energy Service Company
RET	Renewable Energy Technology
SANEDI	The South Africa National Energy Development Institute
SMME	Small Medium or Micro Enterprise
TEES	Technically effective, Economically valid, Environmentally friendly, Socially acceptable
VPS	Village Power Supplier
WRC	Water Research Commission

ACKNOWLEDGEMENTS

The WRC is gratefully acknowledged for providing funding, guidance, research management and administration. Special thanks are given to the participating households in Mahlabathini for their enthusiasm, monitoring and dedication during the project. Our sincere thanks are also given to Tony Lopes from Lowtech.co.za, for his passion and technical support throughout the project. We also wish to acknowledge contributions made by the active members of the reference group:

Mr B Madikizela (Chairman)	*Water Research Commission*
Mr M Braack	*DEA-NRM*
Dr M Roets	*Scientific Roets*
Mr G Maguire	*Project 90*
Ms T Calmeyer	*ILISO*
Mr N Naidoo	*Prime Africa*
Ms L Lodenkemper	*Aurecon*
Mr J McCosh	*INR*
Dr M Nakin	*WSU*
Dr S Braid	*Sam Braid*
Dr W Roets	DWS

This page was deliberately left lank

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

CHAPTER 1. INTRODUCTION

1.1 Background and Motivation

Energy, food and water security form the basis of a self-sufficient economy (Goga and Pegram, 2014). However, one of the factors affecting South Africa's ability to achieve this is limiting resources particularly in rural areas. The water, energy and food nexus is a framework that is increasingly being used to improve understanding of the linkages across these sectors and identify measures to promote human well-being and environmental sustainability (Ringler *et al*., 2013). While a number of frameworks have been developed, the Bonn 2011 framework (Hoff, 2011) is appropriate for the current study as it includes drivers of the nexus dynamics such as climate change (Figure 1.1). The aim of this project was to focus on the energy and climate change sectors of the nexus and develop a tool kit of renewable energy technologies that would lead to more sustainable and integrated resource use at the household level. The objective would be to improve the economic conditions of communities in the Upper Thukela district through demonstrations of how green innovations and technologies can be integrated into their rural livelihoods.

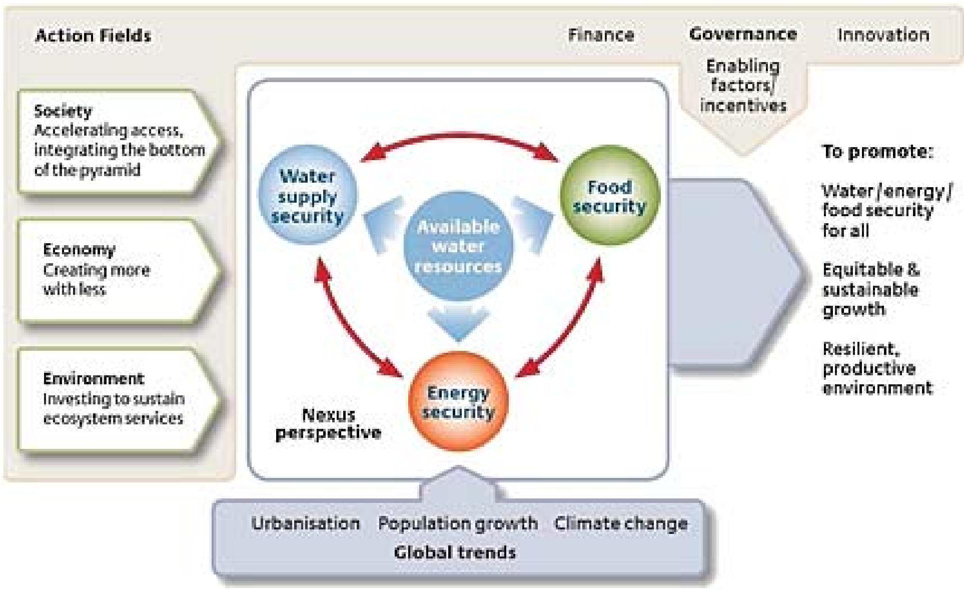


Figure 1.1: Bonn 2011 Nexus Framework (Hoff, 2011)

In their discussion document on 'The policy on agriculture in sustainable development" the National Department of Agriculture (NDA, 2002) proposes to:

- Decrease the depletion of non-renewable energy resources, i.e. oil, gas, coal and promote methods extending their 'life' through recycling, using less or switching to renewable substitutes;
- Develop and implement programmes that would combine, more efficiently, and as appropriate, the use of traditional, renewable energy resources, and cleaner fossil fuel technologies, which could meet the growing need for energy services in the longer term to achieve sustainable development;
- Provide support for the development of safe low-cost technologies that provide or conserve fuel for cooking and water heating;
- Intensify research and the development, diversification and conservation of energy, taking into account the need for efficient use and environmentally sound technology.

During the past few years there has been increasing recognition of the need to diversify primary energy sources and reduce over-reliance on fossil fuels for energy supply (Goga and Pegram, 2014). This is supported by the South African Government's Integrated Resource Plan (IRP) for 2010-2030, which shows the intent of the government to diversify South Africa's energy mix. Although in many rural households of South Africa multiple energy use is already a reality, with households using wood, paraffin, candles and dung as energy sources, there is little knowledge on modern technologies that focus on efficiency, reliability, affordability and renewable energy (e.g. safer and more efficient cooking stoves).

Biomass, particularly firewood, was the most widely used energy fuel in the Upper Thukela with 85% of households making use of it for cooking purposes (Smith, 2011). However, firewood is not readily available anymore due to heavy harvesting. This has resulted in the degradation of large areas causing environmental problems as well as social concerns, with poor households being unable to afford the purchase of fuelwood from outside sources. If sustainable development is to be achieved, it will be necessary to seek alternative energy options and technological innovations to improve the efficiency of energy use as well as finding solutions to economic and environmental problems associated with firewood. Even small energy savings can be important for poorer households (Winkler, 2006).

To optimise an energy system, Davidson and Winkler (2006) highlighted three approaches that must be applied:

- An evaluation of future energy scenarios and technology options.
- Information should be clearly disseminated.
- The parties concerned should be empowered to encourage external cost accountability and longer-term energy planning. Initially government can coordinate these steps, but over time they should be self-perpetuating.

The current study reviewed the potential green energy options for the Upper Thukela. Information workshops were held with both the community and experts in the energy field to improve the household member's access to information and knowledge. Community members played an integral role in the evaluation of technologies for the area. Capacity building of the community members, whereby they reported on their experiences of the implemented energy options, was a key factor in the promotion of entrepreneurial opportunities in renewable energy related industries and the long-term planning of the green village concept.

According to UNCTED (2009) there is no "one-size-fits-all" solution to energy challenges; the appropriateness of technology choices depends on the availability of renewable resources, the load needed, the type of utilization, the cost effectiveness of various options and investment parameters.

The aim of this report is to present a tool box of potential green energy solutions for the rural areas of the Upper Thukela region. The report comprises a conceptual framework that includes the following:

- Findings from the baseline survey and questionnaire
- Highlights from an expert workshop on energy options
- A review of potential green technologies
- Criteria for suitability and testing

1.2 Study area

1.2.1 Criteria for selection of study site

The Okhombe community within the Okhahlamba Local Municipality, KwaZulu-Natal was the site for the green innovations technology research and pilot testing under this project. Okhombe is defined as Ward 7 in this local municipality with a recorded population of 8 720 people in 2011 with an estimated number 1 817 households

(Stats SA Census, 2011). The community is surrounded by a horseshoe shaped range of mountains, and is the home to the Khombe river which feeds Woodstock dam (Figure 1.2).

Although the Okhombe Ward 7 is defined by municipal boundaries, the area which has been party to many research projects over the past 20 years (known as the Okhombe community) is defined more selectively as those households within the horseshoe range of mountains and within the Khombe river valley (Figure 1.2).

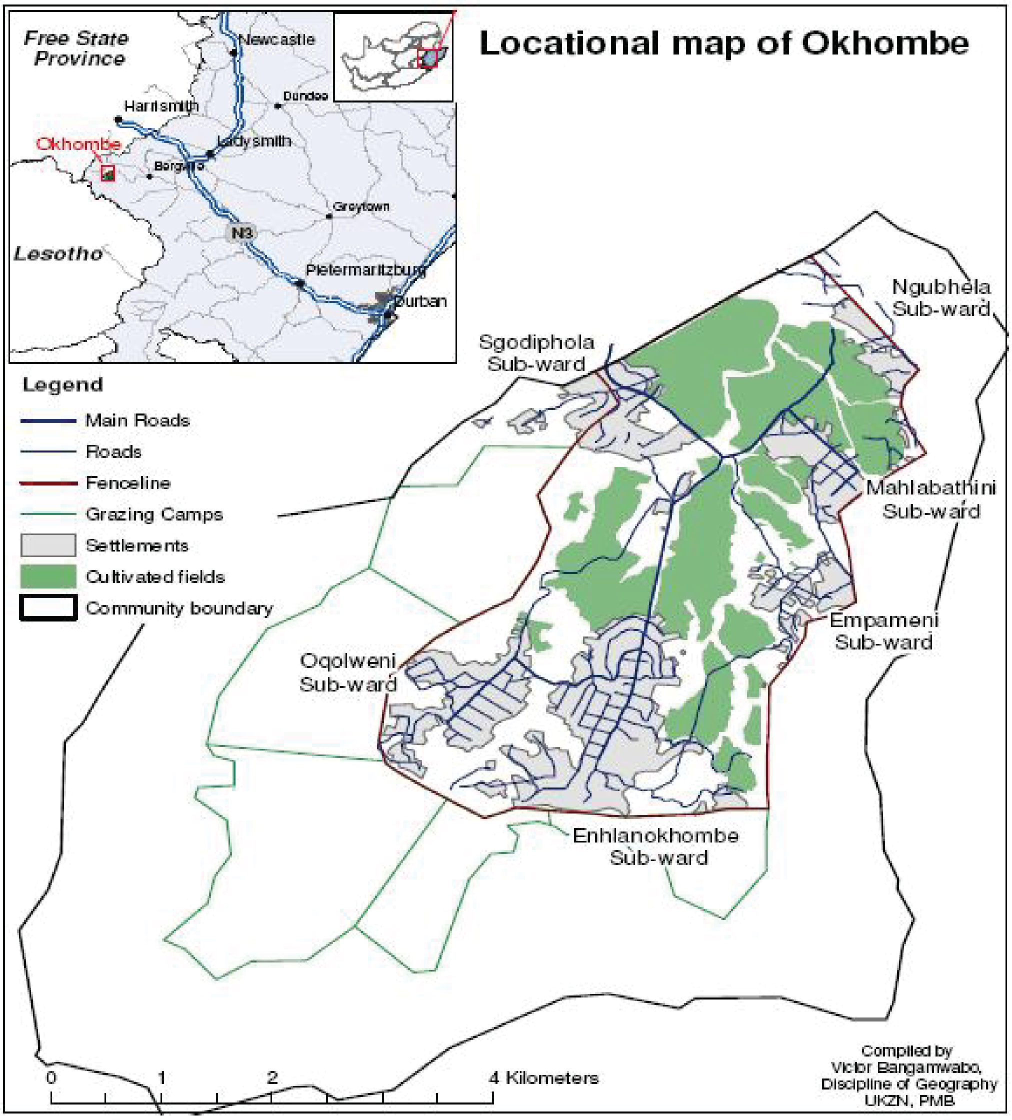


Figure 1.2: Map showing the location of Okhombe (Salomon, 2009)

The Okhombe community is an area with dispersed settlements following (or being followed by) road infrastructure. Within the Okhombe community, there are six villages or sub-wards: Mahlabathini, Sigodiphola, Enhlanokhombe, Empamemi, Oqolweni and Ngubhela (Sookraj, 2002). The approximate delineation of the Mahlabathini village is shown by the red demarcation, within the yellow boundaries of the Okhombe Ward 7 boundary (Figure 1.2). A decision was made by the project team to focus on the Mahlabathini village for the following reasons:

- ***Distinctive boundaries***

Mahlabathini is demarcated distinctly by a number of physical boundaries. A road in the north and river/stream in the west separate this village from others, and a mountain range in the east and south have restricted any further development in these directions (Figure 1.3). A distinct boundary is helpful for a number of reasons. The area could be clearly defined by surveyors conducting data capture in the area. The clearly defined village had potential to be used to test the Green Village concept.

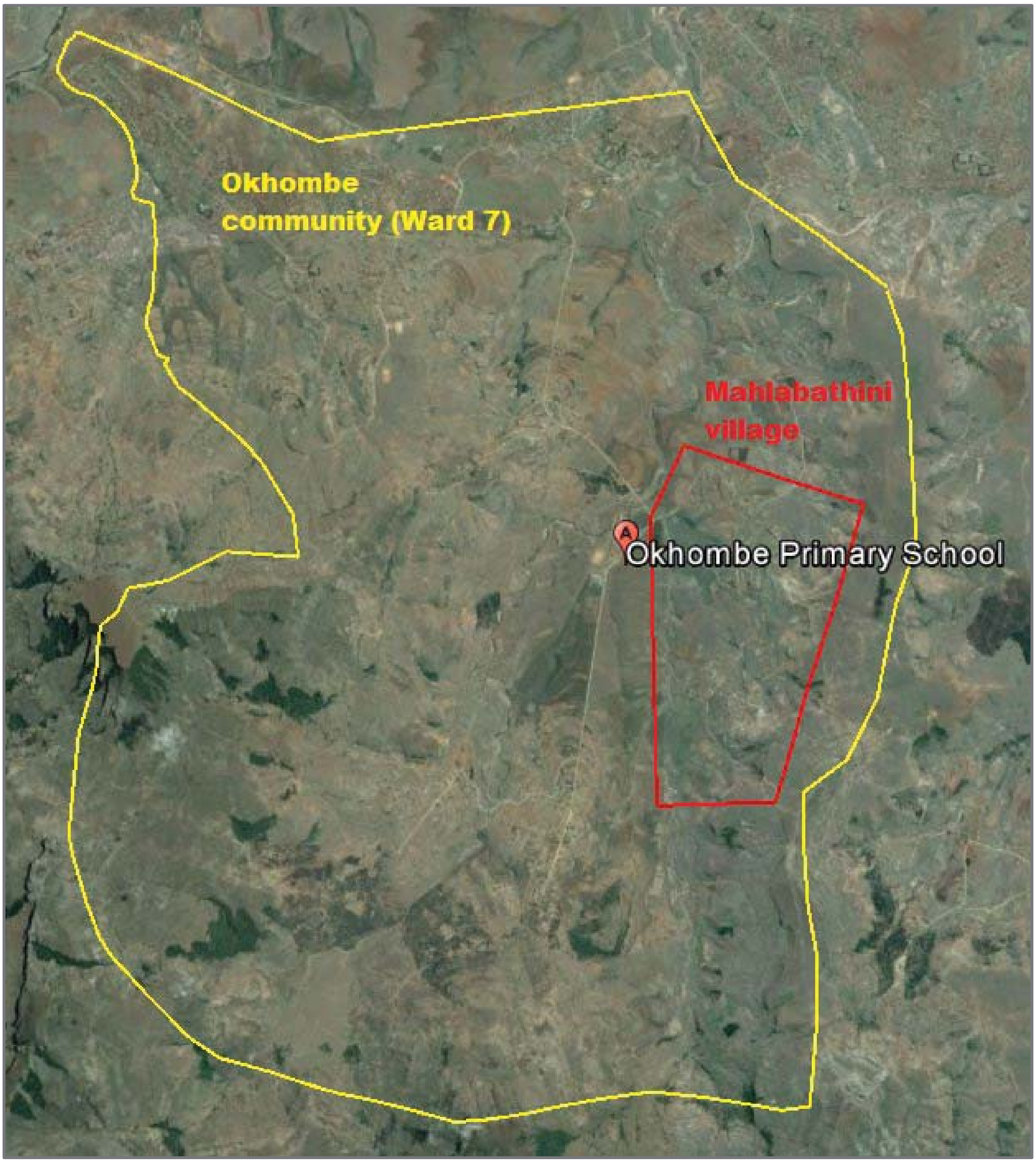


Figure 1.3: Approximate delineation of Mahlabathini village boundary within Okhombe community (Ward 7) (Google Earth, 2015)

The local and tribal authorities could identify approximately 130 households in the village community which provided a feasible sample size for surveying all the households in the village.

The households in this village appeared to be representative of the greater community (Smith, pers. obsv., 2014). Therefore the survey data collected could be compared to those of an earlier study conducted in the greater Okhombe areas in 2011 (Smith, 2011), where differences and similarities could be focused on for extrapolation purposes.

- ***The 'remoteness' of Mahlabathini***

Mahlabathini can be described as 'more remote' in relation to the other villages in the Okhombe community. In addition, the village was one of the last areas to receive reticulated grid electricity with some households still having no access. These characteristics lend themselves to a study focusing on the potential for off-grid options to meet the needs of remote communities in rural areas.

- ***Proximity to an important river course***

The Mahlabathini village borders the Khombe river which is one of the main feeder rivers to the Woodstock dam. The Woodstock dam has strategic importance as a supplier of water for the Drakensberg Pumped Storage electricity scheme. Therefore, soil erosion and siltation via its feeder rivers poses a serious threat to its capacity and subsequently its potential as part of this pumped storage facility (Everson *et al*., 2007).

- ***Potential pilot study scale-up***

If the green energy technologies tested at the household scale in the current project are successful, the Mahlabathini village lends itself to a pilot scale-up where alternative technologies could be installed throughout the village (as per the Green Village concept).

1.3 Green village concept

The Green Village concept is where people have sustainable and affordable access to quality food, water and energy within a well-managed and functioning ecosystem. The concept poses a significant opportunity for researchers and government to investigate rural development alternatives for the provision of basic services in remote and impoverished areas of South Africa. The "green concept" is becoming even more relevant as the impacts of climate change are beginning to be felt in the entire value chain, but in particular in marginalized rural areas. To address these issues a pilot project was implemented with funding by the WRC (Project K5/1955) to examine the inter-relations between the components of the Water-Energy-Food (WEF) nexus at a household level. This pilot project has shown great success in the provision of sustainable energy, water, food and fodder in rural areas of the Upper Thukela. This was been achieved through the implementation of four biogas digesters (anaerobic digesters) and rainwater harvesting mechanisms to provide off-grid water and energy. The challenge now is:

- To test other green technologies that can be implemented in a Green Village.
- To determine whether these technologies can be up-scaled from a small-scale household level to a village level.
- To identify and develop a business (economic) framework that will determine the potential of rural energy alternatives for job creation and the development of SMEs in rural areas.

1.3.1 Community visioning workshop

In the community visioning workshop reported on in Section 2.2 the key concerns reported by Mr Hlongwane included (i) the unavailability of resources [wood in this case], (ii) the cost of energy and (iii) the use of renewable energy, in the form of biogas.

i. With respect to wood, members spoke about the government endorsed alien invasive removal programmes that had removed available wood from their area and made access to wood very difficult. The other resource concerns that were raised during the discussions was the lack of reliability of electricity, and comment that bought fuels (paraffin/LPG) had to be bought from distant urban centres.

ii. The cost of energy was a theme that continued throughout the community workshop process. Cost of electricity and energy fuels was noted as a high expenditure item for households and the need to use multiple energies was raised again as an important mechanism to ensure that some form of energy was available when needed.

Plate 1.1: Images from the community visioning workshop on the 8th September 2015

iii. The biogas digester installed at the Velum Khumalo homestead by WRC Project K5/1955 was repeatedly raised and acknowledged as a potential renewable resource to assist households with cooking energy. The important aspect of this outcome was that support for biogas was clear, and intention and interest in supporting alternative energies was strong.

Another statement, made by Mr Mabaso, revealed and summarised other important discussions from the forum. Mr Mabaso asked whether the project (WRC K5/2423) might be able to assist the community to:
“address ways of using energy more effectively and saving energy as we have problems with electricity not working for long periods?”

This statement again raised the importance and impact of the cost of energy and the unreliability of current resources. The lack of reliability in the electricity system was recognised continuously as a major concern for the people of Mahlabathini, and sentiment was general that back-up, cost effective supply of energy was needed for basic energy delivery.

1.4 The Okhombe Green Village Research

Sustainable community development is often referred to as 'green development' (Geis and Kutzmark, 2006). For communities to achieve social, economic and environmental benefits, sustainable development needs to be tied to a community's vision and goals.

Energy is a key element in community development (Chaurey and Kandpal, 2010). In general, energy use in rural areas can be subdivided into the following three categories:

- Household energy;
- Energy for agriculture;
- Energy for small- and micro-enterprise (Karekezi and Kithyoma, 2002).

These authors reported that the bulk of energy consumed in rural areas is used in households, with cooking accounting for between 90% and 100% of energy consumption. It follows then that the application of green energy technologies should focus on household energy. Increasing the efficiency of household energy use through new technologies has potential to reduce the demand on natural resources such as fuel wood.

Although the Eskom electrification network appears to cover the entire Okhahlamba Local Municipality it does not impact on the disadvantaged rural settlements (Okhahlamba Integrated Development Plan (IDP), 2014). The Okhahlamba IDP (2014) recommended alternative technologies such as safer and more efficient cookers, gas fuel and more efficient and sustainable use of wood for fuel at a household level. The aim of the current project was therefore to directly feed into the Okhahlamba IDP review plan of 2014/15 to address these issues.

Since renewable energy is a new concept to many rural communities, social acceptance and demonstration of new technologies is necessary to understand potential barriers to uptake. Such technologies should include those that promote the efficient use of biomass to ensure that scarce biomass resources are effectively utilised (Karekezi and Kithyoma, 2002). Generally in rural areas, energy from biomass such as wood and livestock manure is the largest energy source for household consumption. However, with Eskom's electrification programme, an increasing number of rural households have access to electricity. An assessment of the contribution of biomass energy to household energy consumption levels is therefore a key element in the development of potential green energy technologies. This is particularly relevant in the Upper Thukela region where the prevalent vegetation is grassland and fuel wood is scarce resulting in the utilization of biomass from indigenous forests. Karekezi and Kithyoma (2002) recommended that technologies should be offered to communities that are associated with income-generating activities as they will be more likely to yield greater benefits to the rural poor. The current project explored a range of renewable energy options with potential for income generation as these would be more likely to promote uptake by the community. Ultimately the aim was to give communities social choice mechanisms which surround green energy technologies.

In their assessment of bioenergy in South Africa, Bole-Rentel and Bruinsma (2013) concluded that research on renewable energy is in its early stages of development and testing and learning still needs to take place. In the current project renewable technologies that were tested in the rural areas of the Upper Thukela were:

- Solar photovoltaic off-grid systems (inclusive of solar photovoltaic panels, charge controllers, energy storage (batteries)
- Biogas (the project has the opportunity to learn from existing biogas digesters in the research area)

- Biomass (clean burn biomass cook stoves – either using readily available biomass or other sources). Further, the opportunity of generating jobs around the creation and/or supply of this biomass may be explored following advice from the experts.
- Solar thermal (using solar energy to heat water)
- Heat exchanges for conversion of existing heat energy to electrical energy.

Demonstrations of these techniques in the Upper Thukela would provide community members with options for social choices which may be implemented at a Green Village scale. The following energy development indicators developed by World Energy Outlook (2014) were used to evaluate these choices:

- Availability
- Affordability
- Adequacy
- Reliability
- Convenience.

The uptake of the technologies favoured by communities will depend on the challenges and opportunities faced by the community.

One of the lessons learnt in the pilot WRC K5/1955 biogas project was that a technology, such as a biogas digester for renewable energy, has different outputs of energy production, not only in different provinces, but even between different households in the same village (Everson and Smith, 2015). Reasons for the variation in biogas production may be related to physical aspects such as temperature or social aspects such as loading rates and operator motivation. The results therefore support the recommendation by Bole-Rentel and Bruinsma (2013) that new technologies should be locally adapted to the household's situation. Since renewable energy systems utilize relatively new technologies, capacity building is essential to develop a sustainable programme (Jones and Thompson, 1996). The capacity building in this project focused on both the community and technical levels.

Since household income is related to the types and cost of energy used (Howells *et al*., 2005) an assessment of these was carried out in the Upper Thukela. Other factors that were taken into consideration were:

1. Economic viability of the different energy options
2. Technical and social acceptability of biogas and other technologies as a contributor to energy solutions
3. Efficiency of the performance of energy technologies (evaluation and monitoring) and potential endorsement by the SABS
4. Institutional and organizational structures and factors with respect to introduction, implementation and uptake of new technologies
5. Capacity building and dissemination to the wider community
6. Potential of technologies to link up with ecological infrastructure and jobs
7. Potential of technologies to impact on the environment and resources (e.g. use of bioslurry from a biogas digester as an organic fertilizer).

The focus of the Okhombe research group was to work with the Okhombe community in identifying challenges, opportunities and a vision of a Green Village, with regard specifically to 'green' innovations and technology to meet food, water and energy needs. The team aimed to approach this by establishing the needs and wishes of the community in the small village of Mahlabathini (the research site within Okhombe). The first step in this process was to obtain base-line data for the assessment of the current energy options utilized by households in the Upper Thukela. The team approached this by carrying out an extensive questionnaire survey in the area.

CHAPTER 2. CURRENT STATUS OF ENERGY ACCESS IN MAHLABATHINI, OKHOMBE

2.1 Community survey – Okhombe

2.1.1 Application development and survey design

The Okhombe research team partnered with a number of service providers in developing innovative table-based surveys, hosted on a novel and versatile Android[1] based application (app.). The application is designed for in-field research, monitoring and off-site review of incoming data. The African Conservation Trust (ACT)[2] has partnered with Kandu[3] in developing this app to monitor development of food gardens, progress of gardeners and to provide a network for rural gardeners to market and sell their available produce. The Kandu application allows for registration of a person and/or household using a geolocation tag. This is the first step in the app process which allows for a unique identity (UID) number to be given to a person, with a GPS location tagged to their respective home. Following this, any of the designed questionnaires can be administered to this person and each are associated with the allocated UID (Figure 2.1).

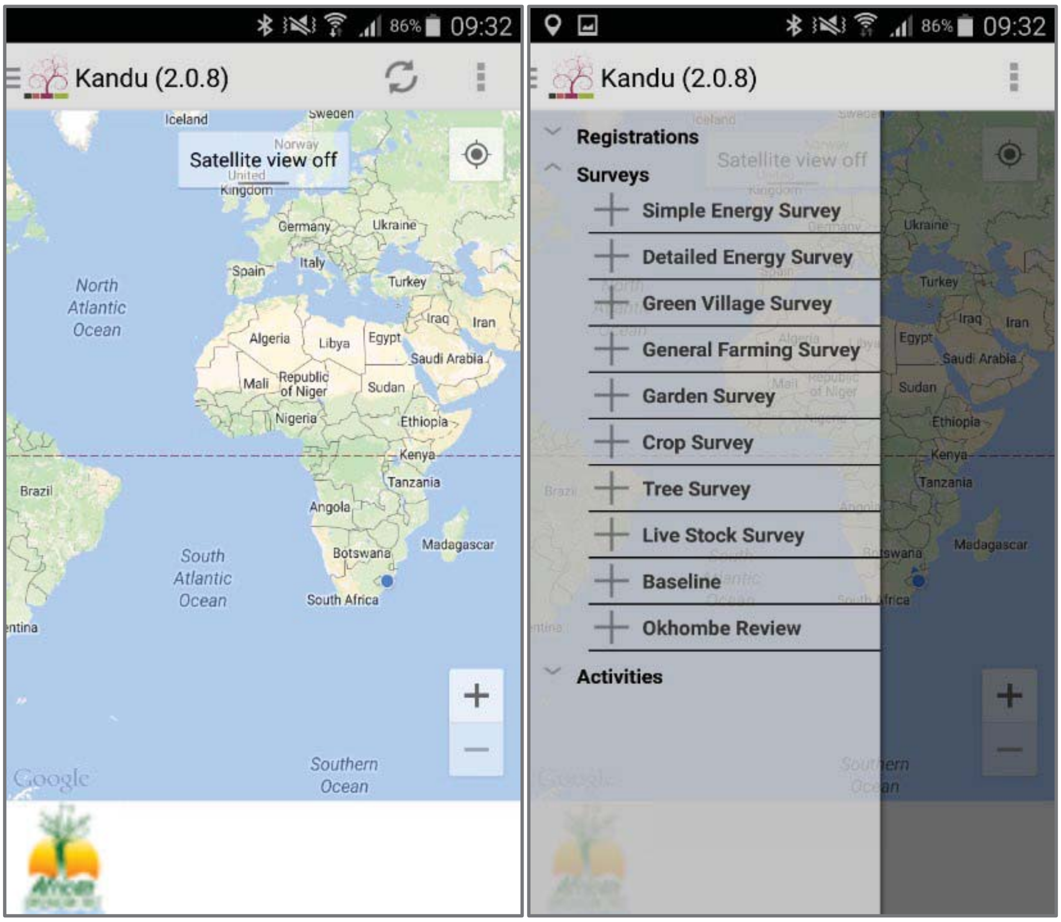


Figure 2.1: Kandu application – displaying geolocation interface and available questionnaires for administration to registered households/interviewees

[1] Android Operating System (OS) – a google based OS used on Android phones and tablets.
[2] www.projectafrica.co.za.
[3] http://ofn.kandu.co.za/

Renen Energy Solutions (Renen[4]) and the project research team worked with these partners to develop surveys to ascertain key data on energy and water use, as well as farming practices and the availability of land in rural areas. The surveys were developed with prior community survey development experience gained from WRC project K5/1955 (Everson and Smith, 2015). Adaptations to previous questions were made and new, Green Village related questions (and surveys), were developed to gather the baseline data for the current study (Figure 2.2).

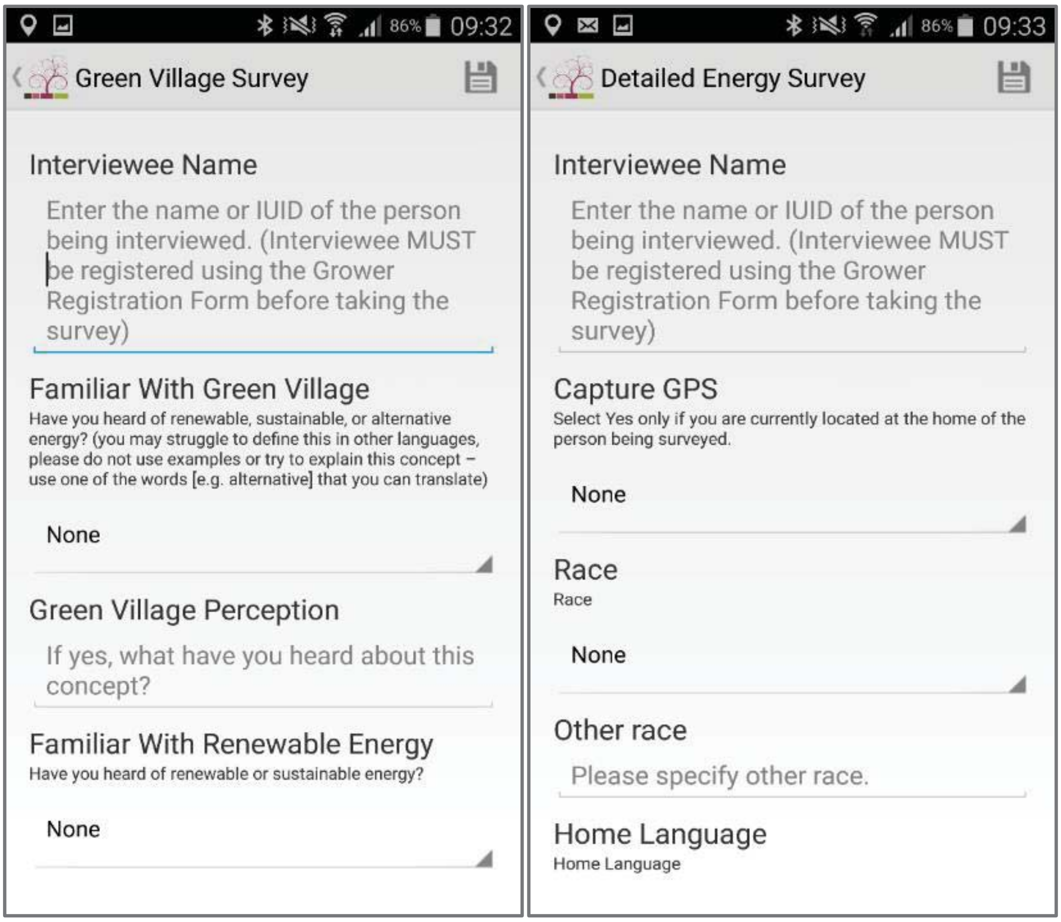


Figure 2.2: Questionnaire interfaces on the Kandu app for a Green Village Survey (left) and a detailed Energy Survey (right)

2.1.1.1 Survey development process

As described, the initial surveys were developed by the team with an understanding of prior surveys and the data requirements of the current project.

Three separate surveys were developed to obtain the following information from the target group:

- Detailed energy survey
  - To gather energy use, practice and choice information.
- General farming survey
  - To gather information relating to peoples general farming practice, land utilisation and use of fertilisers (organic and chemical).
- Green village survey
  - To survey any prior knowledge of a Green Village concept and of renewable energy.

[4] http://renen.co.za – a project contributor on the WRC K5/2423 project.

In house testing and pilot study:

Several internal pilot studies were conducted in which the researchers tested the app. Hypothetical survey information (that covered a variety of responses) was captured by the app and the outputs were analysed to verify the results. This process was challenging as this novel application had several technical problems relating to the question types (open-ended and closed) and movement of data between question categories. The testing of the app and survey allowed for further development of the process with the application developer, and a streamlining of the questionnaires and choice of question types to facilitate a better interview experience. Question type choice (i.e. multiple choice, free text, check box, etc.) proved to be a very important consideration as multiple choice and check box questions can provide a quicker response and easier processing than the use of free text questions. The researchers therefore needed to weigh up the choice of each question type with an intention to limit, or not limit, the interviewee's response.

In-field pilot study:

Once the research team was comfortable that the surveys were appropriate for the research intention, the system and process was tested in field at Okhombe (Plate 2.1). From prior experience, in field testing is pivotal to the success of a survey as it is difficult to hypothesise all variations in the manner in which questions are answered.

Plate 2.1: In field pilot study being conducted with two members capturing data via the Kandu app and two capturing data, comments and observations

Following the in-field pilot study, the surveys were again modified to accommodate the findings of the study. The pilot study revealed a number of challenges which required further question type changes and question modification.

Survey administration

The community surveys were initiated between 29th September and 3rd of August 2015, following a delay caused by the death of an important member in the community[5]. Four Zulu speaking post graduate students were

[5] A note of importance when conducting community based research is the need for understanding and awareness of cultural aspects. For example, the death of an important member of the community resulted in the team having to stop the research process. Not only was the process logistically marred by people's absence from their homes, but the team also felt it inappropriate and disrespectful to enter the community during a time of mourning. The loss of this community member was a sad passing for the community and the research team, as he had played an integral role in research activities and would also have been responsible for gathering a group of people for the community workshop.

employed to conduct the survey. The students had all had experience with community surveys, but not with an application based process, and therefore training was enacted prior to the survey trip to ensure that they fully understood the use of the tablets and how best to apply the information given to them.

The students were briefed that Mahlabathini village (as represented in Plate 2.2) was the key focus of the survey with an intention to get a 100% household survey sample if possible.

Plate 2.2: Map of Mahlabathini with key locations to assist students in surveying the entire village

Technological challenges:

Despite the extensive planning and testing conducted with the Android tablet based system, a number of application glitches resulted in the need for further software changes by the programmer. These glitches included an inability to use the application in off-line mode (a problem in low GSM reception areas) and users being unable to upload captured data. The problems were, for the better part, rectified and the students were able to continue with the surveys.

Another problem which slowed the process was the fact that the tablets used were not able to retain their battery life for a full day, resulting in the students have to take small charging devices and/or return to basecamp to charge devices during the course of a day.

Surveys captured in Mahlabathini:

It was estimated that Mahlabathini had approximately 100 households/dwellings. This estimation was gained from aerial mapping and a count of what appeared to be individual homes. The surveyors identified that there were significantly fewer households in the village (approximately 75) and although it was estimated that the sample size was >71%, the research group decided that more surveys from other communities in the Upper Thukela would provide additional useful data in assessing the needs and opportunities for a Green Village. The students therefore conducted further surveys in the New Stand village (a more urbanised village that had access to electricity since the early 1990s) and Potshini village (far removed from Mahlabathini [40 km by road], but similar in many respects).

Survey team experiences:

On the whole, the survey team reported that the process had been smooth and well received by the community (especially that of Mahlabathini, who were expectant of the researchers). There were, however, a number of predicted and non-predicted experiences which should be recorded here.

Expectations: The survey teams were requested to ensure that they managed the expectations of the interviewees and under no circumstances created any expectation of service delivery or provision by the project. The researchers have worked hard to define their presence as researchers, and not the deliverers of goods or services.

Feedback: Much of the response from the survey respondents was that they wished to receive feedback from the process. Many interviewees stated that they had been part of similar processes in the past and that they had never received any feedback of the outcomes once the project/research was completed. The Okhombe research group will heed this advice and report back by way of a community meeting/workshop during the project.

Externalities: One interesting point raised by a number of interviewees in general discussions was that of negative outcomes of environmental beneficiation projects. Interviewees described that “the government” had come into the area with a strong intention to remove all alien invasive trees, but had not replanted these trees with indigenous alternatives, nor provided any other form of fuel for energy. The community commented that this had left them with minimal energy options so that they had to spend significant amounts of money purchasing wood or other bought fuels. Their disgruntlement was clearly well-founded and showed the importance of the process being conducted in this project – the importance of understanding a community’s position and needs before implementation of a ‘solution’.

Disgruntlement: One interviewee was verbally abusive to one of the student interviewers telling her that he was exasperated by researcher’s presence, and their theft of knowledge from the community. His feeling was that researchers entered the community, “stole knowledge from the communities”, went back to their institutions to gain their degrees with this knowledge, and never returned with any feedback or contribution to the community. This brings valuable insight to the process and a need to return with feedback to the communities involved.

Plate 2.3 shows students using various tablets and devices to conduct surveys in Mahlabathini.

Plate 2.3: Post graduate students conducting surveys in Mahlabathini, Okhombe in July 2015

2.1.2 Survey results

2.1.2.1 Interviewee and household demographics

A total number of 110 responses were captured in Okhombe and the other surveyed communities (New Stand and Potshini) as described in Section 2.1.1.2. Presented here are the results for Mahlabathini village only, as the proposed mandate was to survey this village in entirety, and to present the case of Green Village for this village as a standalone pilot village.

Fifty-three responses were gained from the Mahlabathini village which was estimated to represent a sample of 71% of the total households in the village (75 households[6]).

Interviewee demographic:

Of the 53 households surveyed 62% of the interviewees were male, 38% were female and all spoke Zulu as a home language (Table 2.1). There was a broad age distribution from 21 to 70 years of age, with very few people older than 71 years being interviewed (see Table 2.1 and Figure 2.3).

[6] It was estimated that there were 75 households in the Mahlabathini Village using Google Earth 2015 imagery. It is noted that this form of estimation can be difficult given the varied nature of household positioning.

Table 2.1: Interviewee demographics

Total interviews in Mahlabathini		
Total households in Mahlabathini	75	
Number	53	71% of village households

Interviewee age distribution		
Unknown	11	21%
21-30	8	15%
31-40	8	15%
41-50	7	13%
51-60	11	21%
61-70	7	13%
71-80	1	2%
>80	0	0%

Home language		
Zulu speaking	53	100%
Other	0	0%

Gender		
Male	20	38%
Female	33	62%

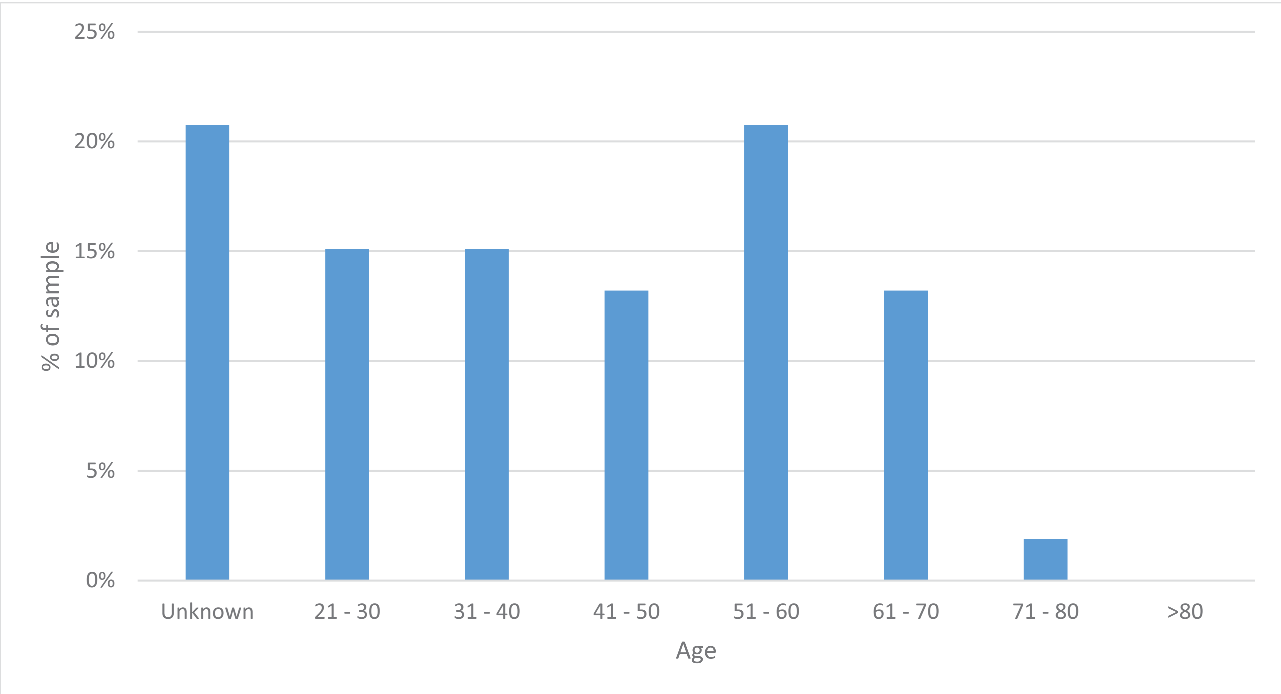


Figure 2.3: Interviewee age distribution

Sample group household demographic:

The 53 interviewees each represented 53 separate households in the Mahlabathini village. The average household size of the sample group was 5.6 people per household which correlated closely with prior studies of the Okhombe community (5.4 people per household found in 2011, [Smith *et al.*, 2014]). The median household size was 5 people and the mode was 4 people. The maximum size was 15 people and only one household had one person as its inhabitant (see Table 2.2).

Table 2.2: Household size in Mahlabathini

Average household size	
Average	5.6
Mode	4
Median	5
Minimum	1
Maximum	15

Interviewees were asked what their household's monthly income was. It must be noted that this is a stated monthly income, not an actual monthly income, and past experience and literature concur that interviewees tend to under-declare their income (Yu, 2013). The majority of the sample group had a household monthly income of between R1 000 and R 1499 (Table 2.3).

Table 2.3: Distribution of stated household monthly income

Distribution of *stated* household monthly income	
Less than R499	0
R500 to R999	5
R1000 to R1499	17
More than R1499	6
Max. stated income	R3 000

The interviewees were asked what the highest level of education of any member in the household was. Table 2.4 presents the results of this question, and while showing that most households had matric graduates, very few other skills were available in the area.

Table 2.4: Education level of household members

Highest level of education in household	
Completed High School	33
Completed Primary School	2
Degree	4
Diploma	2
Some High School	4
Some Primary School	5
Trade	2
None	1

The demographic profile of the household heads displayed a slight dominance of female headed households, and a majority of household heads being within the ages of 51 and 70 years of age (Table 2.5).

Table 2.5: Demographic of household head

Demographic of household head		
Gender		
Male	22	42%
Female	31	58%

Household head age distribution		
21-30	0	0%
31-40	4	8%
41-50	9	17%
51-60	18	34%
61-70	15	28%
71-80	4	8%
>80	2	4%

2.1.2.2 Access to water and water quality

Interviewees were asked a number of questions regarding their access to water, the source of that water and the quality of nearby rivers/streams.

In contrast to previous assessments (Smith, 2011) where almost all households had multiple sources of water collection, only 21% of the sample households reported using more than one source of collection. This could be a result of their geographic setting, or possibly a bias created by the manner in which the question was asked.

Figure 2.4 shows the sources of water and the number of households who access water from them. The community stand tap (which is borehole linked) was the most commonly used source of water, with other people accessing water from a river/stream, and rainwater tanks. Only one household reported having access to water from a tap inside their home.

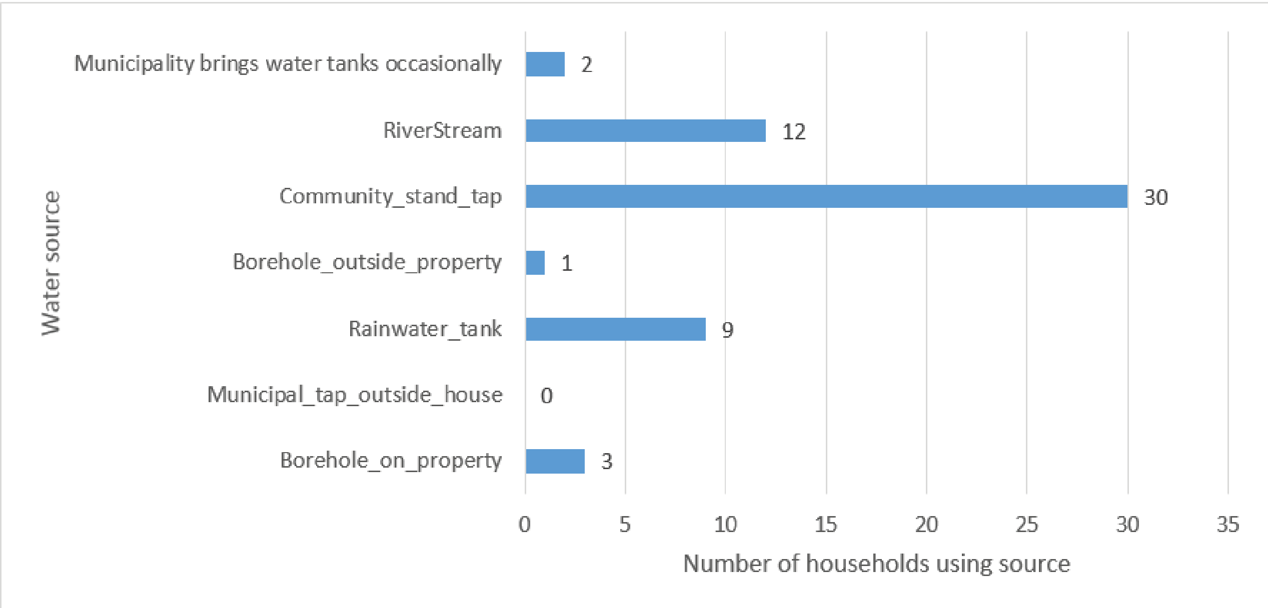


Figure 2.4: Source of water (number of households using specific sources)

All but one household was required to walk some distance to collect water from a source external to their house. A collation of the reported data shows an average time spent collecting water per day of over one hour, and an average daily water consumption of 59 litres per household per day (Table 2.6).

Table 2.6: Details of water collection

Details of water collection	
Households with access in house	1 household
Average time spent collecting per day	70.5 minutes
Average quantity used per day	58.7 litres

Interviewees were also questioned about their perception of the water quality in the nearby Khombe River (a key water source that feeds the Woodstock Dam and Tugela Vaal Pumped Storage electricity scheme). Table 2.7 shows that 92% of the households recognised the impacts of erosion in noting that it became cloudy when it rained in the area. Eighty three percent (83%) felt that the river water was not suitable for drinking. The predominant reason for this was that it was "dirty" and "not safe". Others noted that it was polluted by rubbish, cattle that drank from and crossed the river, and it was generally muddy and polluted by people washing their clothes in it.

Table 2.7: Details of nearby river water quality

Nearby river quality	
Believe/see that river becomes cloudy when it rains	92%
Will not drink water	83%

2.1.2.3 Access to sanitation

Figure 2.5 shows the distribution of toilet types at the various households across the surveyed sample group. Almost exclusively households have access to a pit latrine provided by the government/local authority, with others using a self-built pit latrine and one household not having access to their own toilet.

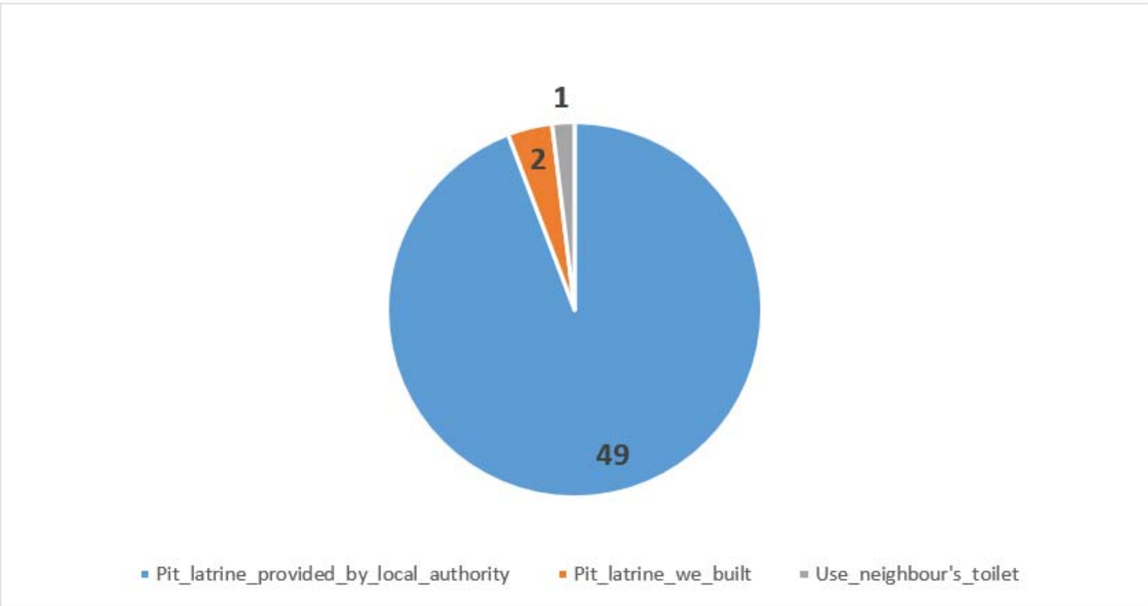


Figure 2.5: Distribution of toilet types at surveyed households

2.1.2.4 Investigation of energy usage

The following Sections 2.1.2.5 to 2.1.2.7 present results of the survey's investigation into the use of energy and perceptions of specific energy types. For each application; (i) lighting, (ii) cooking, (iii) thermal heating, and (iv) water heating, interviewees were asked to define what energy was used most often (primary), used second most (secondary) and used third most (tertiary). In addition the survey aimed to gain insight into what energy was perceived to be best for various applications and the reason for this belief. Further questions were asked regarding cost of energy and expenditure on energy.

2.1.2.5 Energy used for lighting

With respect to household lighting, electricity was the predominant energy used as a primary source, with only two households using candles as their main source of lighting energy (see Figure 2.6). Candles were used almost exclusively as the chosen 'back-up' or secondary option, while few people used a tertiary energy as a third option. These results have changed remarkably since a survey in 2011 when few households had access to electricity (Smith, 2011). The use of candles as a secondary (or back-up) energy is congruent with a response to "Why do you use more than one energy for lighting?" and with findings of the community survey which highlighted the fact that electricity was a highly unreliable energy in Mahlabathini (see Section 2.2).

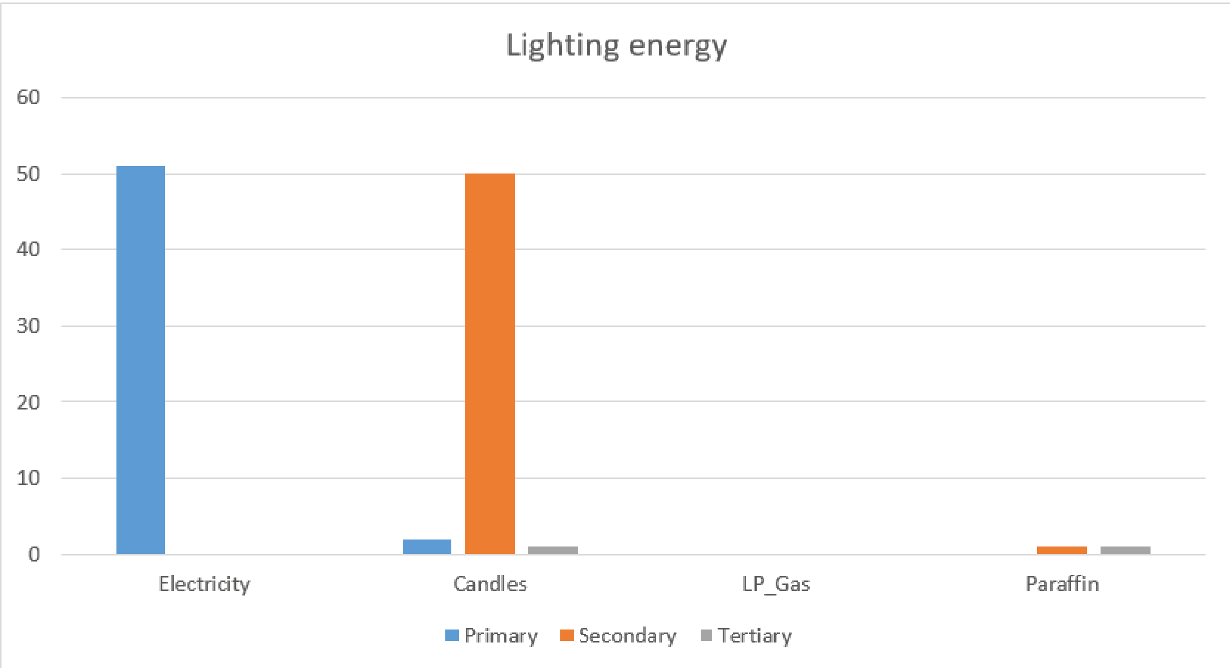


Figure 2.6: Types of energy used for household lighting

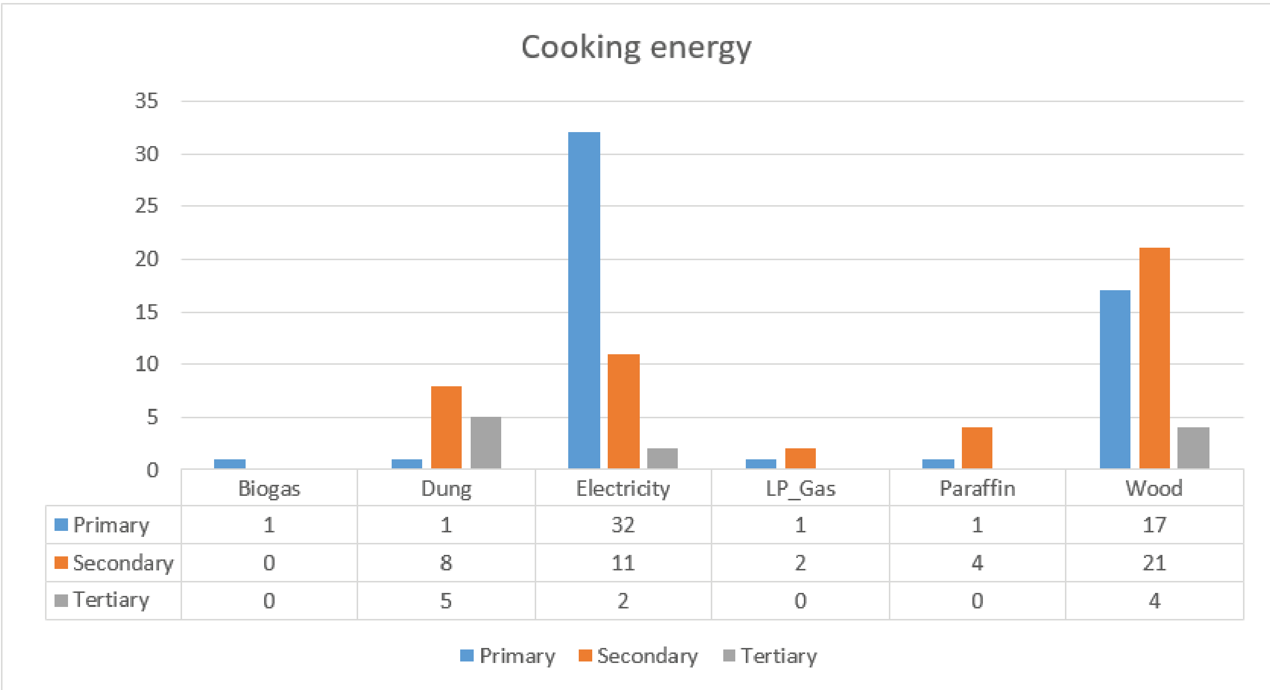
Electricity was exclusively listed as the "best lighting energy". The predominant reason for this being that it was the most effective (i.e. the brightest) energy (listed by 72% of respondents) with other reasons for choice as follows:

- 72% stated that it was the brightest (effectiveness)
- 13% stated that it was the most convenient
- Three people noted that it was safer (than candles)
- Ease of access to electricity was noted
- One person identified the multi-purpose nature of electricity – "it is multi-purpose, I cook and have light on the same energy".

2.1.2.6 Energy used for cooking

Figure 2.7 displays energy used for cooking. Cooking energies were predictably diverse and most households had a secondary energy source (87% of households) and some had a tertiary source (21%). Wood was the most widely used energy fuel across all levels of usage with 85% of households making use of it either as a primary, secondary or tertiary option. Highlighting a significant change from previous surveys conducted in Okhombe, the majority of households (60%) now use electricity as their primary cooking source as opposed to only 22% in 2011 (Smith, 2011). Wood was the second most common fuel used for primary cooking 32%, and it was noted that one household in the community uses biogas (a biodigester funded and researched through WRC project K5/1955).

Wood was the most commonly used secondary source of cooking energy, followed by electricity and dung (dried cow manure). It was noted both in survey interviews and at the community workshop that while dung was readily available, free, and therefore a favoured fuel during winter, it could not be used during the summer rainy months as it could not easily be collected or dried.



	Biogas	Dung	Electricity	LP_Gas	Paraffin	Wood
Primary	1	1	32	1	1	17
Secondary	0	8	11	2	4	21
Tertiary	0	5	2	0	0	4

Figure 2.7: Types of energy used for cooking

Households were asked what they thought was the best energy for cooking (see Figure 2.8). Interestingly only 49% believed electricity to be the best cooking energy, despite 60% of households using it as a primary source. The community workshop findings revealed that electricity was seen as an unreliable resource in the area, as storms, wind, and load shedding resulted in unpredictable outages (see Section 2.2)

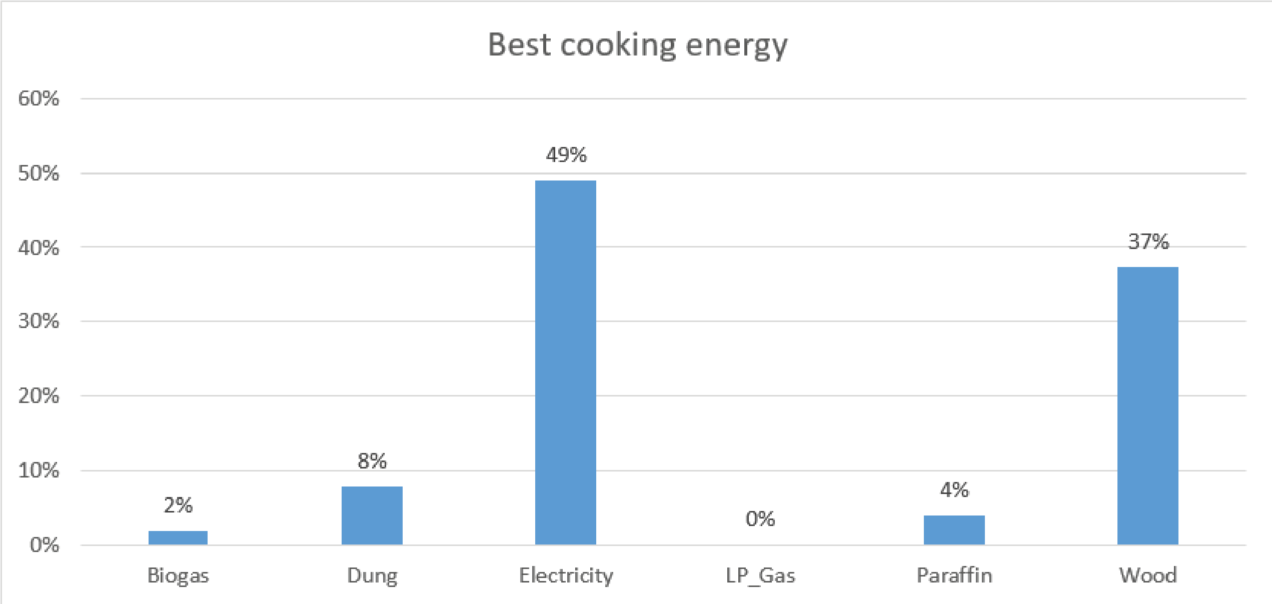
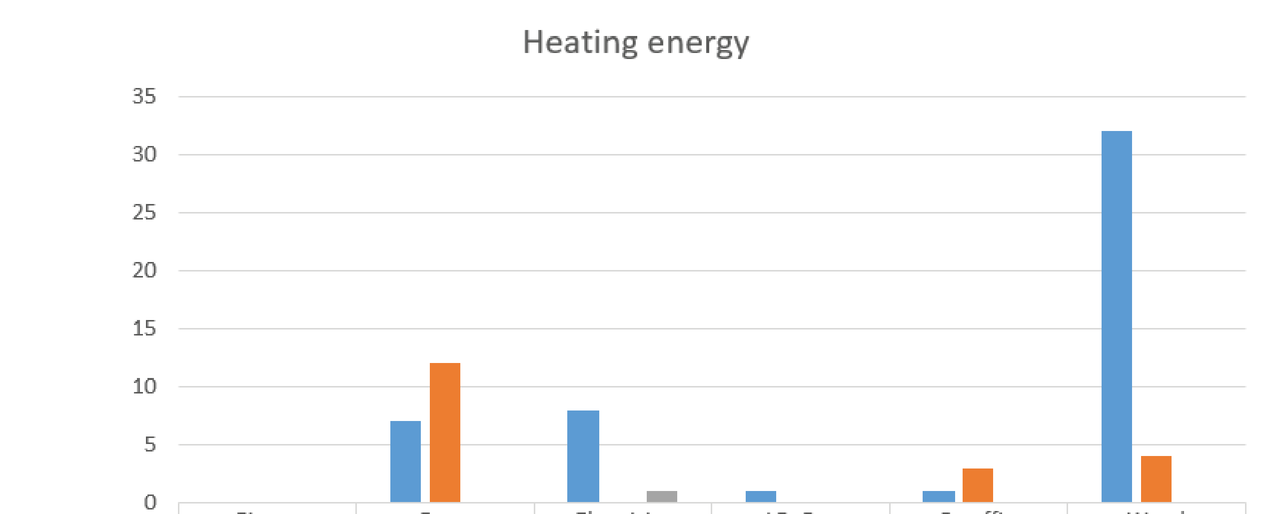


Figure 2.8: Most preferred energy type for cooking

Of those who chose electricity as the best energy for cooking, all noted that the reason for doing so was because it was faster and/or more effective. Others recorded that it was clean and safe. The reasoning for choosing wood was more diverse with respondents noting that it (i) was dual purpose (i.e. could be used for home heating and cooking), (ii) was cheaper, (iii) was accessible, (iv) was faster, and (v) was known – "I am used to it, I grew up using wood so I am comfortable with the use". Those who chose dung all noted that it was simply cheaper (or free), while paraffin and biogas were noted to be better/quicker than wood.

2.1.2.7 Energy used for thermal heating

Figure 2.9 shows the distribution of households using different energy for heating their homes. Wood was most widely used by households (60% of households) as a primary thermal heating energy. Electricity and dung were used by 15% and 13% of households respectively. Only 39% of the sample group recorded using a secondary fuel for heating, and only one noted a tertiary energy. This is likely owing to the fact that thermal heating is not a persistent necessity, and therefore reliability issues pose only a minor inconvenience. Dung was the most highly ranked secondary source of energy for heating.



	Biogas	Dung	Electricity	LP_Gas	Paraffin	Wood
Primary	0	7	8	1	1	32
Secondary	0	12	0	0	3	4
Tertiary	0	0	1	0	0	0

Figure 2.9: Types of energy used for heating

The choice of a most preferred energy for heating was relatively congruent with the actual use thereof. Figure 2.10 shows that 61% of households believed wood to be the best spatial heating energy, while 22% selected electricity and 10% chose dung.

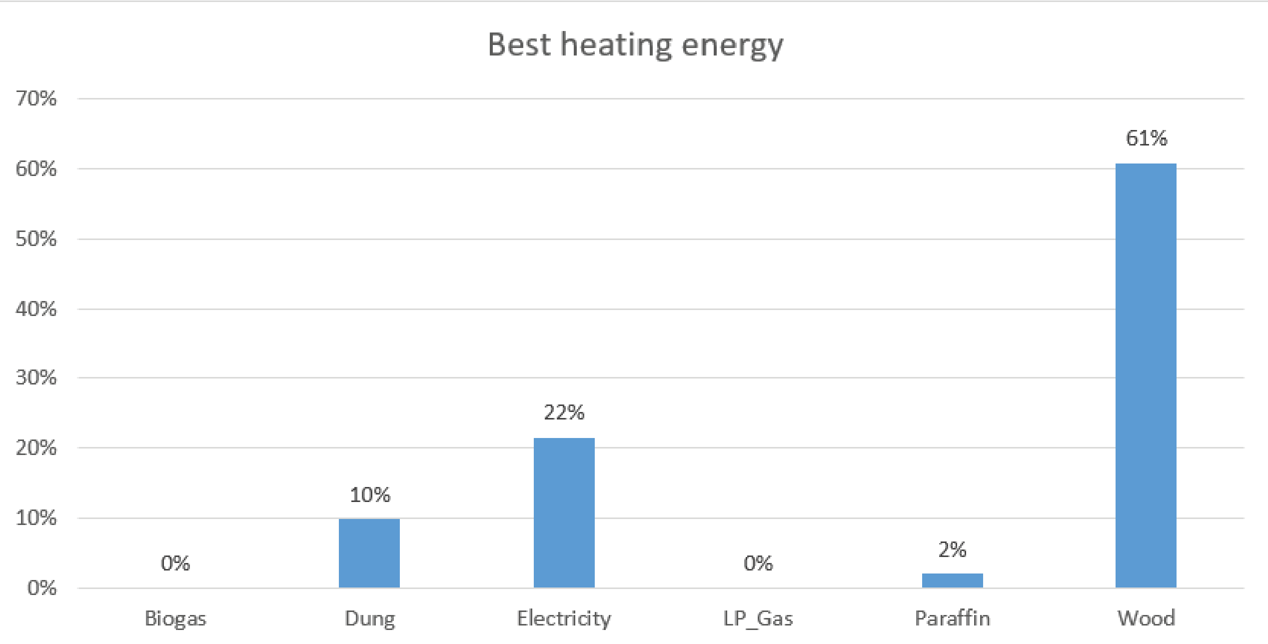


Figure 2.10: Most preferred energy type for heating

Those who chose wood as their preferred energy for heating were divided in their reasoning. Most people (38%)[7] stated that it was the most efficient (i.e. warmer and more effective), while the remainder felt it was more cost effective (29%) and more readily available (25%). Of the respondents who chose electricity, the majority believed it was the most effective/efficient source of spatial heating, despite some noting that it was expensive. Others noted its convenience and two people stated that it was their only available option. People who used dung recorded that that it was cheap and available.

2.1.2.8 General energy preference

Interviewees were asked to rate, in order of preference, what was the most important consideration in choosing an energy for their household. The responses were ranked from primary (most important) to tertiary (third most important). The results are compositely presented in Figure 2.11.

Primary reason for energy choice:
Fifty-nine percent (59%) of households stated that effectiveness/efficiency was the most important consideration when choosing energy. Twenty six percent (26%) stated that cost effectiveness (affordability) was the most important and the remainder marked ease of access as their key consideration.

Secondary reason for energy choice:
Households were evenly spread in selecting a secondary reason for choosing an energy with 28% stating affordability, 25% noting efficiency and 30% recording ease of access.

Tertiary reason for energy choice:
Only 49% of the respondents recorded a third order ranked reason for choosing an energy. Of these, ease of access was noted as the most important tertiary reason for choosing an energy.

General assessment:
Some of the other reasons noted by the respondents for energy choice were convenience and reliability. Although these were not expressly offered as options, interviewers were asked to seek an open response first, and then prompt with the options as well as noting the option to choose 'other'.

The responses gained from the survey correlated closely with those recorded at the community workshop (see Section 2.2). It was surprising to the researchers that efficiency of an energy was ranked more highly than affordability in both cases given that the community generally has limited monetary resources, and affordability would therefore be expected to ultimately dictate final choice. This noted, it is possible that the participants rated the energy choices according to their immediate experiences and ease of use rather than thinking of the long term costs.

As noted, reliability and convenience were not expressly stated as rank options, and given the repeated importance of these characteristics at the community workshop, it appeared that a question bias might have distorted this result.

[7] Percentage of the captured responses to the question.

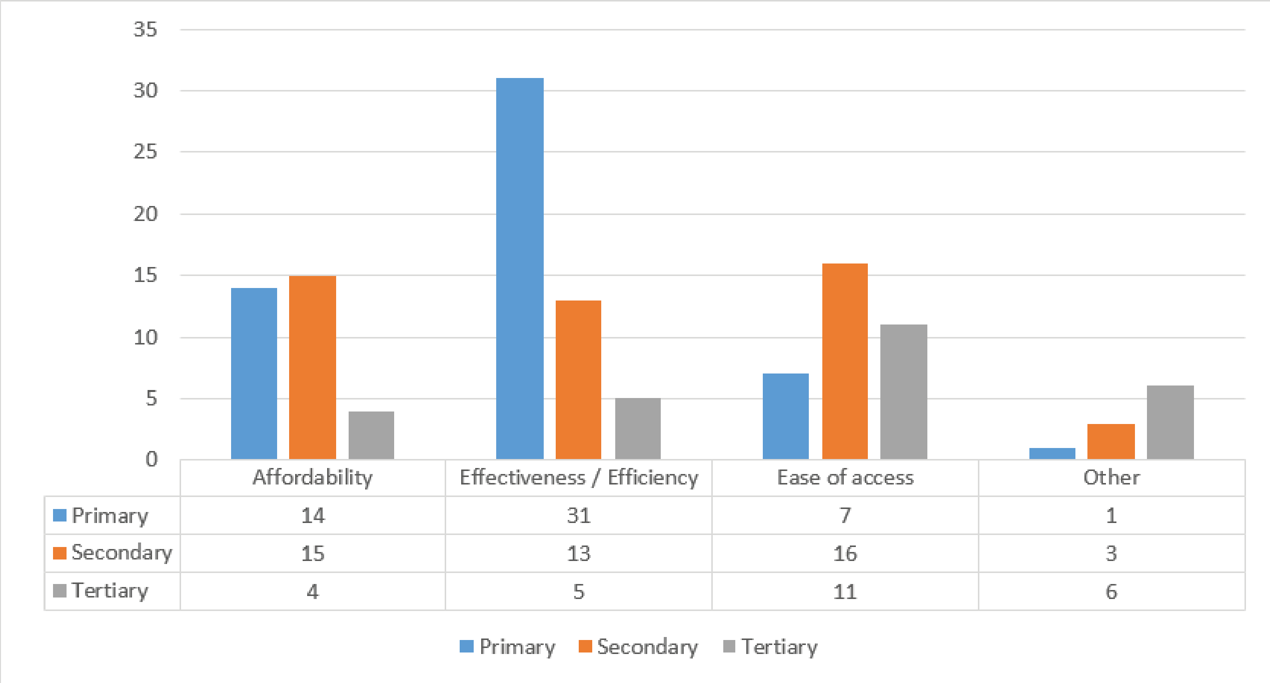


Figure 2.11: Reasons for choosing energy

2.1.2.9 Response to Green Village and Renewable Energy survey

A separate questionnaire in the survey aimed at identifying whether the community had any knowledge of a Green Village concept, or of renewable energy in general. It also aimed to ascertain what some of the greatest problems in the area might be, to assist the research team in developing mechanisms to address them.

Knowledge of a Green Village and Renewable Energy:

When asked whether the interviewees had heard of a Green Village or this concept, only one respondent noted that he had (Table 2.8) – and he stated that he "thought it was about growing crops". Forty three percent (43%) of the respondents had heard something about renewable energy. The perceptions of these respondents are recorded in Table 2.9, with the most predominant response noting biogas as a type of renewable energy. This is not surprising given the presence of a biodigester in the village and the research project focused on it (WRC project K5/1955).

Table 2.8: Response to questions regarding a Green Village and Renewable Energy

Have you heard of a Green Village or the concept of a Green Village?	**Yes**	**3%**
	No	**97%**
Have you heard of renewable, sustainable, or alternative energy?	**Yes**	**43%**
	No	**57%**

Table 2.9: Perceptions of renewable energy

Perceptions of renewable energy from the 25 households who had heard of it
• Good because they can be used even when there's load shedding • To save electricity • I heard that biogas produces bioslurry which can also be used to improve soil fertility • Solar can be used for lighting and to heat water when there is a geyser • It is good • They are expensive • Biogas is a substitute for cooking with electricity • Solar use sunlight and you use a car battery to convert it to usable household energy • Good energy sources • Substitute electricity • Biogas is safe to use and cost effective, electricity is expensive and we have high unemployment rates • You can convert the energy to household usable energy such as lighting and charging phones • Biogas is a renewable energy • I know it uses sunlight energy which is converted using a battery to household usable energy such as lighting and charging phones and cooking • Biogas can be used in place of electricity for cooking • Heard the word but know nothing of it • I have heard that there is a house that uses biogas and it produces waste used as fertilizer • Can be an alternative to electricity • Biogas • I heard that you pour cow dung in the tank and it produces gas for cooking • Biogas is renewable energy • About alternative energy • I heard that you can produce energy from dung and use it for lighting • Not clear • I have only heard the name

Following the enquiry into peoples' knowledge of renewable energy, the interviewers described what was meant by renewable energy using examples to explain what it was. The interviewees were then asked if they thought renewable energy could work in the Mahlabathini village. Eighty percent (80%) of the respondents believed it could work and was a good idea for the area, and of these respondents 48% proposed biogas as an appropriate energy and 53% suggested solar energy would work well. Some households noted the biogas would only be available to people who owned cattle and therefore believed solar was a better renewable energy for the village. Another household expressed their concern about solar as they understood it wouldn't work well on rainy days.

Food, water and energy access:

Households were asked whether they believed they had sufficient energy and water to meet their daily needs, and whether they could produce enough food in their gardens and farms to feed their families. Fifty-six percent (56%) of the respondents believed they had sufficient access to energy and water, while only 25% believed they could live self-sufficiently on their farms. At the time of the community workshop the local community stand water pump was broken, and water access was a significant problem (one month after survey). It is expected that the response to "sufficient water availability" might have been largely different, and this raises concern over the fragility of water supply in the area.

Table 2.10: Response to enquiry into food, water and energy access

	Yes response
Sufficient Energy	56%
Sufficient Water	56%
Sufficient Food Grown	25%

Household management problems:

Interviewees were asked to rank, in order of most to least important, the household or living management problems that affected them. Figure 2.12 summarises the responses of their ranked allocation.

Under the first order rank 48% of households recorded access to water as their biggest household management problem. The cost of energy was ranked second (19%) and access to energy third (10%). Food shortage and soil erosion were also noted as highly ranking household/living management problems.

With respect to second order ranked management problems, energy costs (22%), access to water (20%), access to energy (16%) and soil erosion (16%) where most highly ranked.

Cost of energy was the most highly ranked third order (tertiary) household management problem (31% of households who recorded a third order rank). Nineteen percent (19%) noted food shortage as a third problem, with 12% recording both access to farming equipment and access to energy.

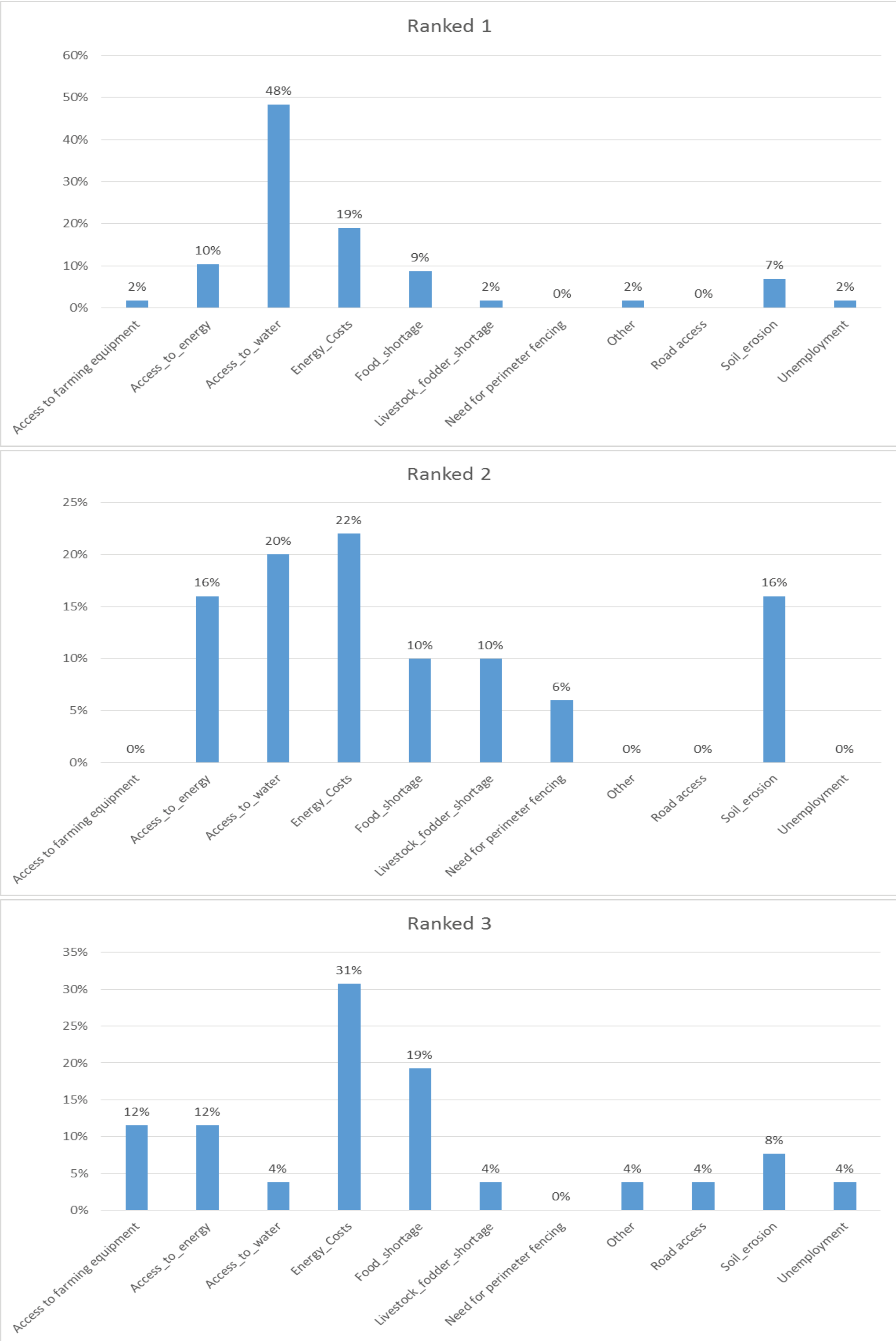


Figure 2.12: Household management problems by rank

2.2 Community workshop: community visioning of a green village in Mahlabathini

2.2.1 <u>Workshop attendance</u>

The workshop was attended by 40 community members.

2.2.2 <u>Introduction, objectives and background to the workshop</u>

Before embarking on the workshop, the tribal councillor (Mr Masengemi from Mahlabathini) welcomed the team. He indicated that he would be attending the tribal council meeting the next day where he would report back on the progress the community was making to uplift their livelihoods.
The main objectives of the workshop were:

- To determine the community's perception of a Green Village
- To assess energy types used by the community (e.g. electricity, biogas, LPG, fuelwood, charcoal, crop residues and animal dung);
- To get an indication from the community in terms of value, cost, safety, convenience, efficiency and practicality to households;
- To rate the quality of these energy options;
- To determine constraints to improving energy access; and
- To identify other technologies the community have heard about or would like to test (e.g. energy saving stoves, Wonderbags, etc.).

The team presented the background to the research project, citing previous projects that have pioneered an interest to conduct more research in Okhombe. This new research project would explore solutions to upscale the WRC Biogas and Water Harvesting project from household level to a whole village. This approach allowed the team to progressively move to the GV discussion.

One of the comments from the participants indicated that there was an interest to find affordable energy alternatives. For example, Mr Hlongwane stated:

> "*My wife has to go far away to collect the wood for our household as I cannot afford electricity. I am interested to find out how together with other community households that are struggling like myself, can get support to plant and reproduce resources (trees) for firewood. If that is not possible, how can we, like the Khumalo household, access biogas digesters so that we do not have to install electricity which we will not be able to afford anyway even when it is there?"*

Mr Mabaso asked whether the project could also *"address ways of using energy more effectively and saving energy as we have problems with electricity not working for long periods?"*

2.2.3 <u>Community's interpretation of the 'Green Village' (GV) concept</u>

Participants were asked if they were familiar with the term 'green village' and if anyone could describe how they understood it. No-one present had heard of a green village.

On brainstorming what it may mean, the following responses were given by participants:

> *"It is where our cattle can graze freely, and we are just relaxing. Right now we are in the desert – the Green Village has abundant water for everyone*" (Mr Mabaso).

> *“It is where cattle can feed and have sufficient food. That place has good life, and is not only benefiting one person or for a few people …. People are supporting each other. There is a sense of working together; to make sure that everyone has the good life. Finding a better and cheaper alternative to energy than electricity is part of this good life”* (Mr Masengemi).
>
> *“The Green Village would have communal gardens. At the moment the gardens don’t have any water, so we are struggling. The communal gardens in the green village should not only provide for consumption but also for marketable products” (Mrs. Shabalala).*

Following acknowledgement of the interpretations given by participants, the community were asked if there was any direct translation of some of the interpretations given, to isiZulu. The participants collectively reached a consensus that “amadlelo aluhlaza” (greener pastures) best described how they envisioned the green village. After the facilitator posed a question whether ‘amadlelo’ was not associated with cattle grazing land, some of the participants connected ‘amadlelo’ to the ‘green pastures’ which is broadly how they viewed the green village.

2.2.4 Revisiting Okhombe community visioning

Participants were then presented with one of the visioning diagrams (Figure 2.13) that the Okhombe community had drawn in 1999-2000 to depict what the community would like to see in the area in five years. A number of people present at the workshop were involved in drawing the picture 15 years ago. The diagram was used to demonstrate that what the people drew in 1999-2000 was actually a GV. On the diagram the following were illustrated:

- People had water that was piped to their households;
- The cattle were grazing the plentiful grass;
- People were working in community gardens which produced enough food to eat and sell to make money;
- Fields were ploughed by livestock for crops;
- Erosion gullies were fixed;
- Trees were grown for firewood;
- There was enough firewood to be harvested by women for energy; and
- People were talking to each other indicating that they were happy

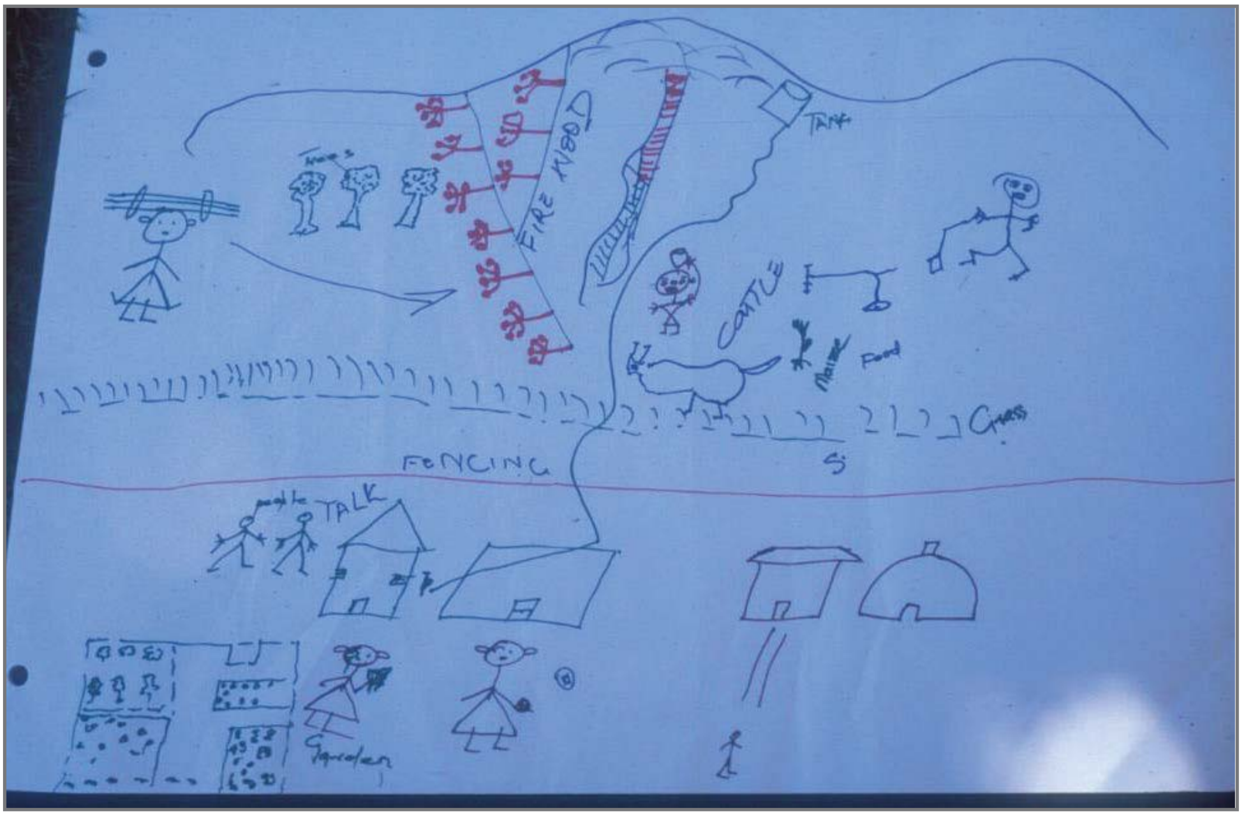


Figure 2.13: A visioning diagram produced by participants during Okhombe Landcare visioning workshops (1999-2000)

The facilitator noted that something had changed since the visioning workshops and asked what people thought this was. One of the participants indicated that now there was electricity. Another participant stated that now there were few trees for firewood.

Participants were then handed out a green village photo which was developed in Nepal (Figure 2.14); this was used to explain how the GV concept worked. It was noted that the biogas that was featured in the GV was similar, but not the same as the one installed in one of the community member's household. A debate was then held about how a GV integrates various aspects: water, food, fodder, and energy into village life.

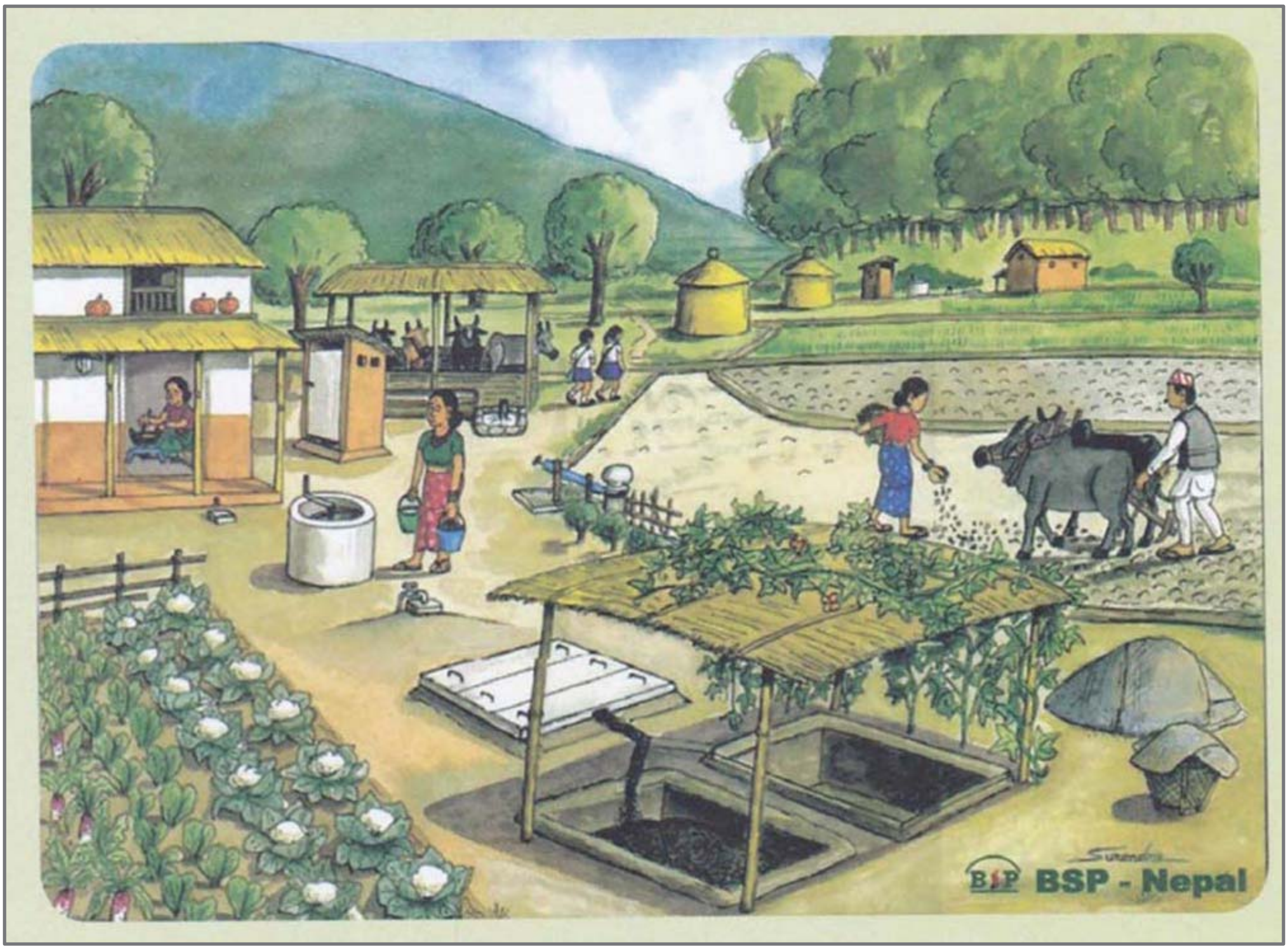


Figure 2.14: A depiction of a "Green Village" (source Biogas Sector Partnership – Nepal)

2.2.5 Which energy types does the community use?

The facilitator initiated a brainstorming session on energy choices available to the participants. The following choices were given:

- Candles
- Paraffin
- LP gas
- Dung
- Solar (for lights not for cooking)
- Electricity
- Firewood (the participants highlighted that firewood is not available anymore, and that people often use dung instead; they also indicated that a bakkie full of wood costs R1000 and lasts less than one month in winter)
- Biogas (the people have noticed that the household that uses this type of energy in the community saves a lot of money as they do not have to use a lot of electricity.)

2.2.6 Advantages and disadvantages of energy types

The participants were then divided into five focus groups of eight people each (40 in total). The groups were asked to discuss each of the energy choices that they had come up with in the brainstorm session and to outline the positive and negative factors of each. The leaders were asked to report back to the Workshop. Overall, the following were reported back:

Energy choice	Positive	Negative
Biogas	• Can be used to cook • Have heard it can be used to cook and boil water, and iron • Don't have to pay • Each HH should have a vegetable garden. But don't have water which is transferred to JHB. • They are a deserted village. • Can use biogas for cooking and lighting – there is no shut down	• Does not depend on weather. Works when it rains • No negatives as don't know much about it • If you don't have cow dung it doesn't work • As it is integrated it has benefits like water and fertilizer • No negatives
Electricity	• They like it because they can easily light up their HH. • Readily available. • Can use for appliances, e.g. TV, etc. • You can perform a lot of activities with electricity • Can be used for cooking, lighting and charging, etc.	• When windy they experience challenges as it does not work; • If you have no money you can't afford it • If there is lightning it doesn't work. • It can shock people. • Load shedding is a problem • It doesn't warn you when load shedding so you get caught out • Expensive • Expensive • It is costly, it shuts down, it is weak when it is raining
Candles	• Has multiple uses, e.g. floor polish and light • Can be used for light and floor polish • Light and floor polish •	• It is costly because they run out quickly and you have to keep buying them • It has burnt a few HH so dangerous • Dangerous if left unattended as can burn whole HH • Expensive from Bergville – transport and cost
LP gas	• Very useful especially as a supplement to electricity especially at funerals • Quick • Can be used for cooking	• Very expensive • Need to be very cautious when using it • Dangerous • Expensive from Bergville – transport and cost • Dangerous, it bursts, it decreases oxygen to humans
Paraffin	• Can also be used for polish if mix with candle wax and light • Used for cooking and in lamps • Cooking and light • For cooking when the power is shut down	• Expensive • Expensive from Bergville – transport and cost • Produces smoke • Dangerous as children drink it thinking it is water • Dangerous • Too expensive R13/litre
Cow dung	• Useful in winter but not in • summer when wet • Can be used for floor polish as well as cooking • Floor polish, cooking • Cooking and heating	• It has a strong smell • Not available in summer • It is wet in summer • Can't use it in summer as it is wet •
Solar	• It has multiple uses • Lighting and charging things • Can be used for charging and lighting	• If no sun can't generate it. • Doesn't work if no sun • If no battery doesn't work • Only works when the sun is out as takes power from the sun

2.2.7 Energy ranking exercise

The participants then formed three groups to rate the different choices of energy using the following energy development indicators where 5 was the most important and 1 was the least important. The participants used matches to represent their rating of energies along the indicators as presented in Plate 2.4.

Plate 2.4: Energy ranking exercise using match sticks and a criteria matrix

The participant's rating was presented by the groups as follows:

Energy development indicators	Group 1	Group 2	Group 3	Average
Reliability	5	3	5	4.3
Accessibility/availability	1	1	2	1.3
Affordability	3	2	1	2
Efficiency	4	4	3	3.7
Convenience	2	5	4	3.7

This was followed by an interrogation of the participant's results, especially the low "affordability" indicator rating of two (2) which contradicted the concern about costs in the earlier discussions. The community responded that in their minds they were thinking of biogas which they are aware is not expensive, and hence they had not considered themselves using other forms of energies.

The facilitator then requested that the participants repeat the exercise, focusing on the currently used energies to present a realistic situation. The groups' new ratings were as follows:

Energy development indicator	Group 1	Group 2	Group 3	Average
Reliability	4	5	4	4.3
Accessibility/availability	3	1	3	2.3
Affordability	5	4	5	4.7
Efficiency	2	3	2	2.3
Convenience	1	2	1	1.3

2.2.8 What individual households pay for various energies

In a plenary session, participants were asked how much they paid for various energies that they currently use. The figures were brainstormed as follows:

LP Gas	R80 / 7 litre
Paraffin	R80 / 5 litre
Electricity	This was not asked
Candles	R13.95 for 6
Firewood	R50 / wheel barrow R1000 / bakkie (there was variation amongst participants)

The facilitator then handed blank papers to each individual participant and requested each household to write how much they spent per month on each energy option. Households were also requested to indicate (with a zero) where they do not use a particular energy. The following costs were presented:

LP gas	Electricity	Candles	Paraffin	Firewood
R500 for 50 kg (2 mnths)	R150	R48	20 L, R360/1 month	Winter R1000 and summer R350
R350 for 9 kg	R200	R27.95	25 L , R325 (1 month in winter and 2 months summer)	Winter R1000 summer R700
R90 for 8 kg	R0 (no access)	R13	R26/ 2 litres	R1000 for 3 months in Summer and 1 month in Winter
R250	R200	R13	R160/month	R1000 for 1 month Winter and 2 months Summer
R350	R250	R28 for 2 months	R26/2 litres	R1000 in Winter 1 month and 3 months in summer
R0	R100	R120	R13.50/1 litre	R200 summer, R1,200
R200	R400	R14.95	R360/month	R1000 in winter and lasts 2 months in summer
R160	R200	R25	R320	R1000 for 2 months in summer and 1 month in Winter X3 persons said this
R300	R150	R13	5 litres/R55.95	R1000 Winter and 3 months summer X2 persons said this
18 kg for R345	R100	R13	2 litre/R26	R800 Winter, and R100 in Summer
9 kg for R350	R800	R13.95	10 litres/R145 month	Winter R1000 per bakkie
R350	R300	R13.99	R60	R1000 per bakkie
9 kg for R350	R600	R13.95	R80	R0 collects in the area
13 kg for R500	R150	R50	20 litres/1 month/R350	R1,500 bakkie 1 month in winter and 3 summer
13 kg for R550	R200	R37.95	20 l, R100	R700 winter
10 kg, R120	R250	R46.50	2 l/R26	R700 winter
7 L for R160	R100	R47.80	20 l/R360	R500-R800
7 L for R180	R400	R100	20 l/R260	R1000
50 kg for R200 (1 month)	R200	R100	R200-R750 winter and R100-R400 summer	R500
R200	R150	R48	10 l/R160	R1000/6 months
50 kg for R500 (2 months)	R100	R28	5 l/R85.99	0
19 kg for R495	R50	R35.95	R220	0
R100	R100	R100	R200 summer, R400 winter	0

2.2.9 <u>Way forward: selecting the research site (households) for energy technologies</u>

The facilitator asked how the households should be selected to test the different energy technologies. The following responses were received:

- The community meet together and vote for which houses are needy.
- Choose a central house where everyone can view the new technologies

A consensus was agreed whereby a community meeting should be held where everyone votes for needy households.

The workshop was adjourned, noting the main outcomes as:

- The community had a better understanding of the green village concept.
- The most important indicators for the community's preference of an energy option was "affordability" and "reliability".
- The community was prepared for the research phase of the green village project and would report on the project progress at the Amazizi Tribal Council meetings; and
- The community would arrange a meeting to identify the needy/poor households to implement the pilot phase of the GV project.

CHAPTER 3. TOOLBOX OF GREEN OPTIONS FOR RURAL ENERGY

3.1 Introduction

The aim of this chapter was to present a tool box of potential green energy solutions for the rural areas of the Upper Thukela region. The report comprises a conceptual framework that includes the following:

- Key considerations from the baseline survey and questionnaire
- Highlights from an expert workshop on energy options
- A review of potential green technologies
- Criteria for suitability and testing

3.2 Background to report – community survey and workshop

3.2.1 Community survey

As described in Section 2.1, a community survey was conducted in Mahlabathini on July 2015. Fifty-three households, representing 71% of the village households were surveyed to gain knowledge of their energy use practices, choices and preferences.

The community survey gave valuable insights into the energy use practices and needs of the community members. While some of the findings were ascertained through direct questioning, others were more qualitative in nature and came as a result of generalised discussion, stimulated through the survey process.

3.2.1.1 Key and relevant findings

Use of multiple energy sources:
Only five out of the 53 households surveyed in Mahlabathini did not use more than one energy option for cooking at their households. Figure 3.1 summarises the reasons for using multiple energies for cooking[8]. The leading reasons for requiring multiple energies for cooking are "lack of availability" and "back-up required", with 38% and 24% of households stating that these were the primary reasons for needing to have and use more than one energy option for cooking.

Lack of availability represents a summary of responses which stated that firewood and dung were often not available for use, and that electricity was often unavailable due to load shedding and unreliability of service. With respect to firewood, it is noted that little firewood is available (collectable) in the area, and households are required to purchase it from external sources (Smith, 2011; Smith, pers. obsv., 2015). It was explained to the interviewers that dung was generally available in winter when there was little rainfall, but when it rains cattle dung could not be collected.

The general feedback was that energy alternatives were critical for households, as they could not rely on the one energy to provide for their needs at all times. This is a finding that was reiterated during the community visioning workshop.

---

[8] Note: we use cooking as the key example here as it is a critical requirement at all households and therefore offers the most relevant finding.

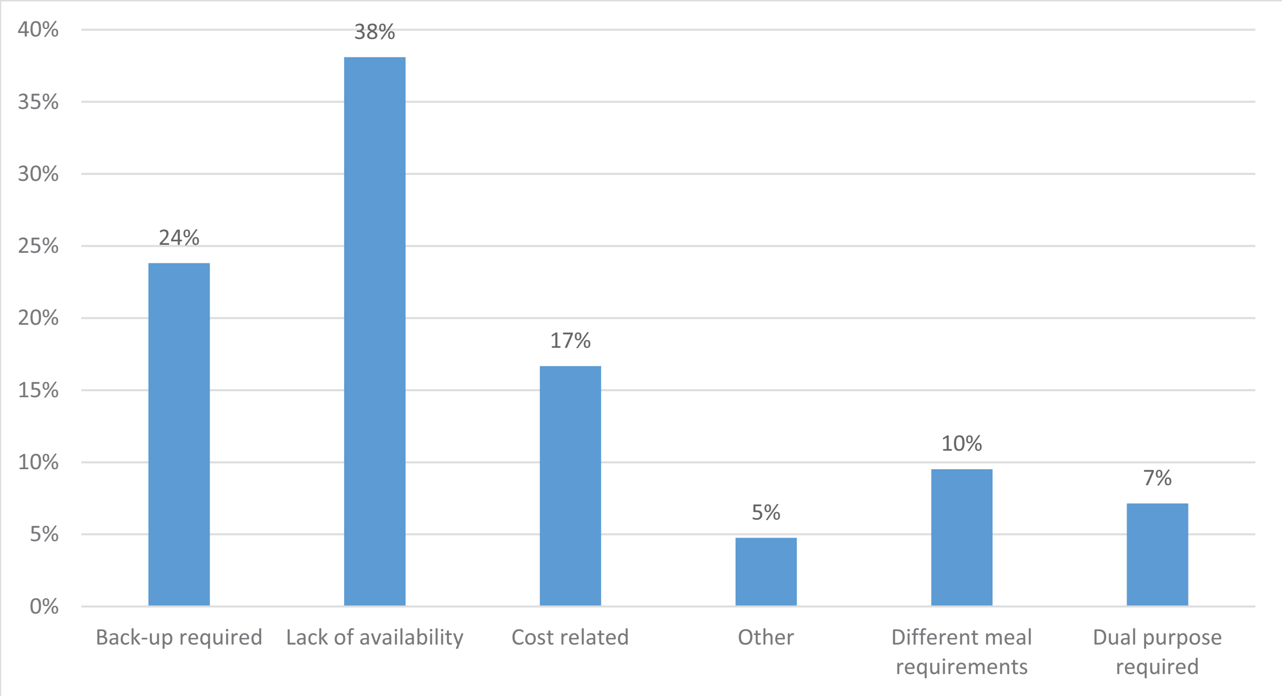
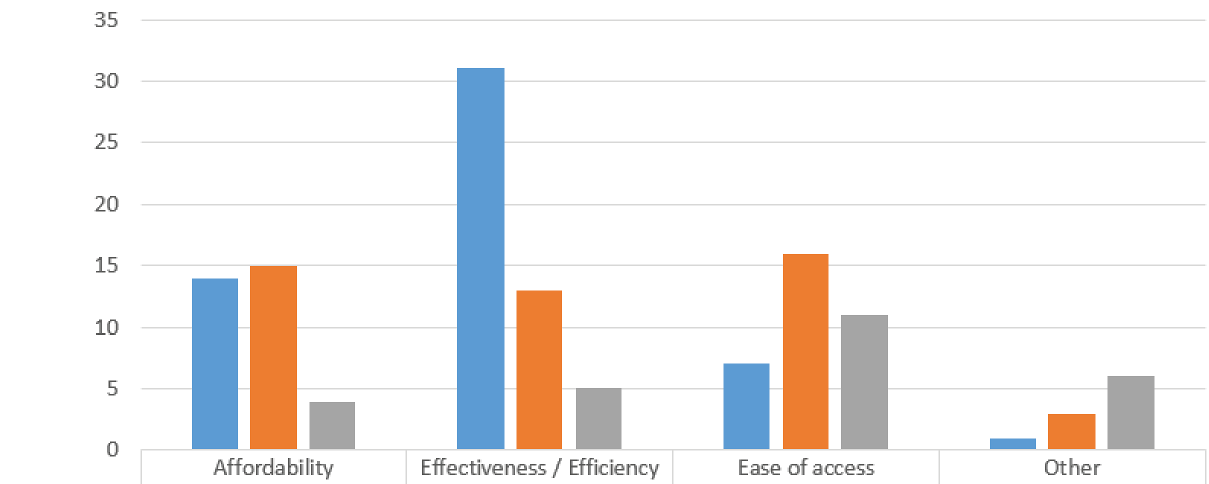


Figure 3.1: Reasons for using multiple energies for cooking

Cost of energy:

As can be seen in Figure 3.1, cost related considerations were also key in requiring multiple energy sources. For example, households explained that they were often required to source wood, dung or other sources of energy when they were unable to afford electricity.

This finding was strengthened by the response to questioning what people's specific reasoning was for choosing a particular energy source. Figure 3.2 displays the response to this question and shows that affordability (i.e. the cost of an energy option) was a key primary and secondary reason for choosing energy.



	Affordability	Effectiveness / Efficiency	Ease of access	Other
Primary	14	31	7	1
Secondary	15	13	16	3
Tertiary	4	5	11	6

Primary Secondary Tertiary

Figure 3.2: Reasons for choosing energy

The relevance to this report is that energy costs are a problem for people of Mahlabathini. This finding is supported by research conducted in 2011, which identified that a significant portion of household stated incomes was spent on energy (Smith *et al*., 2014).

3.3 Expert workshop and interviews

3.3.1 Report on expert workshop

An expert workshop was held in November 2015 to generate knowledge, develop ideas and get feedback from experts in the various government departments and organisations on the most appropriate energy technologies to implement in this project. A summary of the process is outlined below and further details are included in Appendix 10.1.

1. Explanation of workshop purpose and expected outcomes.

The project team gave an outline of the link between the WRC K5/1955 project which determined the feasibility of implementing an integrated study on water, food and energy for sustainable livelihoods and the current WRC K5/2423 project which focuses on energy options for rural communities. The agenda was presented and the purpose of the workshop and expected outcomes were explained.

2. Presentation of project activities so far, and feedback from workshops and surveys in Okhombe.

The progress in WRC K5/2423 project was presented including the results of the android cell phone based survey. This was a good learning experience in which the team interviewed 110 households with 53 based in Mahlabathini, the proposed Green Village site. The interviewees ranged in age from 21-80, and were mainly female. The water sources graph was presented and related to the current situation in Mahlabathini where the community stand tap has been broken for a month and people have to walk up to two km to get water.

3. Implementation options for a small scale pilot study in a rural area. Advice on best practice.

There was considerable debate on the amount of biogas produced by biogas digesters. Workshop participants stated that you can increase gas production if you double manure and water inputs. However, biogas production is related to microbes so one needs to be careful about changing the conditions in the digester. The microbe cultures cannot cope with huge shocks. At different temperatures you get different colonies that can't take temperature change. One way to increase production is to purchase a "kickstart" culture that has the best microbes. One can also develop one's own culture to start off a digester. Another option in winter is to recycle some of the waste.

Biogas digesters can also be used for sanitation. In terms of green sanitation options, one can also use low-flush toilets.

The process of selecting households that will benefit from implementation of the different small scale off-grid energy options was discussed. The community selected the households based on criteria such as poverty and ability to engage in the project.

4. Technology options for testing: energy, food and water with a focus on energy for cooking, heating and lighting.

Agama suggested a number of options:

- The project could try small wind turbines since the area has high winds. The most suitable turbines would be small wrap-arounds which cater for wind in different directions. This has a vertical motor and it was advised the options from Kawasaki be explored (units ranging from 500 W to 15 kW output capacity)
- Solar thermal water heating systems were also suggested as potential options with a cost of approximately R6 500 (not installed).

- Solar home systems can be used for lighting and energy for TVs and radios. There are new solar panels which are dual with a PV panel on top and a water heater below. Above 60 degrees it is efficient.
- Micro water turbines may be suitable in the area and can run on a 110 mm pipe. It can feed into a battery pack and just needs a controller.
- Wood pellet stove – This stove which needs pellets has potential as a small business as the pellets can be imported into the area and sold.
- There are other small clean burning stoves on the market that need to be tested. Some provide a USB port with energy for charging cell phones and an LED light.
- The SANEDI RECORD delegate stated that another option is a fold-up solar cooker that works very well. The panels open up to capture solar energy and it uses no fuel at all. The panel that supplies power to the house is popular. One can train people to implement and operate these systems which are both user-friendly and environmentally friendly.

It was clear from the discussion that one needs a composite solution to address all the household energy requirements, not just cooking.

5. Post research planning – how best to deliver findings to the right audience, and who that audience should be. Advice on how to take initiative through to government.

- The centre manager of RECORD, SANEDI outlined the current energy projects that are being carried out by Working for Energy. The focus is on biogas digesters and 100 have been rolled out already in the Eastern Cape. The system comprises a big digester which is built underground with brick. This creates a business in the community where people are trained on how to build and maintain the digesters.
- The SANEDI centre manager recommended working with the Department of Energy programme to get government support. Lessons learnt from the Lucingwini project in the Eastern Cape could also be useful. The concept is a micro-grid comprising 3 turbines and converters for wind and solar energy. The aim of the project was to put in a rural off-grid system. However, it was not well received. The systems were built to take a certain amount of power but couldn't cope with the community's needs. In addition, the community associated the implementation of the project with the drought and blamed the project for lack of rain. As a result, it was vandalized although some PV panels and inverters were rescued. An important lesson was that the community needs to accept the project before it starts.
- There is now a national biogas platform sponsored by SAPPI. This is a good way to reach out to a lot of people and have a lot of input.
- A company called EcoVest Holdings have a home energy solution with support from the Department of Environment Affairs (DEA). They manufacture solar solutions for off-grid use. They have a PV panel to supply energy for a TV and cell phone. Their model fits well in SA. The project team were recommended to contact EcoVest to learn more about their model.
- The WRC needs to get Water Affairs on board. Other government departments are the Dept. of Energy, the Technical Dept. of Thukela and South African Local Government Association.

It was concluded that the project needs to look at multi-solutions to energy requirements and several government departments should be contacted for potential input into the project.

3.3.2 Report on energy, community project experts

Further to the expert workshop, a number of experts with direct experience in rural development and specifically renewable energy applications, were contacted for their advice on a number of key aspects related to implementation of technologies in rural areas. The experts interviewed for this purpose were:

- *Tony Lopes (Lowtech.co.za)* – extensive experience in the application of 'low tech' sustainable solutions for rural and peri-urban areas, as well as experience in conducting training seminars to assist people in developing their own green options.

- *Warren Confait (Renen Energy Solutions)* – an owner of a renewable energy specialist company, and an engineer with direct experience of biogas application in rural areas (amongst other technologies).
- *Gray Maquire (Project 90x2030)* – extensive experience in the application of rural development projects and addressing community needs through community visioning workshops and associated processes.

The experts were asked for their advice specifically on what to consider implementing for research, how to select these technologies, and how to conduct the implementation process. The following broadly categorises some of the feedback from this process:

3.3.2.1 Key considerations when choosing implementation technologies

A variety of valuable suggestions were made with regard to the choice of technology to support rural development, and specifically for this project, the choice of technologies that can be tested.

It was advised that 'simple' or 'basic' technologies be chosen for testing first. The purpose for this being that people should (i) be able to maintain the items themselves if possible and (ii) should start with something small and be able to upgrade it if it is useful and serves their needs. Further to this, it was said that 'fancy' or highly advanced systems might offer good service, but were difficult to repair, and would likely also be expensive to maintain and/or replace.

In continuation of the above suggestions, it was advised that technologies specifically be chosen with the intention to have systems in place to support them into the future. The suggestion here follows the concept of SMME development in which, for example, a small local shop could be established to support a range of direct current (DC) solar systems, and appliances that worked with these.

Other suggestions were made to consider potential technologies from a holistic view of various aspects. One of the experts referred to an approach which he had first come into contact as one followed by the ENACTUS Organisation[9]. The system by which this organisation reviews technologies was explained to be three tiered:

- To consider the impact that the technology would have on the environment.
- To clarify the social impact that the technology would have on the users and local community.
- To understand the economic implications a technology would have, and simply how affordable it might be.

3.3.2.2 Key considerations when implementing rural development projects

The experts were asked to share any experiences they had that might assist in ensuring that the implementation process was conducted in a fair manner, but also in such a manner that the community 'bought into' the concept and that the research might have successful outcomes. Two key suggestions were made.

Community involvement:

It was strongly advised that the community should be engaged with and fully involved with the process, especially in a situation where only a small number of households would be partisan to the project implementation (as is the case in this project). It was further added that the research team should be careful to assist the community in selecting people who were diligent and committed to assisting the team in reaching clear project outcomes.

[9] http://enactus.org/ – En (entrepreneurial), Act (action), Us (Us).

Aspirational model:

The experts collectively advised that an aspirational model (in differing forms) be used to ensure success of the implementation and greater exposure within a community. This suggestion was described as a form of social engineering to ensure that successful technologies were supported by key leaders in a community who already had a level of aspiration attached to them and would therefore engender acceptance of a successful technology. This concept was explained by one of the experts by way of an example: it was noted that while a small solar PV lighting system might not have been seen as something to aspire to, if it were used successfully by a well-placed and respected member of a community, it was their experience that this would increase the likelihood that other community members would accept the technology.

3.3.2.3 Technologies suggested for potential implementation and testing

Finally, the experts where asked what technologies they believed might be valuable additions to a rural community and would therefore be worth implementing and testing under the project.

One of the experts advised that simple technologies, that could be made in the communities or at least installed and maintained by SMMEs would be first choice. The suggestion here was that sustainability would be a key concern, and that the technology could be supported well into the future. With respect to actual product suggestions, it was advised that solar PV be considered, and that efficient cook stoves be considered. The caveat to the latter suggestion was that the community situation should be considered first, and available resources (e.g. wood) should be taken into account when making this decision. Finally, it was advised that efficiency technology also be considered, specifically items like the Wonderbag[10] or homemade varieties of this thermal insulation cooking system.

Another specific suggestion was to consider installing a 'coke bottle solar water heater'. This technology was explained as being simple, cheap to establish and generally effective in delivering warm water for household requirements.

A final and generally accepted suggestion was that a range of products should be considered as a combined option for homes. This suggestion has been described as a 'composite solution' which responds to different household requirements with a range of technologies. The need for this was described as one that was prudent given the specialist abilities of renewable energy technologies to deliver on specific requirements, and to ensure that a household was afforded a robust variety of technology to support their needs.

3.4 Available options for implementation and testing

3.4.1 Solar photovoltaic (PV)

3.4.1.1 What it is and how it applies to rural settings

Solar photovoltaic cells convert sunlight into direct current (DC) electricity (Figure 3.3). Solar PV cells are typically made of silicon, although many different types and forms of solar cells have recently been developed and efficiencies have increased greatly since first development (Shanan, 2014). Although the science behind the process of solar electricity generation is complex, a simplified description explains the process that photons (light energy) initiate a flow of electrons within the solar cell, creating electrical voltage and current (NREL, 2014).

[10] http://nb- Wonderbag.com/International.

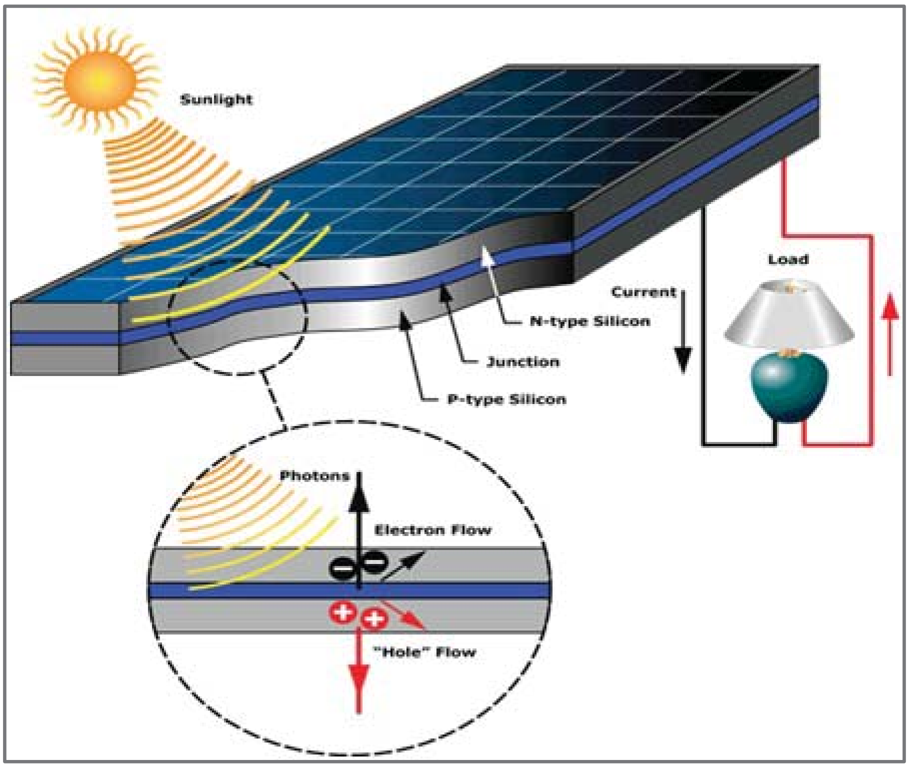


Figure 3.3: The basics of the solar PV process (source: 3rd Electric)[11]

Various types of domestic solar PV systems are available. The broad categories of systems are typically described as follows (Léna, 2013; The Green Age, n.d.):

Grid-tied: These systems are alternating current (AC) based and allow the user to be connected to both grid electricity and solar PV. Depending on the system and its installation, these can be used to feed solar generated electricity back into the national grid if own requirements of energy do not consume all generated electricity. Although this is practised in South Africa, it is not currently legal for low voltage connections and is only allowed on a case-by-case basis and in certain municipalities (Smith, 2015).

Off-grid/stand alone: Off-grid systems have no direct connection to the grid. They can consist of solar PV panels only, with energy being used as it is produced during the day; or, then can include battery systems which are charged by excess solar PV generated electricity, and the stored energy is used from the battery. These systems can either produce/use DC electricity, or an inverter can be used to convert the DC energy into AC.

Hybrid: Although definitions of this vary, a hybrid system typically combines solar, inverters, batteries and grid electricity. The grid can be used either when own consumption exceeds that being produced by solar, or can be used in conjunction with solar to charge battery banks. Battery power and grid power can also be used simultaneously. A hybrid system can also include another type of electricity generator (e.g. diesel engine generator).

Although domestic solar PV is generally used for, or in conjunction with, grid-connected electricity (i.e. grid-tied), the situation in rural areas – often without access to grid supplied electricity – is that of an off-grid system, usually requiring battery back-up to increase usability.

[11] 3rd Electric. 2012. Available at: [http://www.3rdelectric.com/solar-information] (Accessed 2016/01/26).

3.4.1.2 Response to needs in Mahlabathini

As reported in Section 3.2, it was clear that in Mahlabathini off-grid solar PV systems would be appreciated for perceived cost savings and to provide back-up or emergency power in case of electricity outages.

Most households in Mahlabathini have recently received electricity and therefore were able to share some of their needs with respect to it. Electrical lighting was commonly seen (96%) as the most effective energy for lighting a household. Other points noted in the community workshop were that people appreciated the ability to charge cell phones, listen to radios and watch television. It was generally understood that cooking and heating with electricity was expensive (i.e. high consumers of energy).

Taking these needs into account and having conducted a broad market review of the available options, it appeared that a small, off-grid back-up lighting and charging system would respond to the basic needs of the Mahlabathini community. It was suggested that a DC system be used, as AC systems are prohibitively expensive and can often be misused (i.e. AC appliances can be used with the system, and can overload and damage equipment and batteries [e.g. kettles, stoves, heaters]). At basic form, a DC system could be installed to include lighting and a cell phone charging station. A slightly more advanced system could make the use of DC appliances possible. It was noted, however, that DC appliances were difficult to find generally and were especially uncommon in rural areas (Smith, pers. obvs., 2016; Maquire, pers. comm., 2016). This realisation raised the opportunity for market development as a potential small business opportunity.

Considering these aspects, the team has conducted market research and identified the following options for potential implementation. It must be noted that a plethora of options are available and therefore the following presents broad ranges of these.

3.4.1.3 Options for consideration at Mahlabathini

3.4.1.3.1 Option 1: Entry level basic DC solar PV kit

Cost:	Approx. R500-R5 000
Description:	Entry level solar PV kits come in a range of types and sizes (Figure 3.4). These kits usually include solar panels, a charge controller[12], a battery (usually built into a pre-wired box) and lights, chargers, and other usage devices which are typically pre-wired with set cable lengths and connected fire USB or other jack points. The ability of these systems is limited although they do serve good purpose for lighting and charging cell phones.
Practicality, sustainability & maintenance:	• Practically, these systems are very easy to install and move from one location to another. • Not suitable for lighting a whole home or dissociated huts due to limitation of set cable lengths • Systems usually carry a 12-month guarantee – although the practicality of using this is limited in rural areas without established shops and support systems. • Cheaper systems are not expected to have long life-spans and would likely be difficult to fix/maintain in the event of faults. • Long term sustainability is not expected of these goods.
Possibilities for training, job creation, SMME[13] development:	• This group of technology could be sold at existing local stores, or by new SMMEs – thus supporting the development of small retail enterprises. • No opportunity for local manufacturing. • Beyond initial sale, there is expected to be no use for direct maintenance or continued job development opportunities.

Figure 3.4: Entry level basic solar PV kits (source: Sustianble.co.za[14])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini

These systems are considered to be a good option for an immediate, low-cost requirement for basic lighting and cell phone charging. They are not expected to be sustainable or offer economic development other than through first level retail. It is, however, believed that they should be implemented to gain community feedback on practicality and value.

[12] A device used to control the amount of energy being fed into the battery, so as to protect the battery.
[13] Small, medium and micro enterprise.
[14] Sustainable.co.za. Available at: [http://www.sustainable.co.za/solarq-lighting-solar-2-led-light-bulb-kit.html] (Accessed 2016/01/27).

3.4.1.3.2 Option 2: Basic, fitted DC solar PV kit

Cost:	Approx. R4 000-R15 000
Description:	A basic DC solar kit is intended here to be similar to an entry level kit, with more capacity and with wiring fitted to a house (Figure 3.5). The kit therefore still consists of a solar panel/s, battery/ies and a wired charge controller and control box, but this system can be made and adapted to the requirements of each home and can be wired throughout a home or homestead to provide basic lighting and some charging ports. The suggestion of a DC system is to keep costs down (AC inverters are expensive) and to avoid loading of the system with high energy using equipment (e.g. kettles and heaters)
Practicality, sustainability & maintenance:	• Practically, these systems require skill for development and design, but can be installed relatively easily by a trained individual. • From a use perspective, they are more practical as they can provide basic services throughout a home, and wired according to the needs in that home. • Well designed and built systems, with quality products are expected to have a reasonable lifespan. • Maintenance can be undertaken by a trained individual, and various items in the system can be replaced in the event of failures.
Possibilities for training, job creation, SMME[15] development:	• This technology offers a good level of training and SMME development possibility. The systems can be manufactured locally in communities and can be installed by trained local people. • The systems are likely to require periodic maintenance, which could also be supported by a local SMME.

Figure 3.5: Solar kit with internal, fixed wiring (source from left: Sustianble.co.za[16], AES[17])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
These systems are considered to be potentially very relevant and applicable to the situation in Mahlabathini. They would likely provide all necessary lighting for a home, and basic charging facilities – i.e. ideal for reliable, low-cost energy provision. It is believed that at least one bespoke system should be tested by the project and other, previously installed units should be reviewed by way of a case study.

[15] Small, medium and micro enterprise.

[16] Sustainable.co.za. Available at: [http://www.sustainable.co.za/solarq-lighting-solar-2-led-light-bulb-kit.html] (Accessed 2016/01/27).

[17] African Expedition Support (AES). Available at: [http://www.africaexpeditionsupport.com/napenda-solar-community/] (Accessed 2016/01/28).

3.4.1.3.3 Option 3: Basic, fitted AC solar system

Cost:	Approx. R4 000 upward
Description:	A basic AC solar system (Figure 3.6) only differs from Option 2 (described above) in that it includes an inverter to convert direct current into alternating current. Alternating current is the type of electricity supplied by the national grid. These systems allow for any appliances to be connected and used, and it is therefore important that fuses or breakers be installed to restrict people from connecting appliances that will overload the system, damaging the inverter and batteries.
Practicality, sustainability & maintenance:	• Practically, these systems require skill for development and design, but can be installed relatively easily by a trained individual. It is important, that system be understood and explained clearly to the user • For the user, they provide extended possibilities as standard AC appliances can be used. It is important, however, that the system be understood and that its capacity limitations be explained clearly. • Well-built and designed systems are expected to have a relatively long lifespan. If the system is not designed and used appropriate, overloading will damage inverters and batteries will not last long. • Maintenance is not expected to be extensive, but could be supported by a local SMME and would need to be conducted by a skilled/trained individual.
Possibilities for training, job creation, SMME[18] development:	• This technology offers a good level of training and SMME development possibility. The systems can be manufactured locally in communities and can be installed by trained local people. • The systems are likely to require periodic maintenance, which could also be supported by a local SMME.

Figure 3.6: Solar panels, batteries and an AC inverter (source: Sustianble.co.za[19])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
These systems are considered to be potentially very relevant and applicable to the situation in Mahlabathini. They would provide basic lighting and would provide an extension of other services. However, there is a big concern that the lack of local knowledge and understanding of the systems would result in people using the systems inappropriately with high energy use AC equipment. This situation would lead to damaged equipment and frustrations. Although they are considered to be valuable in the right setting, the cost is prohibitively expensive within the project budget and should rather be explored conceptually or through case studies of already installed systems.

[18] Small, medium and micro enterprise.

[19] Sustainable.co.za. Available at: [http://www.sustainable.co.za] (Accessed 2016/01/27).

3.4.2 Solar thermal

3.4.2.1 What it is and how it applies to rural settings

Solar thermal differs from solar PV in that it uses the energy of the sun to generate heat as opposed to generating electricity (SunWater, n.d.). Solar thermal energy is required in rural areas in the form of solar water heating. Solar collectors are used to perform this task and are a type of heat exchanger that uses solar radiation to heat a transport medium (usually water or oil). The solar radiation is absorbed by the collector and converted into heat – either to heat water directly or through another medium (like a copper element) over which the end user water is heated (Kalogirou, 2004).

3.4.2.2 Response to needs in Mahlabathini

The community survey conducted in Mahlabathini identified that all respondents heated water with over 92% doing so on a daily basis. The most common reasons for water heating were for (i) washing dishes, (ii) bathing, (iii) making tea – and these were shared by a significant majority.

It is recognised that sanitation is of key importance to development and has been expressly stated as a right that the South African government has intentions to deliver on: "It should never be forgotten that 'Sanitation is Dignity' and dignity is a basic human right" (DWA, 2009 cited in DWA, 2012). Further to this, it is generally understood that hot water plays an important role in personal hygiene and general sanitation (Adams *et al.*, 2009).

Solar collectors, either purpose built or low-tech home built versions, can be used to heat hot water in rural areas and can reduce the need for heating water by way of traditional methods (fire) or the costly use of electricity or other bought fuels. It is believed by the researchers and consulted experts that solar thermal water heating would benefit the Mahlabathini community greatly and should be explored through the project.

3.4.2.3 Options for consideration at Mahlabathini

3.4.2.3.1 Option 1: Low pressure solar geyser

Cost:	Approx. R5 000 upward (excluding installation)
Description:	A low pressure solar geyser (Figure 3.7) uses solar collector tubes to heat water directly. The water enters the tubes (usually glass), is heated by the sun, and moves into the geyser through heat convection. The system is not under external water pressure, and is usually placed on a house's roof – which provides sufficient pressure for use in a shower or tap below.
Practicality, sustainability & maintenance:	• These systems are easy to install and use in rural areas. The only practical limitation is the requirement of water pressure to get the water into the geyser on a roof (i.e. ground level tanks, below the geyser, are not sufficient). • At user level low pressure geysers are simple and simply require a basic explanation of the times of day when water can be used, to best optimise the system. • There are no moving parts in these systems and materials are typically robust and sustainable. Hail damage, or freezing are the only sustainability concerns. • In the event of hail or freezing which cracks/breaks collector tubes, maintenance is simple with trained users being able to replace tubes themselves or a local supply being able to perform the job. • Hail damage can be prevented partially by use of a simple protective shield (e.g. a frame with chicken mesh).
Possibilities for training, job creation, SMME[20] development:	• Low pressure geysers are easy to install and could be supported by a local SMME and trained local community members. This SMME is not likely to have a sustainable income, as these installations would be once off. It is suggested therefore that the SMME be involved in a range of services (e.g. solar panels and systems).

[20] Small, medium and micro enterprise.

	• Hail and other damage is likely to occur from time to time in Mahlabathini and other rural areas of the Drakensberg. It would be suggested that any local supply or SMME carefully consider the produce they are using and ensure that consistency of collector tubes be maintained so that local stock can be kept for all local geysers.

Figure 3.7: Low pressure solar geyser (source: Mistro Holdings[21])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
A low pressure solar geyser is considered, in theory, to be ideal for basic hot water requirements in Mahlabathini. Implementation of a unit would be valuable and testing should focus on the household's experience with the system's service delivery and fulfilment of their requirements.

3.4.2.3.2 Option 2: High pressure solar geyser

Cost:	Approx. R15 000 upward (excluding installation)
Description:	High pressure solar geysers (Figure 3.8) work similarly to low pressure systems, excepting that the end user water is not heated directly in the collector, but rather by a heat transfer element. The collector contains a fluid which is heated by the solar radiation and the end user water runs over an element which exits the tube. These systems are typically applied in urban settings where pressurised municipal water is available.
Practicality, sustainability & maintenance:	• High pressure solar geysers are complex to install and require a higher level of skilled technicians (relative to that required for low pressure installation). • These systems also require pressurised water, which is not available in Mahlabathini. • Sustainability is akin to that of a low pressure system, with the only main concern being damage due to hail or extreme weather conditions. • Maintenance generally requires a higher level technician as these systems employ electrically driven pumps and more complicated plumbing.
Possibilities for training, job creation, SMME[22] development:	• Considering the limitation that this technology requires pressurised water, it is not expected that any possibilities exist for implementation in Mahlabathini or other rural villages with no municipal water delivery.

[21] Mistro Holdings. Available at: [http://www.mistoholdings.co.za/products.html] (Accessed 2016/01/28).
[22] Small, medium and micro enterprise.

Figure 3.8: High pressure solar geysers displaying a collector tube and copper element (source: Diman[23])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
High pressure solar geysers are not relevant to the situation at Mahlabathini due to the high level of skill required for their installation and maintenance, and the fact that pressurised water is not available at each household.

3.4.2.3.3 Option 3: Low tech, low pressure solar geyser (plastic bottle geyser)

Cost:	Variable
Description:	A low tech version of a low pressure geyser can be made from a variety of available consumables (e.g. recycled coke bottles; Figure 3.9).
Practicality, sustainability & maintenance:	• These systems are highly practical from a cost perspective and in the expectation that communities could be taught how to manufacture them themselves. • The effectiveness and actual practicality is largely dependent on the design and construction of the system which would require training from experienced people. • The sustainability of these systems would naturally be dependent on the materials used and the integrity of construction. It is assumed that lifespans would be limited, but that maintenance should be manageable with recycled products and performed by the people who constructed the system.
Possibilities for training, job creation, SMME[24] development:	• It is likely that these systems could be built at household level and that training would be required to assist people in initial developments. • Job creation and SMME development could be feasible, although it is expected that people would be able to produce these systems themselves and would not purchase them externally.

[23] Diman. Available at: [http://www.dimanoverseas.net/solar-water-heaters-collectors.html] (Accessed 2016/01/28).
[24] Small, medium and micro enterprise.

Figure 3.9: A 'home made' coke bottle low pressure solar water heater (source: Tony Lopes, lowtech[25])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
As a cost effective option, these systems are expected to be highly applicable to the impoverished Mahlabathini community. The effectiveness, sustainability, ease of construction and maintenance remains to be unseen. It appears valuable that the project team explore this option further and enlist the assistance of an experienced developer.

3.4.3 Wind power turbines

3.4.3.1 What it is and how it applies to rural settings

Wind turbines use the kinetic energy of the wind to turn propellers which in turn drive a turbine to generate electricity (U.S. Dept. of Energy, 2016) (see Figure 3.10). Wind energy generation is entirely dependent on having wind, and is therefore limited to areas where winds are (i) strong enough to propel a turbine, (ii) consistent to ensure that energy is available when needed – unless a storage facility is available. Wind turbines range from large (1.2 MW capacity) to micro (less than 1.5 kW) for home application of off-grid monitoring sites.

[25] Tony Lopes (lowtech.co.za). Available at: [https://sites.google.com/site/lowtech12/solar-geyser] (Accessed 2016/01/28).

Figure 3.10: Inner workings of a wind turbine (source: U.S. Dept. of Energy[26])

3.4.3.2 Response to needs in Mahlabathini

Wind energy offers the ability to make electricity and as described under Section 3.4.1.2, the Mahlabathini community would benefit greatly from low cost, consistent electricity and back-up supply electricity. The critical concern regarding wind energy generation is whether there is sufficient, consistent wind to make any wind turbine technology economically viable. In some cases, wind turbines can be combined with solar panels to provide greater consistency of delivery. Although this is highly area specific, it is possible that wind occurs at times when sunshine is unavailable, therefore complementing each other.

3.4.3.3 Options for consideration at Mahlabathini

3.4.3.3.1 Option 1: Micro wind farms

Cost:	Entirely size dependent, likely R1 million upward for a small farm
Description:	Wind farms are typically built on a large scale in areas with highly consistent, strong wind (Figure 3.11). These farms are multi-million-rand investments which feed power back into the national grid. A micro-wind farm could be considered for a rural village where wind speeds and consistency were sufficient to provide constant energy, and where an electricity grid was already established and could be fed into. Although differing by situation, a minimum, consistent wind speeds of 23-25 km/hour is stated as being required to make a wind turbine a commercially viable project (U.S. DOE, 2011).
Practicality, sustainability & maintenance:	• A wind farm is not considered to be practical given the available information for the area and other rural areas. Wind conditions need to be optimal for such systems and the Okhombe community is found in a relatively protected bowl, surrounded by mountains. Costs and required expertise are not practical within this research project.
Possibilities for training, job creation, SMME development:	• Not applicable for rural areas. Extensive experience and internationally imported knowledge is required for the development of wind farms in South Africa.

[26] U.S. Department of Energy. Available at: [http://energy.gov/eere/wind/animation-how-wind-turbine-works] (Accessed 2016/01/28).

Figure 3.11: A wind farm in the United States of America (source: Progressive Today[27])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
These systems are prohibitively expensive and sufficient information is not available to determine whether wind strength, consistency and demand for electricity in the greater area would make this technology economically viable.

3.4.3.3.2 Option 2: Micro home wind turbine

Cost:	R16 500 for 200W
Description:	A micro home wind turbine consists of a small propeller which is driven by wind to turn a turbine and generate DC electricity (Figure 3.12). Such a system would usually be wired to a battery bank (as per description of solar PV kits) as inconsistencies would make direct use unlikely.
Practicality, sustainability & maintenance:	• Even at micro scale, wind turbines are prohibitively expensive for application in rural areas. A solar panel with similar generation capacity would cost less than one fifth of the example system. • Wind turbines are complex pieces of equipment with moving parts which would likely require maintenance over extended periods. This maintenance can only be carried about by highly skilled people and it is not likely that such skills could be transferred to local people in a small rural village.
Possibilities for training, job creation, SMME development:	• Given the cost of the technology currently available, micro wind turbines appear to be prohibitively expensive and too advanced to provide training and transfer opportunities on a small and isolated scale.

[27] Progressive Today. Available at: [http://www.progressivestoday.com/missouris-carnahan-family-to-sell-last-of-its-u-s-wind-farms/] (Accessed 2016/01/28).

Figure 3.12: Micro wind turbines (source from left: AliExpress[28]; Bobvila[29])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
These systems are prohibitively expensive even for a low energy capacity delivery. Further, little is known of the wind capacity in the area and this would require further determination.

3.4.4 Micro and pico hydro power

3.4.4.1 What it is and how it applies to rural settings

Hydro power is energy generation using the gravity fall of water. Both stored water (in man-made dams) or naturally elevated water which can 'fall' in altitude are capable of delivering kinetic energy to drive a turbine and generate electrical energy (see Figure 3.13, IRENA, 2012). The critical consideration with hydro power is that a sufficient head of water is required to provide kinetic energy to drive an appropriate turbine. In addition, the availability of consistently flowing water, or storable water, should be considered for application and economic viability.

[28] AliExpress. Available at: [http://www.aliexpress.com/store/product/300w-small-mini-micro-wind-turbine-generator-on-sale/710643_534278257.html] (Accessed 2016/01/28).
[29] Bobvila. Available at: [http://www.bobvila.com/articles/home-wind-power/#.VqosUxX5iUk] (Accessed 2016/01/28).

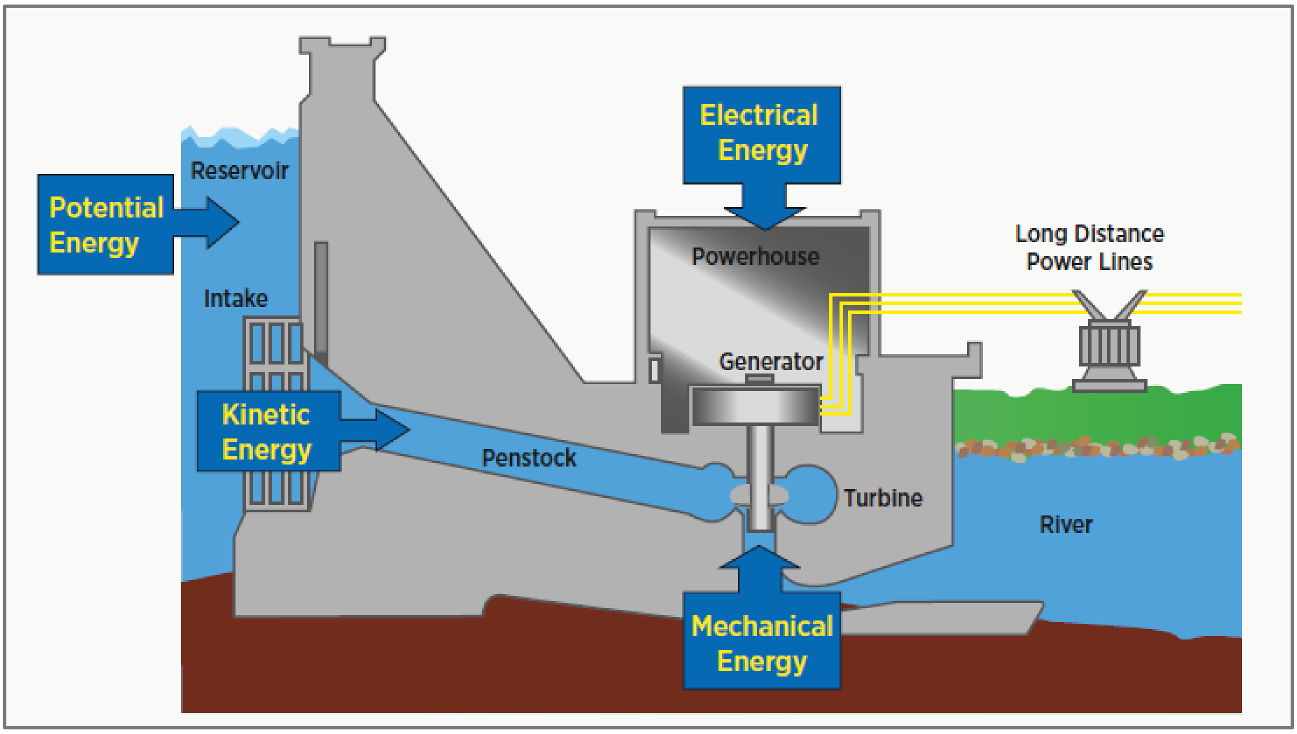


Figure 3.13: Cross sectional diagram of a hydro power generator (source: IRENA[30])

3.4.4.2 Response to needs in Mahlabathini

Similarly, to discussions put forward for solar and wind power (Sections 3.4.1.2 and 3.4.2.2 respectively) the broad need in Mahlabathini is for more reliable, less expensive electricity.

3.4.4.3 Options for consideration at Mahlabathini

The applicability and reliability of hydro power is reliant on sufficient, consistent water, with appropriate energy potential (elevation linked) to make it technically and economically viable. There appears to be no applicable areas in the Mahlabathini community or along the nearby stretches of the Khombe River which would provide technical viability (Smith, pers. obsv., 2016). Furthermore, the Khombe River is known to slow up dramatically and even stop flowing during winter months (Smith, pers. obsv., 2015).

Micro and pico hydro power is also especially suited to remote areas which do not have access to a national grid and which are prohibitively removed from making such a connection viable. This is not the case in Mahlabathini, as a grid connection is already available and established at most households.

3.4.5 Clean burning biomass stoves

3.4.5.1 What it is and how it applies to rural settings

Biomass burning for energy (namely for space heating and cooking) is common in rural South Africa and is frequently practised in Okhombe (in which Mahlabathini is situated) (Smith, 2011). Biomass is considered to be a renewable resource, but only in situations where it is sustainably managed, and this is of first consideration when considering biomass stoves and heaters for rural development.

[30] IRENA. 2012.

Although biomass burning is common place, the method by which this is done is often in open fires – an activity that is inefficient and detrimental to human health when done in confined, unventilated areas. Indoor air pollution (IAP) is a major concern for human health and has been linked directly to lower respiratory infections which are the number one "leading causes of burden to disease" (ETC UK, 2007: 7; Ter Heegde and Sonder, 2007: 3; WHO, 2004). In the context of this report and in recognition of the intention to identify a tool box of green (sustainable) technologies, that promote economic development – only efficient, clean burning biomass stoves would be considered. Further, it is noted no wood is directly available within the surrounds of the Mahlabathini community, but it is common place for households to purchase wood from external areas by the bakkie load (Smith, pers. coms., 2015 and Project community survey July 2015) – and therefore, more efficient technologies for combustion of this biomass should not be discounted.

3.4.5.2 Response to needs in Mahlabathini

Mahlabathini borders the central Drakensberg mountain range and is a cold area during winter months. Spatial heating is therefore a requirement which demands high energy. Both cooking and heating are activities which demand high energy inputs. It was revealed during the community workshop and community survey that households predominantly used firewood for heating and were aware that heating and cooking with electricity was expensive (i.e. high consumption of energy).

Further, the fact that these activities are high energy consumers means that stored energy (batteries), and related equipment, would need to have a large capacity and would therefore be significantly expensive. Stored energy, generated by solar or other renewable technologies, are therefore not economically viable for cooking and heating.

Considering a multifaceted energy solution for people, it is therefore prudent to investigate the value of clean burning biomass alternatives.

3.4.5.3 Options for consideration at Mahlabathini

3.4.5.3.1 Option 1: Improved biomass burning stoves

Cost:	Wide ranging
Description:	Improved biomass stoves or improved cooking stoves (ICS) come in a vast range of types and sizes with a variety of functional designs (Figure 3.14). In general principal, these stoves use a variety of methods to combust biomass more completely and efficiently by using primary and secondary air. These stoves are also expected to produce less indoor air pollution, either through their process of combustion or by venting the emissions externally.
Practicality, sustainability & maintenance:	• With appropriate training, improved cooking stoves can be easy to construct with locally available materials and are therefore simple and practical for application. • They are also practical in the sense that biomass is a well-understood fuel and although not readily available, is currently accessible (to be discussed under "Relevance and applicability"). • Maintenance and sustainability would depend on specifics of the stove and whether it is locally manufactured/home built or imported. • Unless high quality steels are used for imported (manufactured) stoves, sustainability is likely to be minimal and imported units would need to be supported by a local supplier (SMME). • Failing/broken wood burning stoves pose similar detrimental threats to human health through indoor air pollution (IAP).
Possibilities for training, job creation, SMME development:	• Training could quite easily be conducted and structured to support own-construction of some types of improved cooking stoves. • SMME development and job creation would likely be in the form of a retail and installation business that sold products and supported them. As noted above, unless stoves are made of high quality goods, they are not likely to be sustainable and this could create challenges for local suppliers.

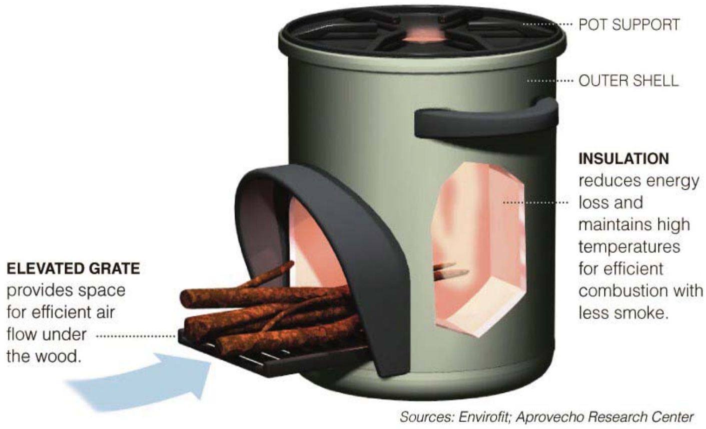


Figure 3.14: An externally vented cooking stove (left) and improved cooking stove (right) (source from left: Ndebele stoves[31]; Bioenergylists[32])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
Although improved cooking stoves are relevant and applicable given the current use of firewood/biomass for heating and as a secondary energy for cooking, firewood is largely unavailable in Mahlabathini and must be bought and transported in. The community workshop and survey revealed that the government's alien invasive removal programs have made firewood increasingly difficult to access – and subsequently more expensive. Given this limitation on available fuels and a concern over promoting use of indigenous wood stocks – biomass stoves are not believed by the researchers to be key green toolbox options.

3.4.5.3.2 Option 2: Biomass pellet stoves

Cost:	Approx. R400-R2 500
Description:	Biomass pellet stoves are equipment designed to combust compressed wood pellet (Figure 3.15). Wood pellet is generally made from sawmill residue waste, and is therefore a carbon neutral fuel[33]. Although a variety of these stoves exist, the two common versions are (i) top-lit-up-draft stoves which are self-perpetuating after an initial input of energy (e.g. starter fuel), and (ii) fan driven stoves, which use a small air fan to promote airflow. Pellet stoves typically have a very low emission of carbon monoxide and particulate matter, with fan driven models offering slightly greater emission reductions and efficiencies.
Practicality, sustainability & maintenance:	• Pellet stoves are easy to use and efficient with the need for basic user training. They do, however, require a varied user practice as start-up can take up to five minutes and users need to gain experience with methods of cooking. • These stoves are limited to a set burn time (approximately 1.5 hours at maximum) and are usually single plate – this offers an obstacle to use which requires adaptation to cooking practices. • Sustainability and maintenance depends largely on the type and quality of stove – stoves are expected to last only between 1 and 5 years. Some stoves have replaceable burn chambers, but otherwise have no need for, or possibility of, maintenance.
Possibilities for training, job creation, SMME development:	• Pellet stoves provide the opportunity for job creation and SMME development. Both stoves and pellets can be sold by small businesses and individuals. • Pellets need to be replenished and therefore local SMME or individual entrepreneurs can purchase and distribute these. Although this fuel is acknowledge as an "import" to the area – it is a sustainable fuel, and the alternatives – electricity, firewood, paraffin – are also all imports. • Further, pellet demand supports jobs at pellet factories. There exists future potential to explore the conversion of alien invasives into wood pellet or wood chip for use in these stoves.

[31] Ndebele stoves. Available at: [http://www.ndebelestoves.co.za/newStoves.htm] (Accessed 2016/01/28).
[32] Bioenergylists. Available at: [http://stoves.bioenergylists.org/taxonomy/term/137] (Accessed 2016/01/28).
[33] Depending on the source of waste. Wood pellet is currently made in South Africa from only waste wood materials and therefore classifies as a carbon neutral (even mitigator) fuel (Dillon, pers. comm., 2016).


Figure 3.15: Compressed wood pellet fuel (left) and an ACE fan driven pellet cook stove (right) (source from left: Energy North[34]; ACE[35])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
Pellet stoves are considered to be highly relevant and applicable as a back-up supply for cooking and heating in Mahlabathini – and possibly as a primary source if households find stove use easy and acceptable. The fact that pellet is not available locally and would need to be transported from far (Pietermaritzburg) does make them unpractical and not economically viable, unless an SMME is setup and a critical mass of stove usage can support bulk delivery of pellet to the area (and surrounds). The project should explore the practical use of various stoves, and can draw on experience of other SMME development projects to ascertain the viability of a stove and pellet supply business in Mahlabathini.

3.4.6 Biogas

3.4.6.1 What it is and how it applies to rural settings

Biogas is categorised as a biofuel and a gas, which is created in the process of organic decomposition under the absence of oxygen (anaerobic digestion) (Bio2Watt, 2014). Biogas typically consists of methane (CH_4), carbon dioxide CO_2 and other trace elements of sulphur – in varying ratios, dependent on the organic matter being broken down (Amon *et al*., 2007). Biodigesters are used to make biogas and are essentially constructions of greatly varying sizes and designs, which provide an oxygen free environment for the anaerobic digestion process to take place.

Although biodigesters can exist as multi million rand power plants, they can be used in rural areas in the form of small constructed or premade tanks / bags / pits. These domestic digesters come in a variety of designs (see WRC K5/1955 Guidelines report [Smith and Everson, 2015]). These digesters can be fed with a variety of available organic materials, including food waste, manure and agricultural residues. The gas generated can be used directly for combustion in cooking stoves or for heating. Biogas appliances are also available for lighting, refrigeration and other uses – although the simplest form of use is for cooking and WRC Project K5/1955 revealed that the BiogasPro digester (a relatively big domestic digester) is unlikely to produce sufficient gas for all household cooking requirements (Everson and Smith, in press).

[34] Energy North. Available at: [http://www.energynorth.ca/wood-pellets/benefits-of-burning-wood-pellets] (Accessed 2016/01/29).
[35] African Clean Energy (ACE). Available at: [http://www.africancleanenergy.com/] (Accessed 2016/01/29).

3.4.6.2 Response to needs in Mahlabathini

As has been noted previously, cooking is an important and high energy using activity in Okhombe. Currently the majority of people use electricity for cooking, and firewood as a secondary option (project community survey, July 2015). The community workshop revealed that people had significant problems with the reliability of electricity and were cognizant of some of the health problems associated with indoor air pollution relating to solid biomass burning.

Biogas potentially offers a viable alternative for cooking and, once installed, provides 'free energy'[36] that is easily accessible. The community survey and general experience in the area has shown that cattle are an integral part of community life and cattle manure use, for a variety of activities, is common place. The collection of cattle manure for feeding to a biodigester is, therefore, easily achievable. Although studies are still under process, an additional benefit from a biodigester is bioslurry – the digestate produced after anaerobic digestion can be used as a fertiliser for crops, to potentially improve crop production (Everson and Smith, 2015).

3.4.6.3 Options for consideration at Mahlabathini

There are a vast variety of anaerobic digesters for application in domestic settings. These digesters are often expensive, or require experience for development and construction. For the purposes of this project, the researchers have selected only two categories of technologies. The first to be presented is already installed in Mahlabathini, and further research will be conducted on it – as per the directive of this research project.

3.4.6.3.1 Option 1: Agama BiogasPro6

Cost:	Approx. R40 000 including installation
Description:	The Agama BiogasPro is a prefabricated tank digester of approximately 6 000 litre capacity, made of roto-moulded LDPE (Figure 3.16). The tank has a gas storage of approximately 1 000 litres and under optimal conditions can produce approximately this amount of biogas per day from cattle manure.
Practicality, sustainability & maintenance:	• Installation of these tanks is non-complicated, although does require experience and understanding of gas installations and civil installation under varied ground conditions. The tanks are also large and heavy, making local transport and installation only possible with some skill and appropriate equipment. • The BiogasPro is a relatively new technology and therefore long term sustainability is unknown. The suppliers expect that the tanks have at least a 15 to 25 year lifespan with maintenance only required on gas lines and minor parts. • Project experience has revealed that tank failures can occur, either due to poor tank formation or installation. Further, experience has shown that maintenance and continual training is required.
Possibilities for training, job creation, SMME development:	• Local installers can be trained to conduct all installation activities. This process would not, however, be economically viable unless a number of digesters were to be installed in one area. • Maintenance and support is certainly required at intermittent times. Again, it is necessary that numerous installations were available to warrant the training and support of a job to conduct these services.

[36] Free in monetary terms, although it is noted that the opportunity cost of biodigester operation is not taken into account.

Figure 3.16: The AGAMA BiogasPro6 (source: AGAMA Biogas[37])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
There is already an Agama BiogasPro installed (via WRC Project K5/1955) at Mahlabathini. The feedback from this and other biodigesters installed through the project is that they have made a valuable contribution to people's lives and cooking needs. The existing digester will be studied to further understand its relevance and applicability to the area and needs of the people.

3.4.6.3.2 Option 2: Low tech biogas digester

Cost:	Material choice and availability dependent (approx. R5 000-R10 000)
Description:	Low technology biogas digesters can be made using the general principals of anaerobic digestion and available materials. Materials used can be in the form of HDPE plastic or water tanks/crates. The method of construction is dependent on the available materials, but can consist of a lined pit (a plug flow digester) or a retrofitted tank (see Figure 3.17 below).
Practicality, sustainability & maintenance:	• Low tech biodigesters may offer practical value in a rural community where existing materials can be used to construct them by trained community members. • Most low tech digesters are above ground or surface built, and this does offer a major practical concern for use in a cold rural area. Anaerobic digestion is highly effected by fluctuations in temperature and low temperatures can cease the methane generation process. • Low tech digesters, depending on type, are not expected to be sustainable, but maintenance is expected to be relatively low tech (in line with the materials used and type of construction). • The success of low tech biodigesters is not well known but from empirical evidence in South Africa, does not appear to be extensive.
Possibilities for training, job creation, SMME development:	• Community members can be trained to build these technologies themselves and/or to develop SMMEs to develop the technologies in the community. The degree of success in this regard is dependent entirely on the success, longevity and practicality of these technologies.

[37] AGAMA Biogas. Available at: [http://agamabiogas.co.za] (Accessed 2015/02/25).

Figure 3.17: An example of a low tech (source: AGAMA Biogas[38])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
Given the temperature concerns in Mahlabathini, as shown by poor performance of a below ground digester (i.e. less susceptible to elemental conditions) during winter months, it is not expected that a low tech biodigester will offer a viable solution in Mahlabathini. The research team will, however, explore this further by reviewing some existing, running examples of this technology and will enlist the help of an expert to review the area and build a low tech digester at Mahlabathini if pre-feasibility suggests value in doing so. It is noted that initial feedback from one expert has been that this technology is not an option for the area (Confait, pers. comm., 2016).

[38] AGAMA Biogas. Available at: [http://agamabiogas.co.za] (Accessed 2015/02/25).

3.4.7 Solar cooking oven

3.4.7.1 What it is and how it applies to rural settings

Solar cooking ovens use directed solar radiation to heat a pot or the contents of a container. Solar cookers use reflective material to direct sun energy into a space or to a direct point (see Figure 3.18; HowStuffWorks, 2009).

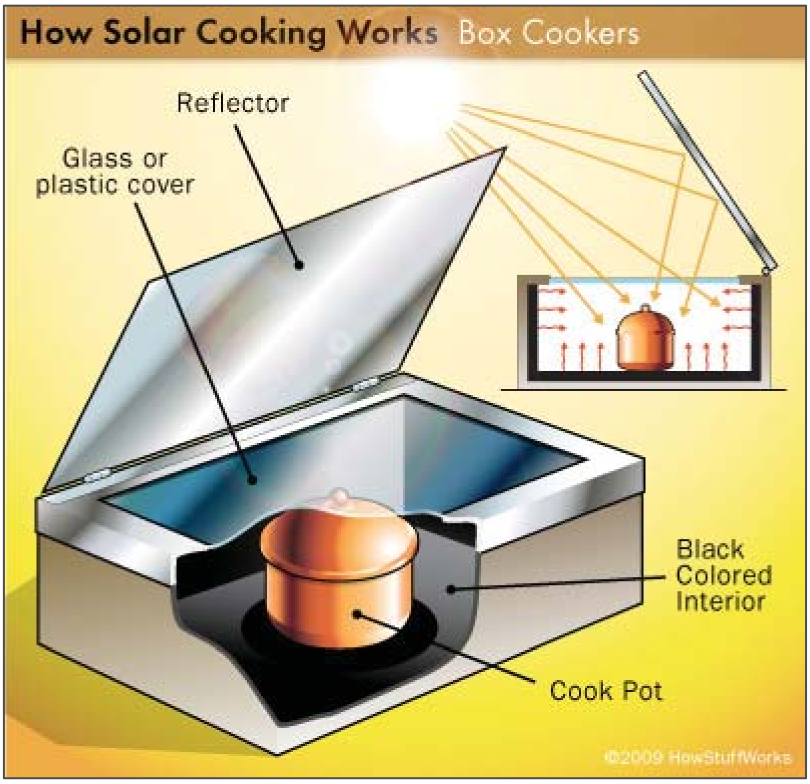


Figure 3.18: Diagram showing how a solar oven works (source: HowStuffWorks[39])

3.4.7.2 Response to needs in Mahlabathini

Solar cook stoves are not likely to offer a complete solution to peoples cooking requirements, but could provide back-up supply for unreliable electrical connection and a cost effective option when conditions are appropriate

3.4.7.3 Options for consideration at Mahlabathini

3.4.7.3.1 Option 1: Solar cooker

Cost:	R800-R3 500
Description:	Solar cookers come in a variety of shapes and sizes but are generally parabolic in shape with a reflective silver surface which reflects solar radiation to a central point (Figure 3.19).
Practicality, sustainability & maintenance:	• Solar cookers are not practical for all conditions as they require strong direct sunlight. In addition, they require people to change cooking practices dramatically and to leave food outside in the sun (potential for theft). • Solar cookers are expected to have a good longevity and not to require maintenance.
Possibilities for training, job creation, SMME development:	• Pre-manufactured solar cookers could be included in the suite of offering from a local SMME to support local sales.

[39] HowStuffWorks. Available at: [http://www.sustainable.co.za/energy-efficiency/solar-cookers.html] (Accessed 2016/01/29)

Figure 3.19: A parabolic solar cooker (source: Scinet[40])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
Solar cookers could provide valuable alternatives to grid electricity in the form of a back-up option and cost saver. Their actual ease of use and applicability remains to be seen and should be tested in the community and by community members.

3.4.7.3.2 Option 2: Solar cooker (homemade)

Cost:	Variable
Description:	A homemade solar cooker would follow the same principles as a manufactured version, but could be made with local consumer goods (e.g. a wooden box and reflective material) (see Figure 3.20).
Practicality, sustainability & maintenance:	• Solar cookers are not practical for all conditions as they require strong direct sunlight. In addition, they require people to change cooking practices dramatically and to leave food outside in the sun (potential for theft). • The value and practicality of these systems is also largely dependent on their effectiveness – a product of their design and construction that will only be testable on a case-by-case basis. • The sustainability and maintenance of these items are expected to be dependent on the materials used and the skill with which they are put together.
Possibilities for training, job creation, SMME development:	• There exists a possibility for local manufacture of solar cookers which could support job creation and SMME development.

[40] Scinet. Available at: [http://solarcooking.wikia.com/wiki/How_solar_cookers_work] (Accessed 2015/01/29).

Figure 3.20: Homemade solar cookers (source: Lowtech[41])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
Solar cookers could provide valuable alternatives to grid electricity in the form of a back-up option and cost saver. Their actual ease of use and applicability remains to be seen and should be tested in the community and by community members. The effectiveness of homemade models also requires testing.

3.4.8 Energy efficiency options

3.4.8.1 What it is and how it applies to rural settings

Numerous technologies exist to improve energy efficiency of lighting, heating and cooking. These products essentially use advanced technology to make better use of technology, or technology practices to use less energy, while still delivering household requirements.

In rural settings, these technologies can assist greatly by reducing consumption of energy and therefore saving people money.

3.4.8.2 Response to needs in Mahlabathini

As was noted in feedback from the community workshop (Section 2.2), community members specifically asked for ways they could use energy more efficiently and therefore save money. Expenditure on energy forms a large percentage of household costs in the research area (Smith, 2011), and households would therefore benefit greatly if they could reduce their consumption and household costs. Low cost options are often available to improve energy efficiency.

3.4.8.3 Options for consideration at Mahlabathini

3.4.8.3.1 Option 1: Wonderbag and other thermal insulation cookers

Cost:	R10-R500
Description:	Thermal insulators can be used to retain the heat of pots and other cooking implements to continue cooking of food once heated. The Wonderbag (Figure 3.21) is a bag filled with insulation material (polystyrene and other materials) which can be used to retain the heat of a pot. Blankets, boxes and other equipment can be home made to perform the same function. These items essentially allow people to bring a food to boiling point, place it in the insulation device, and the cooking process can continue without any further energy required.

[41] Lowtech. Available at: [http://www.lowtech.co.za/solar-oven] (Accessed 2015/01/29).

Practicality, sustainability & maintenance:	• Wonderbags are highly practical for use in rural areas, although it is noted that they do require changes to cooking practices which are often not appreciated and carried out. • Wonderbags specifically have shown significant sustainability, and are easy to repair and maintain – as they are made from readily available materials.
Possibilities for training, job creation, SMME development:	• People can easily be taught to make Wonderbags, and other, similar insulation boxes. • The Wonderbag model is designed specifically with job creation in mind, and indeed SMME development is also a viable possibility.

Figure 3.21: A Wonderbag with a pot placed inside (source: SFGate[42])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
Wonderbags and other insulators are considered to be highly relevant and applicable for reducing cost of cooking in rural areas. These technologies should be tested in Mahlabathini, as they do require changed cooking practice and the up-take of these changes remains to be seen.

3.4.8.3.2 Option 2: LED lighting

Cost:	R60-R200 per light
Description:	LED or Light Emitting Diode lighting is an advanced lighting technology that uses less energy to deliver the same light output (lumens) (see Figure 3.22 for typical energy efficiencies of various lightbulbs).
Practicality, sustainability & maintenance:	• LED lighting is typically expensive, but uses significantly less energy than incandescent and CFL bulbs. This technology provides equally bright light and does not require any user changes. • LED bulbs are said to be more sustainable than incandescent bulbs and CFLs because they expected last longer and do not contain toxic elements, like mercury (as found in CFLs).
Possibilities for training, job creation, SMME development:	• Efficient lighting could be supplied by a local SMME, but does not necessarily provide any greater opportunity that existing lighting.

[42] SFGate. Available at: [http://cached.newslookup.com/cached.php?ref_id=325&siteid=2266&id=4286822&t=1388788507] (Accessed 2015/01/31).

Figure 3.22: From left to right, incandescent, CFL and LED light bulbs (source: Renen Energy[43])

Relevance and applicability to the rural setting and needs of the people at Mahlabathini
LED lighting is expensive, but provides significant energy saving and is therefore applicable to the needs of Mahlabathini. LED lighting can be damaged with poor energy supply, and therefore implementation will be required to test its sustainability in the area.

3.5 Technology selection for implementation and testing

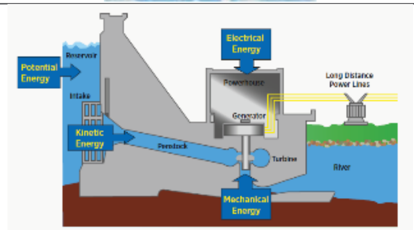
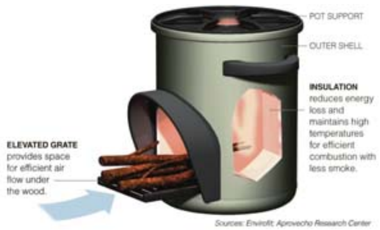
Table 3.1 presents a summary of the technologies that have been reviewed in this report. The technologies have been separated according to the broad category of energy/service provision, and have been rated on a subjective basis of value for the Mahlabathini community. This rating is based on empirical experience and observations from the community that has come from over 15 years of research in this community. It is also based on experiences of two directly relevant household surveys in the area (in 2010 and 2015) and experience from previous implementation projects and community workshops. The valuation is further based on a literature review, market reviews and the feedback from experts in the field (expert workshop 2015/11/25 and expert interviews).

[43] Renen Energy. 2015. Report number: REN1509-02.1.

Table 3.1: Summary of potential implementation technologies

Technology category	Technology	Example image	Rated value for project implemen-tation (1-10 where 10 = good)	Expected cost for actual implementation system	Document Ref.
Solar PV	Entry level basic DC solar PV kit		7	< R1 000	3.4.1.3.1
	Basic, fitted DC solar PV kit		9	R6 500	3.4.1.3.2
	Basic, fitted AC solar System		2	>R10 000	3.4.1.3.3
	Low pressure solar geyser		8	R6 500 (150 litre)	3.4.2.3.1

Technology category	Technology	Example image	Rated value for project implemen-tation (1-10 where 10 = good)	Expected cost for actual implementation system	Document Ref.
					
Solar thermal water heating	High pressure solar geyser		0	>R15 000	3.4.2.3.2
	Low tech, low pressure solar water heater (coke bottle water heater)		8	<R500 (coke bottle type)	3.4.2.3.3
Wind turbines	Micro wind farm		0	Unknown	3.4.3.3.1

Technology category	Technology	Example image	Rated value for project implemen-tation (1-10 where 10 = good)	Expected cost for actual implementation system	Document Ref.
	Micro home wind turbine		5	>R16 500 (200W)	3.4.3.3.2
Micro/pico hydro power	Micro/pico hydro power		0	Unknown	3.4.4.3
Clean burning biomass stoves	Improved biomass burning stoves		5	<R1 000	3.4.5.3.1
	Improved biomass burning stoves (flued)		5	<R5 000	3.4.5.3.1

Technology category	Technology	Example image	Rated value for project implemen-tation (1-10 where 10 = good)	Expected cost for actual implementation system	Document Ref.
	Biomass pellet stove		7	R600 (non-fan driven) R1 500 (fan driven with solar panel)	3.4.5.3.2
Biogas	Agama BiogasPro 6		7	R40 000	3.4.6.3.1
	Low tech biogas digester		4	<R5 000	3.4.6.3.2
Solar cooking oven	Solar cooker		6	R1 500	3.4.7.3.1

Technology category	Technology	Example image	Rated value for project implementation (1-10 where 10 = good)	Expected cost for actual implementation system	Document Ref.
	Solar cooker (homemade)		6	Unknown	3.4.7.3.2
Efficiency technology	Wonderbag		9	R220	3.4.8.3.1
	LED lights		9	R500 for five lights	3.4.8.3.2

3.6 Implementation and research plan

3.6.1 Implementation and community engagement strategy

One of the key factors ensuring the acceptability of the project by the community was to include them in the decision-making process of the project. The following steps were taken to ensure community involvement in the selection of the households who were to test the different energy technologies:

- Selection of the technologies to be tested by the project team following the expert workshop and budget allocation.
- Presentation of the technologies to the Mahlabathini tribal council member.
- Community meeting to vote for (i) needy households and (ii) a central household where everyone can view the new technologies.
- Household site visits by the project team and community members to facilitate selection of households and allocation of the technologies.
- Community workshop to announce the outcome of the selection process. Signing of the memoranda of understanding with successful households.
- Planning of training days, demonstration days and knowledge dissemination to community members.
- Community monitoring workshop to set up a monitoring programme for each technology. This included data management and how to record cost savings and efficiency of technology.

3.6.2 Research, testing and monitoring programme

3.6.2.1.1 General research plan and intentions

The intention of this project was to research sustainable technologies in ‘real-world’ scenarios – by installing a selection of them at rural households in the Mahlabathini community (Okhombe, KwaZulu-Natal) and conducting research with the community members. The focus here was to avoid researcher bias, and allow communities to use technologies as they would without direction (post initial training). This method of research, although taking many forms, is generally described as ‘community participation research’.

Participatory research is described by Cornwall and Jenkins (1995) as, “breaking the mould of conventional research” … “a process of sequential reflection and action, carried out with and by local people rather than on them” (1995: 1667).

With respect to the diffusion of innovations in developing nations, and specifically the diffusion of wood burning stoves, Agarwal (1983) noted the “inappropriateness of the usual ‘top-down’ approach” and the need for community involvement in the design process (1983: 359).

With these principles in mind and with over 10 years of actual experience of participatory research in the Okhombe community (Everson, pers. obsv., 2017), the intention of this project was to install technological green energy innovations in selected rural households and implement a capacity building programme to support these. This programme comprised of on-site training for implementation of the technologies, followed by a monitoring and evaluation programme which enabled households to test and evaluate the impact of the integration of these technologies into their daily lives. While some basic data collection was required of the households in some cases, the intention of the researchers was to support this with data collection on the household’s personal experience (qualitative research).

CHAPTER 4. COMMUNITY ENGAGEMENT

There is a growing concern that green economy enterprises tend to ignore the social dimension to community activities (Davies and Mullin, 2011). Therefore, through a participatory research, research communities are engaged, to limit distrust, as well as negotiate a balance between valid, generalisable knowledge and the research community (Macaulay *et al*., 1999). The latter is focused on improving research protocols by incorporating local knowledge and expertise. Similarly, community engagement underscores the economic development model narrative of green economy positing to improve human well-being and social equity while reducing environmental risks and ecological scarcities (Bailey and Caprotti, 2014).

In Okhombe, the community was involved in three stages (i.e. project inception; community research group formation and implementation of household technology).

4.1 Project Inception & Community Research Group Development

4.1.1 Permission from the tribal council and local authority

Prior to conducting the survey the project leader met with Okhombe community councillors to introduce the project and request a meeting with the AmaZizi Tribal Council to gain approval of the project. At the meeting held at Okhombe on 9 April 2014 the following councillors were present: M. Xaba (acting Nkosi), S. Dubazane, M. Hlatshwayo, T. Shezi and N. Masengemi.

The project leader outlined the status of the current WRC biogas project and the progress made with project activities. The concept of a Green Village was explained as well as how it linked to the current WRC project. The tribal council and community members were formally requested to grant approval of the proposal to implement a project to investigate the potential of Mahlabathini as a Green Village. This proposal was based on the fact that Mahlabathini had a distinct boundary and comprised approximately 100 households which was feasible for a pilot Green Village project. In addition, when it was first proposed it did not have electricity. It was emphasized that there was no guarantee that the proposal would be implemented as it depended on getting funds. However, initial steps had been taken to get funding from the Department of Trade and Industry.

Mr Xaba (acting Nkosi) stated that he gave his full support for a Green Village project at Mahlabathini. He said he had visited the household of Mr Velam Khumalo and was impressed that gas for cooking could be produced from manure. Everyone present at the meeting agreed and gave their support for the project. However, approval by the AmaZizi tribal council was still required. The project leader agreed to give a presentation to the tribal council on 22 April 2015 to obtain their permission to implement the project.

4.1.2 Project presentation to the AmaZizi Tribal council

The presentation to the AmaZizi Tribal Council took place on the 22 April 2015.

There were twenty-nine community members attending the meeting including the village headmen (Izinduna) from each ward of Amazizi.

The village headmen attending the meeting are shown in Table 4.1:

Table 4.1. Village headman who attended the AmaZizi Tribal Council meeting

	Name	Ward name
1	Simphiwe Dubazane	Okhombe
2	Majongosi Hlatshwayo	Okhombe
3	Mpotozi Hlatshwayo	Mpophomane A
4	Gabriel Mthethwa	Ezimbokodweni
5	Efrem Malinga	Newstand
6	Hendry Miya	Obonjaneni
7	Sfiso Mloyi	Ebusingatha

The project leader outlined the proposed Green village project which would be funded by the WRC. The new project would build on the findings of the pilot WRC project which examined the integration of green options for energy, food, fodder and water at four households in the Upper Thukela. The tribal council's approval of the new project was requested.

The following comments and questions about the proposal were made:

1. Mr Dubazane confirmed that the tribal council approved of the project. He said he had seen the biogas digester at Mr Khumalo's home at Okhombe and confirmed that it was reliable and did not go off when it was windy.
2. One of the community members who had seen the crop produced using the bioslurry mentioned that bioslurry does improve the crop productivity.
3. Community members appreciated the presentation and they said combining the biogas and green village projects seems to be the best way to save energy. In addition, they said that they would love to have biogas and wood pellets in their houses.
4. One community member said that while green energy would be good, a major problem in the community is water scarcity as currently they don't have water. There is no water from the taps and boreholes and they don't know where the problem is. At the moment a tanker is delivering water but it only arrives at midday. The project leader stated that water scarcity is a serious problem that needs to be addressed urgently.

The Tribal Council granted permission and advised the project leader to liaise with the local Induna (Mr Dubazane) regarding the process and activities of the project.

Mr Dubazane was informed of the surveys to be conducted and he in turn informed the community that researchers would be present in the area. Sadly Mr Dubazane passed away a week before the intended start of the survey and the process was delayed. The project team liaised with the acting Induna, Mr Masengemi for all subsequent project activities and communication. Project presentation to the community

A community visioning workshop was conducted to present the project as well as determine the needs of the community from the green village concept which the project presents. The details of the visioning process are highlighted in Section 2.2.

4.2 Community Research Group Formation

4.2.1 <u>Selection of households for technology implementation</u>

The meeting took place on the 11th March 2016, in the presence of one of the project team members who was available to support the community with the extremely difficult task of selecting 14 beneficiary households for the implementation of different green energy options which ranged in price from R220 to R8 000.

The meeting was attended by a total of 27 people who had been part of workshop held on the 10 March to present the technologies.

4.2.1.1 A community-led strategy to household selection

Mr Masengemi provided the background to the meeting, highlighting the discussion points from the main workshop on the 10 March. He also indicated that one of the issues that had been identified was the need to devise their own strategy prior to select the households for implementing the technology. He noted that the project team member present was also available in case of need to clarify the project process.
Mrs Hlatshwayo then revised all the technologies that had been presented on the 10/3/2016. The community also added points on the technologies from what they had understood the project team's presentation.

The participants explored how to deal with the fact that most people in Okhombe and those that attend the meetings have electricity.

- The decision was that even those households with electricity should be given an opportunity to explore these technologies as they are looking for alternatives to electricity. The community noted that only one, if not two, families in Mahlabathini are without electricity in their households. These household owners, including people who do not usually attend the project meetings, were informed to attend the meeting but did not show up.
- Participants also noted their wish for people from Ngubhela and Mpameni who have always attended previous Green Economy Project meetings to be included in the selection of households
- Participants also decided that related members of the community would only be selected provided they live in different households and if they conformed to the project rules presented by the project team.
- The community **rules** were formulated in a plenary, and were viewed as pivotal to the selection of the households:
    - ✓ Highly involved in the project, works with research team and records progress
    - ✓ Always attend the meetings unless there is death in the family,
    - ✓ Take care of the technology, making sure it is safe from thieves,
    - ✓ Avoid ruining of technology and
    - ✓ The household selected must be in need of using the provided technology

4.2.1.2 Household Selection

Mrs Hlatshwayo and Mr Msibi facilitated the household selection process using the list of technologies presented in the technology workshop. Mrs Hlatshwayo requested the participants to nominate the households.

During the selection the representative project team member excused herself, to allow the community to make their own decisions in the selection process. The project team member returned to capture the names supplied by the community (see Table 4.2*).*

Table 4.2: Household selection for technology implementation

TECHNOLOGY	HOUSEHOLD (MAHLABATHINI)	HOUSEHOLD (MPAMENI)	HOUSEHOLD (NGUBHELA)
1. Solar PV and two stoves	Mrs Mkhonza (2 people)		Mr Hlongwane (4)
2. Solar PV and two stoves	Mrs Ndinisane (2)		Miss Zwane (5)
3. Solar PV installed system	Miss T Masengemi (6)		
4. Solar– hot water	Mrs T Hlatshwayo (5)		
5. Biogas thermal	Mr B Shezi (4)		
6. 2 Solar cookers	Mrs N Msibi (7)		
7. LED light	Mr S Msibi		
8. LED light	Mrs Masengemi		
9. Wonderbag	Mrs Lakanja (4)		
10. Wonderbag	Miss N. Msibi (4) Mobile:073 755 3871		
11. Wonderbag	Mrs N. Msomi (11)	Miss Mkhulisi (6)	
12. Wonderbag	Mrs B Ndlovu (4)		
13. Wonderbag	Mrs B Sengwayo (4)		
14. Wonderbag	Mrs N Msomi (9)		
Numbers in brackets indicate the number of people staying in each household.			

The project team member indicated that the project was still focusing on Mahlabathini but that the request will be communicated to other research team members who were better informed.

A list of project activities following the household selection were then outlined to the community to consist of:

- Confirmation of technologies and the households with the rest of the project team members, and to communicate whether or not Mpameni and Ngubela households would be included in the project (and if not, what the next step will be to extend the project to the two sub-wards);
- Training of the research households; and
- Project meetings with the selected households (this would include monitoring of progress in households' record of data).

The research project team member re-emphasised the need to record both positive and negative information as experienced by the households, before breaking for lunch (Plate 4.1).

Plate 4.1: Some of the participants who attended the meeting are enjoying lunch while listening to the next steps of technology implementation

4.2.2 Community Workshop on the Green Tool Kit Technology

The workshop took place on the 10th March 2016 in Mahlabathini.

4.2.2.1 Renewable Energy Options

Nine (9) different renewable technologies were presented as options for testing in this project. The project team presented photographs of each technology, accompanied by a description of how the energy works. Pros and cons of each technology as well as the criteria required to operate the system were also presented by the project team.

i. Solar hot water geyser

This geyser can sometimes be seen on government houses. Water runs through the pipes and is heated up by the sun. One of the participants questioned the functionality of the technology in winter. The project team responded that it doesn't matter if it is cold, but that it doesn't work when cloudy. One problem highlighted was that it needs a lot of water pressure. The participants did not know of any households with the required pressure. Due to local constraints to access water the technology may not be suitable.

ii. Home-made solar geyser made from recycled coke bottles

This does not need high water pressure as participants can manually fill it up. There is no knowledge of how well the technology works hence the project would be interested to learn test it. The participants were informed that a follow-up workshop would be relevant to get someone to show the project team how to design a home-made technology as well as install it.

iii. Solar PV electric system

The technology has a small panel (about A5 size). It is mobile and can be moved from room to room where it can charge lights and support a cell phone charger.

iv. Solar PV installed

This is larger than the previous system and is fixed on the roof of the house. It needs to be safe as can be stolen from the roof. It can store more energy so can last longer in cloudy conditions. It can charge 5 lights and cell phone charger and possibly radio. In response to a question about the ability of the system to save more energy if it is very hot, an explanation was given that it can't last longer as it does not use the heat of the sun it uses electrons. It also is not mobile so it charges the same lights.

v. Wood pellet stove

This uses a fuel that is made from sawdust waste. It is better than wood because it is compacted and produces more energy than wood and it burns cleaner. There are 2 different stoves that will be given to a household, to test and compare. Use a cup of pellets and some paraffin to start burning as pellets can't light by themselves. One person asked whether the project will buy the pellets of which the response was that these would be supplied for the first 6 months of the project after which the cost would have to be covered by the households. It may be possible to get a sponsor to cover the costs for a bit longer. Note that one cannot save unused pellets or add more pellets in the middle of cooking. Need to learn how many pellets are needed for heating specific items.

vi. Solar cooker

There are 2 types: one that can be purchased that looks like a satellite dish and one that can be home-made that looks like a foil lined box. People had seen the bought one. It has to be placed outside so can use the heat from the sun which is directed into a pot. Need one household to test both to see which is best. Cooking takes longer.

vii. Biogas digester

In addition to the one installed at Mr Khumalo's a low-tech system would be tested. This one is different as the tank is above ground and the gas is stored in a tractor tube.

viii. LED lighting

Most of the participants knew about this technology as Eskom and the government had given out some of the 13-15 V globes. The 6-8 W globes are much more expensive and last for longer. The project team tasked the households to test how long the globes would last. The participants were requested to record the quality because if the energy quality is low this could affect the lifespan of the respective globe. Participants were also asked to observe if the globes were brighter than the normal bulbs the households are more familiar with. If lights flickered, this may indicate that the globe was damaged. Households that use electricity throughout the month could further test both the globe quality as well as quantity of energy in the globes.

ix. Wonderbags

Heat food in a pot and then transfer to the bag for continued cooking. The project requested households to volunteer testing of the wonderbags, which may impact their cooking practices as the technology can take longer than in the normal practice.

4.2.2.2 Project criteria for household selection

The project team highlighted the following points to be noted during the selection as well as in the actual piloting:

- ✓ Fourteen (14) HHs to be selected by the community to test the technologies presented.
- ✓ Households to be interested in the research as the feedback is critical for the success of the project.

- ✓ The participants were warned that some of the technologies may not work in the community while others may not be suitable for the local context.

4.2.2.3 Community questions on the project:

The project team allocated a slot for the community to raise any questions regarding the project. Some of the questions included:

Q: Will the project provide any guidance on how to operate the technologies?

A: When each technology is implemented there will be guidance from the project team. There will also be training sessions on the use, maintenance and monitoring of each technique. Also at regular intervals there will be feedback sessions between the households and project team. The project team can also be contacted at any time with questions about the technologies.

Q: Can too much sun damage the solar technology?

A: This is not a problem.

Q: One participant said that it was first time he had attended any community meetings and queried why photos were taken during the workshop.

A: The response was that this was a good question; the project team also added that the photographs are included in the project report and presentations and that each member was allowed to object should they not want their photos taken.

Q: Will the project team replace any failed or damaged technology?

A: This was not possible for most of the technologies because of the limited budget. However, the team can replace LED lights and pellets. If a technology failed it is important to get the community feedback on this so that the project team can include it in the report to the funder.

4.2.2.4 Conclusion to the workshop

The workshop concluded with Mr Masengemi thanking the project team on behalf of the community, for the presentation which was well received. He indicated that they had no further questions, and that if there were other issues they would take them up with the project team at a later stage. The participants then made plans for the second workshop on "Energy technology allocation of households" which was to take place on the following day.

4.3 Implementation of Technology

4.3.1 Community Training Workshop on Energy Systems

The meeting took place on the 6th June 2016.

After opening with a prayer, the project team requested that the households record their names before receiving the technologies.

The project team was notified of the adjustments made to the previous list due to absence of two people: Mr Bongani Mtolo who will now receive the two pellet stoves instead of Miss Zwane and Mr E. Masengemi to receive the ten LED lights instead of Mrs Masengemi.

The project team explained that the training on the different technologies was for all community members including those not selected to implement the technology for learning purposes. The demonstrations and where relevant, descriptions of what technologies, were presented by the project team. These technologies had already been shown to the community via a projected presentation in a meeting on the 10th March 2016 (Section 4.2.1).

i. Wood pellet Stove

The pellets are made from the waste from forestry. These are similar to compressed sawdust. It has very high energy but has to be burnt in special stoves as it can't light by itself.

Two different stoves would be tested by the households, to find out which one works best: i) 'Isitofu' pellet stove does not have a fan or electricity. It has a dial which controls how much flame is produced. ii) The Ace stove has a small battery but no vents on the side as it uses a fan to blow the air through the pellets. It can be used to charge a cell phone and operate a light.

The stoves get hot and must be placed in a ventilated area. If they are left on all night the smoke can cause death. The project team suggested that the participants put them outside after use.

The project team provided instructions on how to operate the 'Isitofu' stove.

On receipt of a new stove one must take the stand and the chimney out the stove.

Then one must use a soup tin to load the pellets into the stove. Each person should count how many tins are used per cooking session. People should estimate how many pellets are needed as more pellets cannot be added halfway through cooking.

A little bit of paraffin to be added to the top of the pellets and light. This will take about 5 minutes to get going.

- A participant asked if one could use spirits instead of paraffin. The project team explained that this was possible, but that it was more dangerous.

When the flame gets big one could change the bottom control dial to control flame size. However, the top one must always be open.

- Another participant asked if one could use the stove for heat as it is cold in winter. The project team responded that this was possible although for the first 5 times of usage the recommendation is to burn the stove outside until the paint inside is burn off.

Other questions which were raised included the following:

- Does controlling the flame mean that one can burn the stove for longer?

The response was 'yes', it is more efficient.

- Does controlling the flame affect cooking efficiency?

The response was 'yes', one need to adjust it to the intensity of energy required to cook specific food.

- Why not methylated spirits?

The response was that it burns faster and is cheaper

- If cooking samp and have not put enough pellets in what can one do?

The response was that one could take the lid off and empty the coals and start the lighting process all over again.

- Where would the participants get pellets from?

The households will get free pellets from the project until December. After six months pellets would be delivered to the spaza store and people can buy from there.

Additional points were made by the project team on the stove. For example, one problem with the stove is that it only cooks for about an hour. This could be used in conjunction with a wonderbag, to carry on the cooking process.

The participants were also advised not to switch fan on at start but to wait for pellets to start burning and then switch on fan. Putting the fan on too early will blow the fan out.

As both stoves burn from the top downwards – one cannot add more pellets once the stove has been lit.

The project team further explained how to fill in the data for the pellet stove. He emphasised that the data required includes: the date, type of stove used, and food cooked.

ii. Wonderbag

The project team indicated the following on the technology:
Once cooking has started for instance, cooking samp and is already boiling one can put the lid with a pot in the bag and tie it up. The will carry on cooking for up to 8 hrs.

The technology is ideal to complement other cooking systems such as electricity, gas, paraffin.

Households could try it to save money. However, this might mean changing cooking times.

- Seven (7) people had heard of a Wonderbag and seen it in the shops. However, none of the people at the meeting had seen one in the community.

The Wonderbags were given to the allocated households.

The households were requested to use the bags as often as possible and to report on which type of food it works best for.

- A question was asked on what to do if the water dries out in the pot.

The response was that this doesn't usually happen as the water is retained in the pot.

iii. Solar oven

The project team gave the instructions as follows:

One should put the pot with water or meat into the solar dome. People can either first boil water or cook meat in another heating system or put it straight in the dome.

The advantage of the oven is that it does not cost a lot. One can buy it for R400 or also make one at home. The problem is that in winter it won't boil water, but in summer it will get very hot.

- The question from the participants was whether homemade ones and the bought ones work the same.

The response was that they do.

The home-made solar oven was shown to the community members, encouraging them to make their own to sell in the community (Plate 4.2).

Plate 4.2: A homemade solar cook box (left), and a bought Sunstove solar oven (right)

iv. Solar geyser

The project team indicated that the technology is used to heat up water.

The person can use 2 litre coke bottles to make one. The black tetra backing brings in more heat but is not necessary.

The water inside the container runs down and heats up through each coke bottle which acts like a mini-greenhouse.

The bucket of water must always be above the containers so that the water moves through the system by siphoning.

A training session was then conducted by Mr Lopes to teach the households how to construct a solar geyser (see Plate 4.3). The instructions were given as follows:

- ✓ Cut the bottom off the plastic 2 litre coke bottles 1 cm below the bottom line.
- ✓ Need one bottle per litre of water. Therefore, if building a 50 litre geyser one needs fifty coke bottles. For the geyser one needs five bottles per column with the last line of bottles to hold the column together.
- ✓ Need to wash each bottle first.

The community members then got involved in cutting and rinsing the coke bottles and painting the six (two down and three across) 30X30X3 mm angle iron pieces. They also cut the Tetra Paks which are used milk cartons made of cardboard, plastic and foil.

- ✓ Need to cut off the top with the plastic hole, the bottom above the join and the edges. This then results in two foil pieces which are inserted into the coke bottles to act as reflectors of the solar energy.
- ✓ Before inserting them one need to wash the two pieces and cut the top corners off so that each piece fits the shape of the coke bottle.

The community members then cut the 15 mm irrigation piping into ten X 1070 mm pieces. Also need twenty 80 mm pieces of pipe which are then attached to an insert T-piece. If they are too hard to put onto the T-piece, can soften them by placing them in the solar oven for a short while.

- ✓ Make the geyser by connecting the short irrigation pipe pieces horizontally onto the 5 T-pieces and the long pieces vertically to the down-part of the T piece.
- ✓ Make up the 10 columns by pushing 5 coke bottles that are lined with the tetra foil pieces onto the vertical irrigation pipes. The bottles should be pushed on with the cap side up. The column looks and fits together better if use the same type of plastic bottles (e.g. coke versus sparletta) as sometimes the bottles differ slightly.

The community members then attached the bottom line of T-pieces and horizontal irrigation pipe to the five columns of coke bottles.

- ✓ This is easier if the pipes are softened in hot water or the sun. Use an up/down movement instead of a screwing movement which cuts the pipe.
- ✓ Need to make sure that the coke bottles are pushed up against each other. One can place the top T-pieces against a wall to ensure this happens.
- ✓ The frame for the geyser was made up from the angle iron which was painted with metal prima. The five pieces of angle iron were put together by bolts. The distance between the top and bottom horizontal bars was 120 cm and a bar was put in the middle.
- ✓ The geyser was then placed on the frame and tied to it with wire.
- ✓ The outside of the 50 litre dustbins were painted with green roof PVA acrylic to protect them from UV degradation.
- ✓ A 2cm diameter hole was drilled into the side of the bucket 10.3 cm from the lip so that the elbow can fit into it.
- ✓ A second hole was drilled into the other side of the bucket 7cm from the bottom.
- ✓ The geyser is connected to the bucket by black irrigation piping.

The solar geyser was set up in the sun at Mrs Hlatshwayo’s homestead and within half an hour (see Plate 4.3).

Plate 4.3: A low-tech solar geyser manufacturing workshop at Mahlabathini village

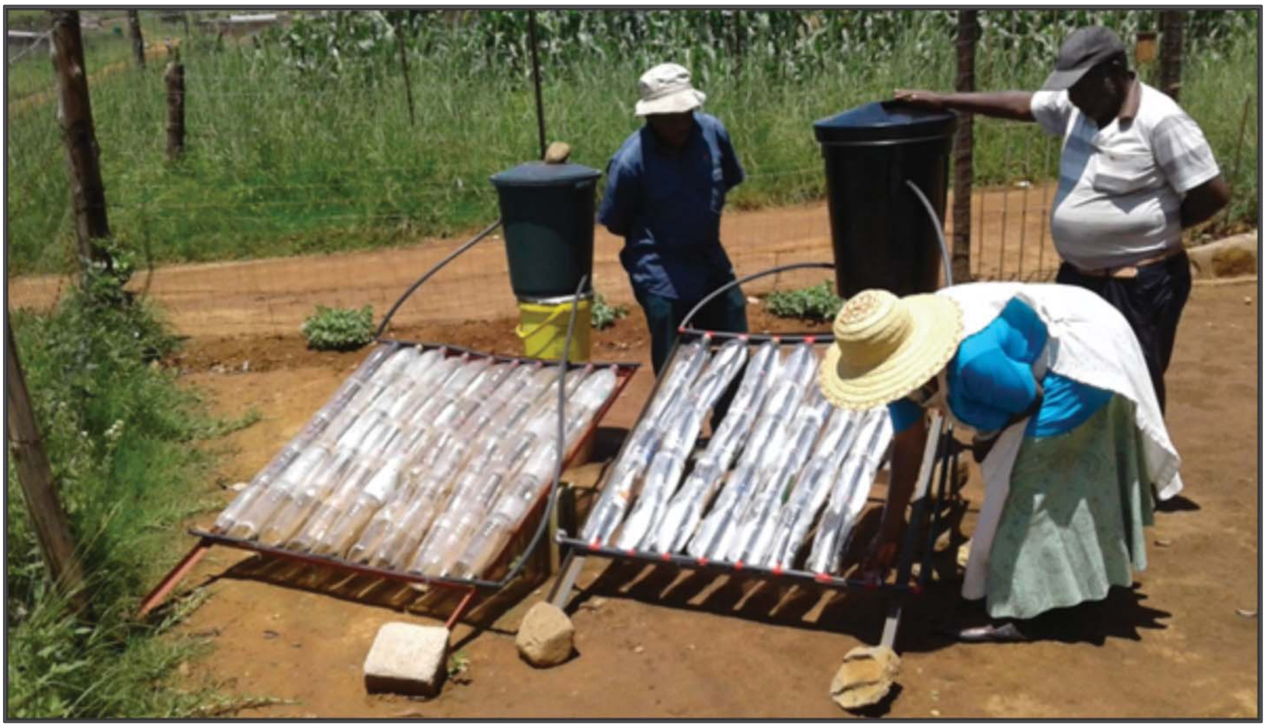


Plate 4.4: Community members inspecting two low-tech solar geysers, one made during the training day (left), and the other made by the community (right)

v. Solar PV System

The project team explained that the system is used to harvest energy from the sun.

The research households were shown how the solar panel charges the LED system which can be used to operate four lights and charge a cell phone at the same time.

The solar panel needs to be put outside in the full sun to charge the battery.

The system has a master on/off switch which controls the system.

The system is simple to use as it has picture icons showing where the plugs fit for the lights and the cell phone charger. The system is easy to mount so that the lights can be used in different rooms.

The household needs to decide whether the solar panel should be brought inside at certain times in case of theft.

vi. LED light system

The Renen team inspected the two households receiving the LED lights to determine their requirements.

It was noted that the one household was a good test of the energy savings as it had 10 light bulbs.

Following the needs assessment, the team would purchase the light bulbs and will deliver them before to the community.

Potential small business opportunities

One of the community members (Mrs Msomi) who attended the training session on the construction of the solar geyser, expressed an interest in opening a small business to make and sell solar geysers to the community. Her unemployed son, Nhlanhla, who participated in the training would be able to help and would like to earn an income.

Mr Lopes carried out a cost analysis of the components and determined that the cost was R400. If labour is incorporated at R150-R300 the final cost will be approximately R700. Although this sounds expensive, a purchased solar geyser costs approximately R6000.

Mr Lopes agreed to make up a list of all the components which Mrs Msomi could use to get a quote for the components when purchased at a local hardware store in Bergville.

The project team agreed to purchase two solar geysers from Mrs Msomi to kick start the small business development component of the project. The geysers will be used at the two households with biodigesters to determine if the addition of warm water to the biogas digester in winter increases gas production.

Although Mrs Msomi initially wanted to start off big and try and sell solar geysers to neighbouring communities, she was advised by the project team to start small and use her own solar geyser as an advert for her sales.

Closing of the training

It was agreed that the extra wood pellets would be stored at Mrs Hlatshwayo’s house.

A community feedback workshop was arranged for Friday 24 June.

After the training on the solar geyser, three community members had constructed a second solar geyser by themselves. This was successfully installed at Mrs Msomi's household.

4.3.2 Community Feedback on Energy Systems

To find out the community's experience of energy systems, a feedback meeting was held with research participants on the 24th June 2016. The report back indicated that the respective households experienced the following:

- **Solar geysers**

Mrs Hlatshwayo wished to use the geyser to warm water especially in winter, for bathing of her school-going children. However, the energy from the sun would only came up around 11.30AM. In addition, the cold weather meant that the solar heat was not strong and could only produce luke-warm which she used in washing of clothes. In summer, Mrs Hlatshwayo reported that the plastic bottle solar geyser would easily get dirty as it has to be kept outdoors for harvesting solar energy. The dirt around the bottles causes the geyser to be not very effective. However, the geyser works very well when it is cleaned.

Mrs Msomi also uses the same technology. She indicated that her kids do not attend the school as yet; hence, the technology was useful for her as she used the solar-heated water to bath the children as the water was warm enough around 2-3pm. Similarly, her solar geyser improved significantly in summer.

- **Solar cookers**

Mrs Hlatshwayo's solar dome (cooker) could not even defrost meat in winter. Similarly, both cookers which Mrs Msibi received only produced lukewarm water which could only be used in the washing of dishes.

However, in summer both participants reported that their solar domes are very effective. They both use them daily, for cooking on a clear weather. Mrs Hlatshwayo often starts off the heating process on the electric stove. Then she moves the pot with food to the solar cooker outside to finish the cooking process. Using the technology has helped her to save significantly on electricity, as she often prepares beans which take long to cook.

Mrs Msibi uses the technology to heat water for the kids before they go to school. She also uses it to cook food.

- **Wonderbag**

Mrs Msomi liked the technology, indicating to use it daily. For instance, after boiling meat for about 10 mins (using electricity), she would then transfer the pot to the wonderbag, and leave the meat to cook overnight. When she is home, she also uses the wonderbag to cook other meal such as potatoes which require close attention.

Using this technology has enabled her to save on electricity and firewood.

Mrs Msomi feels that on a hot weather she has saved a lot from avoiding using electricity. She normally spends about R100/month for electricity but with the wonderbag this has lasted into the second month.

Her challenge however, is the Eskom electricity load-shedding which means sometimes she is not able to start the heating process when preparing her meals. This she therefore ends up using wood.

Her recommendation is that combining wonderbags with Isitofu or ACE would be more beneficial.

Mrs Lakanja's experience of the wonderbag is that she has been able to cook everything in it except porridge which needs stirring. The only challenge is the Eskom load-shedding as she can't start the cooking process. The experience has changed her cooking practice. Before she used the stove now she just starts the cooking process. It hasn't been a problem to cook like this.

Mrs Ndlovu's wonderbag on another hand does not work well. The cooking process does not continue after she has transferred the pot to the bag. She is surprised to hear everyone talking about how much it saves them.

The additional general feedback that other participants added was that the wonderbag:

- ✓ Requires patience because and will not be effective for those who want to finish cooking immediately.
- ✓ Is not ideal to use for cooking for visitors as it takes long.
- ✓ Is recommended only where one has an alternative energy to start off the cooking process.

- **Solar PV and 2 stoves**

Mr Hlongwane, from Ngubhela indicated that the technology works very well. His household does not have electricity which means he is able to use the stove provided by the project. He uses the stove to charge his phone and for lighting his house in the evening. The light is very beneficial especially to his wife who makes craft work and which requires her to sometimes work until very late.

In terms of the stoves: Mr Hlongwane uses the ACE to boil the eggs and cook meat. His experience is that two cups of pellets do not burn hot enough to cook the meat properly. As for the Isitofu, three (3) cups of pellets are required to be able to cook porridge properly. He often removes the chimney to speed up cooking.

Mr Hlongwane's experience differs from that of Mrs Mkhonza in that she did not find any difference between the two stoves. She feels they are both effective. She indicated that when using Isitofu she only needs 1.5 cups of pellets when cooking rice and potatoes. When cooking meat however, she adds 1 more cup of pellets. However, the small quantity of pellets she uses in her cooking could be linked to that she only cooks for two people. She further noted that even after she has finished cooking, the flame remains which she then takes advantage of as a heater, to warm the house as the weather is cold.

As for her ACE stove, Mrs Mkhonza uses it for light, charging and cooking. She uses it for a short time in the evening, for approximately 1.5 hr – because she finishes her day early, not because the energy is finished. She noticed that ACE is quicker.

Her solar PV has been very useful as sometimes they don't have electricity. Electricity load-shedding often happens once a week from 6am-6pm.

Using the technology system has reduced her electricity consumption from spending R100/month of electricity to only R50/month.

Similar to Mkhonza, Mrs Ndinisane praised her ACE. Some of the meal she has cooked with ACE stove includes cabbage and meat. She uses between 1 and 3 cups of pellets to cook cabbage and meat respectively. She often cooks for 3 people.

She especially prefers to use ACE because it is quicker. In addition, the ACE is very useful for charging her cell phone. She also makes craft and uses the lights instead of electricity. She also added that on many occasions the technology saved her from electricity load-shedding which happens often.

As for the Isitofu, her only concerns is the missing stand in the stove, for placing the pot. As a result, the stove generates a lot of smoke which might be dangerous.

Other than this concern Mrs Ndinisane has saved a lot of money by not using electricity often unlike before the project started.

Mr Mtolo's ACE stove has been used to cook porridge, samp and spinach. On average, he uses 3 cups pellets. He finds the stove useful especially for charge his cell phone and to alternate it with electric light.

Like Mrs Mkhonza, Mtolo indicated that even after cooking there is usually some flame still left which he often uses to heat water for bathing.

In his experience the 2 stoves work in the same way. He has not experienced any problems with the stoves and he can easily start the stoves.

In addition to the efficiency of the stoves most households highlighted the following:

- The stoves are reliable compared to electricity. Others added that even without electricity their livelihoods can continue as normal
- They have not purchased wood since they started using the stoves.
- They still use electricity as it remains the main source of energy. However, the level of use has decreased.
- People are eager to continue to use the stoves and pay an amount of R20 for a 5 kg bag of pellets. In addition, a few individuals expressed their desire to sell pellets as a small business.
- Community would be willing to pay R175, R150, R100, R80 for Isitofu but not more even though the actual cost is R600. The community was concerned that Ace stove is expensive – R1600 might be a challenge for people to buy. However, the community was interested to explore buying on credit as the lifespan of the stove was estimated to be 2-3 years.

- **Solar PV**

According to Ms Masengemi, the technology has changed her life because her household is one of the very few families without electricity. Before installation of technology it meant that she had to do house chores in the dark at night. However, with the Solar PV she can now easily continue with her chores into the night. Her home feels very warm than before when she did not have any electricity.
Her fascination is that when it is cold and cloudy the light is faint which means she uses candles. However, on a rainy, sunny day there is enough light.
She is also looking forward to receiving the telephone charger.

- **Thermal Biodigester**

Mr Shezi's technology has not yet experienced any results from the technology. However, he continues to be optimistic as he believes it will save on electricity.

- **Agama biodigester**

Mr Khumalo's biodigester often does not work properly in winter. However, they can still cook other meals halfway. Hence, they have opted to use it to start up cooking and then complete the process in the open fire. The gas picks up in summer as it is warmer. He puts in one bucker (20 litres) of manure and two buckets (40 litres) of water.

- **LED lights**

Mr Msibi reported that the LED globes last longer than the normal globes. He also prefers LED lights as they are brighter. He would like to have the same lights installed outside.

4.3.3 Community Green Business opportunities and experiences

4.3.3.1 Introduction and Opening

The meeting was held on the 18th January 2017.

After a prayer the agenda was outlined

4.3.3.2 Solar geyser business opportunities

Mrs Msomi said that the geyser bottles were a good business opportunity. There needs to be more demonstrations to people to show them how the geyser works then more people would be interested to buy them. There is a lot of interest in it as people see it at the house and come to find out about it. She has not got a price list from Bergville and therefore hasn't tried to make one. She feels the only challenge is that all of them don't know what the costs are and where they can find the parts. Only then can they form a group and come together to look at the business opportunity.

Mr Masengemi stated that even though the new technologies they are using is very useful, he doesn't see any opportunity.

Mrs Msomi said the LED lights worked well and need to be made available locally.

Mr Johannes Zuma said that the solar lights work very well. The problem is that if they break there is no-one to fix them. He suggested that someone be trained to do this although there was still the problem of where and how to obtain the spares.

Mr Mabaso agreed that the geyser bottles had the most opportunity.

People asked if there was an opportunity to make Wonderbags. They would need help with the materials and how to make them. People in the community have sewing machines which they could use to make them.

Mrs Shabalala said that she is already collecting bottles in the hope that she can make a geyser.

People reported that the biggest problem is getting the materials for all the technologies. When asked whether they would be able to go to the local hardware shop and get a price of all the components the participants said they would be able to do this after they had a close look at the one already made. They need to purchase the components and keep the receipts. The project will start by purchasing two geysers. The members will do this by the second week of February. Obtaining the bottles is not a problem but purchasing the steel and piping will be more difficult.

The question was raised on how the community would market the technologies. They said that when they have made the geysers they have plans to call a meeting and showcase what they have done.

One of the youth Sandile Ngema and Mrs Msibi volunteered to lead the process.

Solar ovens business opportunities

People said that they are not sure how to construct these as they are more difficult to make. They will need more training.

4.3.3.3 Pellet stove business opportunities

Participants with stoves stated that they were still using the pellet stoves. They have not tried other fuel besides pellets. Everyone said they had heard you can use sticks as well. Most of them still have pellets. Sandile ran out and has purchased some pellets for R30. One other person had also purchased. The project team noted that this indicated low usage of the stoves and enquired why this was so. They reported that they got two free bags of pellets with the stove and another free bag on the second visit of the Renen team. They paid R50 for the stove, pellets and Wonderbag. Most of them really like the stoves and find them very useful. They would recommend everyone in the community to get a pellet stove. More people in the community have requested them. The actual cost of the stoves is R600. About 25 people would still like a stove.

One person asked what if the stoves arrived before pension day and people want to buy one but will have no money. Delivery day should therefore be after pension day or month end. A decision was made that it would be 8 February 2017. People said the numbers of people wanting stoves may be more than 25. 50 stoves would be brought to the community.

People who were asked to test the use of sticks in the stoves. Some people did not want to try wood as they like the pellets. Some people asked whether they could try charcoal. The response was yes. People were encouraged to report back how effective the different fuels were.

General

Sandile did an experiment to compare the electric stove and the pellet stove. He also wanted to see how long it would take to burn without restarting the stove. He half-filled the chamber with pellets and it burned for 2.5 hrs which was longer than it took to cook the beans. He said the electricity was slower than the pellet stove.

A question was asked about the solar panels and whether the project team would expand on that. The response was that this was not planned as the results of the effectiveness of the different technologies would be reported to government. The reason that they could test more pellet stoves was because the project team received additional funding for this.

4.3.3.4 Community Training and expo days

The research team, with the assistance of Renen, conducted three additional training and expose days to disseminate wood pellet stoves to the community, ensure they were well versed in their operation, and provide opportunity to test the stove business model (see Section 5.7.3).

The three days, spread over two months, encouraged 139 registered participants, and many more who attended but were not captured. Over 100 stoves packs were sold to the community over these days for R50 each. The stove packs included one pellet cook stove (Isitofu), a Wonderbag, and two bags of 5 kg pellet. The cost value of the back was in excess of R600, and was therefore highly subsidised by funding from the Energy and Environmental Partnership (EEP S&EA).

Training days were held at the Mahlabathini community hall (Plate 4.5). The participants were trained on the use of the pellet stoves, correct operational practice, and safety protocol. They were also advised that they could purchase pellet and stoves from the local Spaza store, at the correct retail price. Careful attention was made to ensuring they were told that the price given at the expo day was subsidised.

Plate 4.5: The group gathering before one of the training and expo days at Okhombe

CHAPTER 5. BUSINESS MODELS AND LOCAL ECONOMIC DEVELOPMENT

5.1 Introduction

The Green Village Project was one that aimed to tackle various socio-economic as well as environmental challenges in rural areas of South Africa, and specifically in important water catchments in which many people reside. The project aimed to address some of the known concerns and needs, as well as to identify others through community engagement, and then to pilot and demonstrate various mechanisms that could be used to address sustainable development in these areas. With the food, water and energy nexus at the heart of the projects agenda – the Eastern Cape research team focused on soil degradation and erosion challenges in the Ntabelanga and Sinxaku area (*Volume 1*: Umzimvubu catchment) and the KwaZulu-Natal research team investigated sustainable energy solutions in the Okhombe area *(Volume 2*: uThukela catchment).

This volume reviewed a variety of projects and business models that could aid in improving community livelihoods in poor rural areas. And then presents the findings of their implementation in the Mahlabathini community.

The chapter, therefore, presents a variety of platforms which have been developed for green technology dissemination. The aim of these platforms, programmes and business models is to:

- Achieve the development goals of green technology deployment and rehabilitation of degraded land;
- Create jobs;
- Develop and sustain small, medium and micro enterprises (SMMEs) in rural areas.

The main aim of this project was to investigate methods of improving the economic conditions of communities in the Upper Thukela district through demonstrations of how green innovations and technologies, with respect to energy, can be integrated into their rural livelihoods. A livelihood is sustainable when it can cope with and recover from stresses and shocks, and maintain or enhance its capabilities and assets, while not undermining the natural resource base (Krantz, 2001). In the baseline survey of this study (section 2.1), biomass, particularly firewood, was recorded as the most widely used natural resource used for energy fuel in the Upper Thukela. In addition to alien biomass removal programmes, the fact that 85% of households used firewood for cooking purposes until recently (Smith *et al*., 2014) has resulted in heavy harvesting and the undermining of this natural resource to the extent that firewood is no longer readily available. This has resulted in the degradation of large areas causing environmental problems as well as social concerns, with poor households being unable to afford the purchase of firewood from outside sources. If sustainable development is to be achieved, it will be necessary to seek alternative energy options and technological innovations to improve the efficiency of energy use as well as finding solutions to economic and environmental problems associated with firewood. It must be noted that while the aim of the development of business opportunities was primarily to improve income generation, it also addressed other aspects such as the potential to improve health and social services such as lack of energy, as well as improved livelihoods through capacity building. In addition to the local benefits, the implementation of green energy technologies will also have broader, regional benefits such as a reduction in environmental degradation and positive impacts on the effects of climate change.
Winkler *et al*. (2016) stated that one of the barriers to effective implementation of renewable energy technologies which results in socio-economic development in rural areas, was the lack of knowledge of

renewable energy options among smallholders. Our project therefore focused on building this knowledge through a complex set of processes outlined in Figure 5.1.

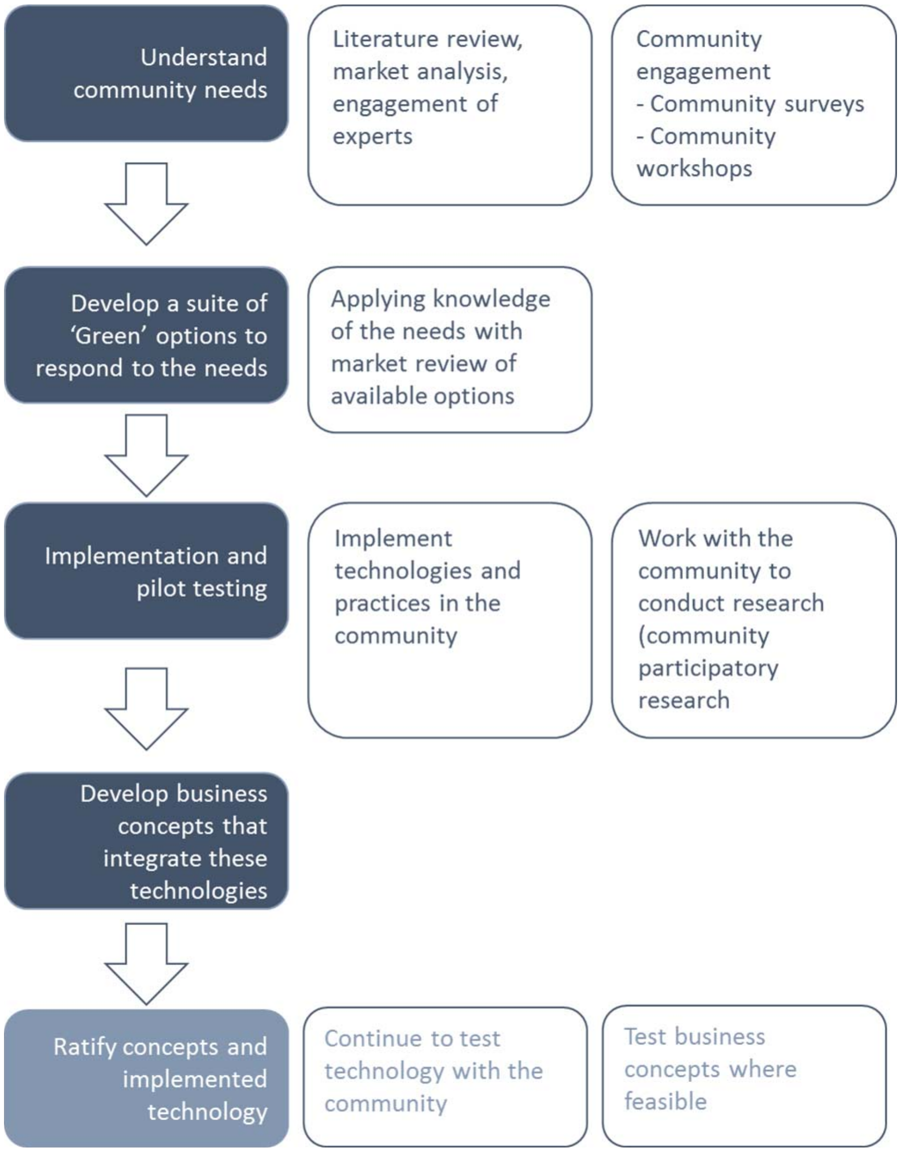


Figure 5.1: Process implemented for the development of business plans

5.1.1 Understanding community needs

For communities to achieve social, economic and environmental benefits, sustainable development needs to be tied to a community's vision and goals. The Mahlabathini community's perceptions of a Green Village are presented in Section 2.2 where they explored the opportunities and challenges relating to green energy.

The key activities undertaken in the course of this research were:

- Community surveys – engaging people on their daily energy related practices and activities.
- Community workshops – discussing energy use, preferences and patterns.

The findings of the community workshop and survey conducted in Mahlabathini, Okhombe have aided the team in understanding the current situation faced in the community and therefore provided a better position from which to investigate various solutions.

Key findings of both the survey and workshop showed that energy, water and food security are of real concern for the people of this village. With respect to energy security, it was clear that access to energy, the cost of energy and the reliability of energy are major challenges that people face each day. The lack of reliability of electricity supply was described clearly, with community members noting how it would likely 'cut off' at any time and could remain unavailable for days. The general energy security problems were highlighted by the fact that households tend to use multiple energies, largely due to changing levels of accessibility, cost and reliability.

In general, it was clear from the results of both the community survey and the community workshop that the community was interested in and supportive of developing a Green Village. Much of the interest and excitement in the topic was founded in the belief that renewable energy could provide an alternative means to strengthening energy security and alleviating the cost of living. Specifically, it became clear that 'off-grid' options to energy would alleviate pressure by providing alternatives to electricity (which has proven to be unreliable), wood and other fuels (which are both expensive and often inaccessible).

5.1.2 Development of a suite of green options

Following the community survey and workshop, the project team engaged with key experts in the energy field to develop a suite of potential green options for rural communities (see Section 2.1).

Following this, market research was enacted and a suite of options, that were readily available and applicable to the Mahlabathini village were selected for implementation and pilot testing. The chosen technologies were:

- Basic solar PV lighting and charging kits.
- Two varieties of wood pellet / biomass stoves, (i) one fan driven with a small solar panel, charger and light, (ii) one non-fan driven Top Lit Up Draft stove.
- A more advanced solar PV back-up system (to be wired into a home).
- Low-tech solar geyser (coke bottle geyser).
- Low-tech 1000 litre biodigester.
- Two types of solar cookers: (i) a bought parabolic dome cooker, (ii) a self-build solar oven box.
- LED lights.
- Wonderbags.

5.1.3 Outcomes

The feedback phase of this project (Section 4.3.1) has shown the importance of community involvement in the testing of potential income generating technologies. Community members highlighted the advantages and constraints with each technology and these were addressed in the development of the business plan. This should lead to more income and more economically sustainable livelihoods, increased well-being, reduced vulnerability and more sustainable use of the natural resource base (Rengasamy undated).

5.2 Business opportunities for rural communities (Mahlabathini – Upper Thukela)

As has been described in Section 5.1, the aim here was to develop a set of concept projects and business plans for implementation in rural areas. The intention of these plans was to provide a means of local economic development, with an integral focus on sustainability – of both the job and/or business created, and of the natural resources and environmental nature housed within that venture.

The fundamental intentions within these developed plans can be summarised as follows:

- Local economic development
    - To generate activities that can stimulated economic progress directly within a surrounding local community.
    - The development of small medium or micro enterprises (SMMEs).
    - The generation of (i) new, and (ii) sustainable jobs.
- Natural resource and environmental sustainability
    - As far as possible to use local, sustainable, natural resources.
    - To ensure reduced detrimental impacts to natural resources, compared to the alternatives – and, where possible, to ensure no impact.
- To, as far as is pragmatically feasible, develop a net export trade balance between the local community and the external surrounds (i.e. the country).
    - It is noted that this intention is not always possible or pragmatic in areas of minimal exportable resources (both natural and human).
    - This intention should, however, be kept in mind in the development of business opportunities.
    - It should be noted that electricity and other fossil fuel based energies are all currently imported to rural communities, and in many areas, similarly biomass/wood is also a net import.

Explanation and formation of project concepts / business plans is summarised as follows:

- Standalone
    - Each plan or concept is designed as a standalone document that can be taken to funders and/or communities for implementation.
- Scale and rollout potential
    - Each of the plans or concepts are designed as single case scenarios for the research communities in questions (i.e. for one business or one job). This does not mean that they are limited to this scale, and rather could be rolled out to other communities or even multiple 'single' cases within the same community (depending on market demand).
- Location/geographical applicability
    - The plans proposed here are specifically applicable to the research communities in question. This, however, does not mean that they are limited to these areas. There are many areas, in close proximity and beyond, that mimic the elements found in the research communities. And, beyond this, the technologies and plans herein are, in many cases, not limited by the characteristics of the research villages – and could therefore be applied in multiple other locations.

Limitations:

- It should be noted that the following business plans are highly simplified. The details, costing, revenues and actions specific to different areas would vary greatly and they should therefore be understood as broad and for example purposed only (to be revised and updated based on specific, known characteristics of an area and scenario).

5.3 Business plan No. 1: Low-tech, community made renewable technologies from recycled materials[44]

Low-Tech Solar Geysers and Ovens

Making solar energy readily available through the local manufacture of Solar Ovens and Solar Geysers from recycled materials

Business Plan

Prepared November 2016

Contact Information

Michael Smith

mikesmith@live.co.za

[44] It is noted that a generic business plan template, including all major business plan sections was used for the following business plans. This template was sourced from LivePlan (www.liveplan.co.za).

5.3.1 Business plan No. 1: Key data summary

5.3.1.1 Brief concept

The Low-Tech Renewable business involves the manufacture of simple renewable energy technologies from mainly recycled materials. The business requires the training of community members to build these technologies which can then be sold for profit to other community members and/or to outside communities.

5.3.1.2 Sustainability contribution

- Job creation.
- Re-use/recycling of waste materials.
- Provision of renewable energy
    - Energy consumption reduction and money saving for product users.
- Local and wider environmental benefit through reduced use of other fuels and energies.

5.3.1.3 Financing and assistance required

Funding: ~R5 000 for start-up capital: simple manufacturing equipment and materials to develop the first month's solar ovens and geysers.

Further funding: ~R2 000 for more advanced equipment to increase the speed of manufacturing (ideal but not a necessary requirement).

Assistance: Business support and training.

5.3.1.4 Potential job creation

Table 5.1 shows the potential job creation for business plan no. 3.

Table 5.1: Potential job creation for business plan no. 1

Job	Job type	Quantity of jobs	Monthly earning potential
Business owner, manufacturer, sales person	Full/part time	1	R2 870
	Total	1	R2 870

5.3.2 <u>Opportunity</u>

5.3.2.1 Problem & Solution

5.3.2.1.1 Problem Worth Solving

In Mahlabathini, and many Drakensberg based rural communities, energy for water heating is both scarce and expensive. Households typically use fire wood or electricity for heating water. There is no pressurised water (municipal type) water in the community, and therefore water heating is by stove top electricity or pots on open fires.

Additionally, cooking is also done at great cost to households in Mahlabathini, as cooking requires high amounts of energy. Electricity is considered expensive by households, and as a result of the area having no wood stocks, fire wood must be purchased by the 'bakkie' load at great expense.

5.3.2.1.2 Our Solution

Low cost renewable energy technologies, that harness 'free' energy from the sun, can be made within the community and supplied to aid households with their (i) water heating, and (ii) cooking needs.

(i) Water can be heated in a solar water heater that uses coke bottles and plastic (HDPE) piping to heat a drum of water (see Plate 5.1).

Plate 5.1: A solar geyser made by Mr Tony Lopes and the Mahlabathini Community Research Group.

(ii) A community made solar oven can also be used to heat water, or to cook food, or to provide some of the energy required before, during or after main cooking activities (see Plate 5.2).

Plate 5.2: 'Low-tech' solar ovens made from plyboard and aluminium sheeting (Lopes, 2016).

These technologies can make use of freely available solar energy to greatly reduce the cost of water heating and cooking in rural households. Additionally, the ease of hot water provision is likely to improve hygiene and sanitation in rural homes.

5.3.2.1.3 Target Market

The target market for this cooking solution is poor rural communities that generally do not have easily accessible cooking and water heating fuels (like wood and electric geysers). Additionally, the solar technologies are applicable to areas that have electricity which is either (i) too expensive for households to use regularly for high energy demand activities (cooking/heating), (ii) unreliable for continuous use.

5.3.2.2 Competition

5.3.2.2.1 Current Alternatives

Traditional energies like fire wood and now electricity are competition for solar technologies.

5.3.2.2.2 Our Advantages

Solar energy is free and freely available in the Drakensberg. Although the weather and outside temperatures do not always permit their use, they can be used on many days and will therefor aid households greatly in reducing their cooking and water heating costs.

5.3.3 <u>Execution</u>

5.3.3.1 Marketing & Sales

5.3.3.1.1 Marketing Plan

In a small community like Mahlabathini (and the wider Okhombe village) marketing will be conducted largely through word of mouth. Further, the business owner could establish his manufacturing activity in a centralised location – where foot traffic his high, and he/she can engage with passers-by to sell the products he is making. One or two demonstration units in the community could also be used for users to give feedback to interested buyers. For example, in Mahlabathini the project team have placed one of the demonstration units at a household on the main access road.

5.3.3.2 Sales Plan

This business is likely to remain small for some time. The business owner and his/her family would therefore be responsible for direct sales to end users. Again, setting up manufacturing or demonstration locations at a key, high traffic area would be advisable. Sales could also be enhanced at market and pension collection days.

5.3.4 <u>Operations</u>

5.3.4.1 Locations & Facilities

The manufacturing of these low-tech solutions does not require significant machinery and need not be limited to a specific location. The owner could therefore conduct manufacturing at his home, and even at a temporary road side store/location to interest potential buyers.

5.3.4.2 Technology

No advanced technology is required for this business; however, a mobile phone could be of assistance to communicate with potential and existing customers, and to provide mobile banking ability.

5.3.4.3 Equipment & Tools

No advanced equipment is required to run this business, although simple tools would be required for manufacturing.
Necessity tools include:

- Hacksaw
- Wood saw
- Spanner
- Screwdriver.

Speed of manufacturing could be greatly increased by:

- Cordless drill
- Cordless jigsaw.

5.3.5 <u>Company</u>

5.3.5.1 Overview

5.3.5.1.1 Ownership & Structure

It is expected that this business model would be formed as an SMME with a single owner – who conducts the operations of the business himself. Depending on the size of the local market and demand for the products made, the business owner could either employ sales agents on a commission basis, or could employ someone to assist with the manufacturing of units while he conducts sales activities him/herself.

5.3.6 <u>Team</u>

5.3.6.1 Management Team

The management team of this SMME would simply be the owner of the company.

5.3.6.2 Advisors

Although these solutions are purposely simple and require minimal technology (i.e. low-tech solutions), some explanation of how they work and training of how they are built is required. The WRC K5/2423 team conducted a training day in which community members were taught how to build these technologies (see Plate 5.3). A further, practical session with business developers would be necessary to ensure the correct materials are being purchased, and that the units are being correctly and efficiently manufactured.

Plate 5.3: A low-tech solar geyser manufacturing workshop at Mahlabathini village

5.3.6.3 Sales team

Under the assumptions of this model, this small business would be owned and run by one individual, who would also act as the sales person for his products.

5.3.7 Financial Plan

5.3.7.1 Forecast

5.3.7.1.1 Key Assumptions

Several key assumptions are used in the development of the following financial assessment. They are namely:

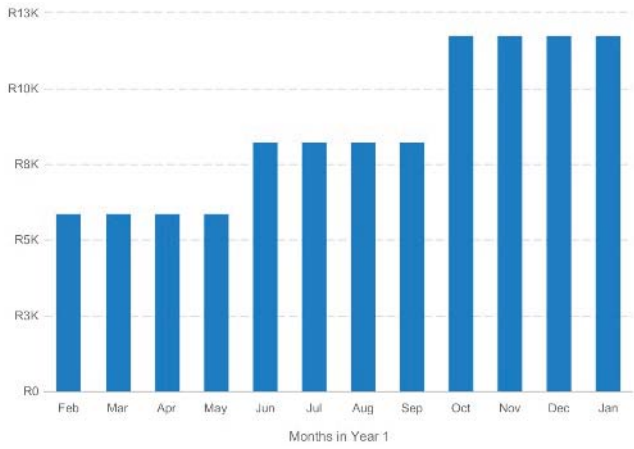
- Product costs (Table 5.2):
  - The low-tech solar geyser is expected to cost approximately R490 in materials and will take 2 hours to manufacture, and will therefore be sold for R650 (32.6% mark-up).
  - The low-tech solar cooker box is expected to cost approximately R393 in materials and will take 1.5 hours to manufacture and will therefore be sold for R525 (33.6% mark-up).
  - Economies of scale have not been taken into account and it is assumed that solar geysers and solar ovens could be made cheaper once the business owner has developed experience and is able to purchase materials in bulk.
- Expected sales

- It is expected that a single business owner will be able to make and sell five units of each product in the first 4-months of operation, increasing to seven units of each per month for the next 4-months of operation and then levelling at approximately 10 of each unit per month.

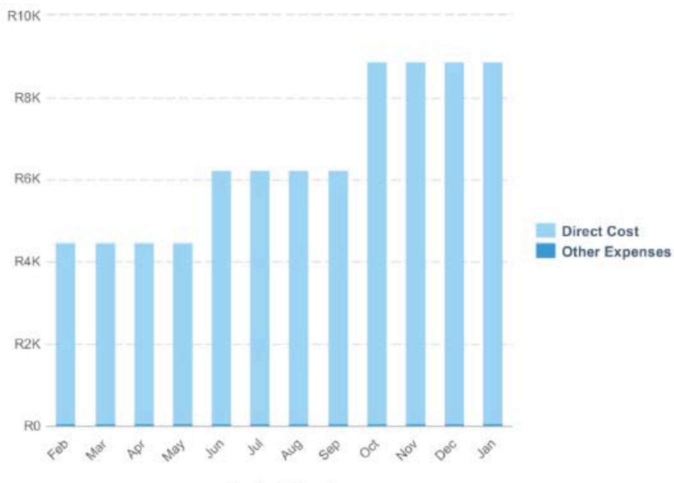
Table 5.2: Estimated material cost for the manufacture of low-tech solar geysers and solar cookers

Solar geysers **Item**	**Quantity**	**Cost**	**Total**
60 litre container (recycled or new)	1	R90	R90
Irrigation type pipes and fittings	1	R245	R245
Bolts and nuts	1	R35	R35
Angle iron for frame (30 x 30)	1	R95	R95
Coke bottles (recycled)	1	R0	R0
Travel for material collection (for multiple geysers and solar boxes)	1	R25	R25
Time for manufacturing (compensation in sale price)	2	R0	R0
		Total	**R490**
Solar oven **Item**	**Quantity**	**Cost**	**Total**
Polycarbonate sheet (1 mm x 2.5 m x 1.2 m)	0.33	R600	R198
Plyboard (2.4 m x 1.2 m)	0.5	R210	R105
Aluminium sheet	1	R50	R50
Screws	1	R15	R15
Travel for material collection (for multiple geysers and solar boxes)	1	R25	R25
Time for manufacturing (compensation in sale price)	1.5	R0	R0
		Total	**R393**

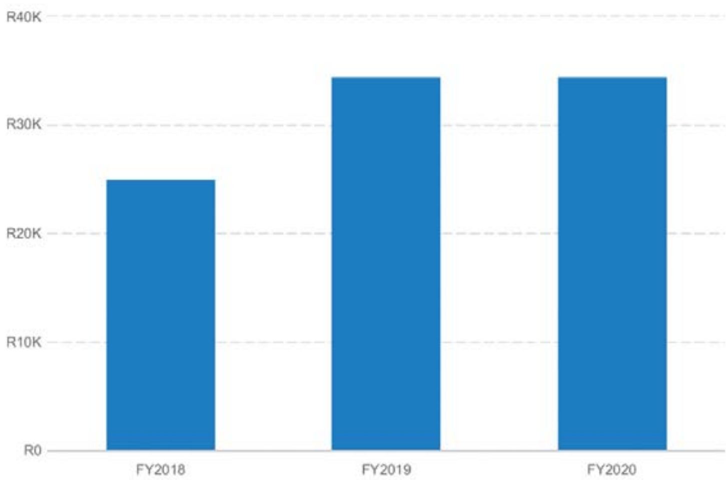
5.3.7.2 Revenue by Month



5.3.7.3 Expenses by Month



5.3.7.4 Net Profit (or Loss) by Year



5.3.8 Financing

5.3.8.1 Use of Funds

One of the challenges with establishing this business is the requirement for some start-up capital to manufacture the products:

- Equipment – a once off purchase for basic manufacturing equipment (hacksaw, wood saw, spanner, screwdriver) to the value of approximately R400.
- Equipment – a once off purchase of more advanced manufacturing equipment for quicker processing (cordless drill and jigsaw) to the value of approximately R2 000.
- Materials for the construction of two stoves and geysers (value of approximately R1 800) which can then be sold to purchase the next round of material.
    - Ideally, grant funding to develop this business could provide the first month's material – a cost value of approximately R4 500.

Total start-up capital required: R5 000.

5.3.8.2 Sources of Funds

Funding is most likely to come from government sources and/or corporate and/or grant funding institutions that have an interest in:

1. Improving the health of rural people by providing a technology that reduces indoor air pollution (IAP) (i.e. by reducing the need for open cooking fires),
2. Providing corporate social investment (CSI) funding to rural populations,
3. Reducing environmental damage in the form of deforestation, by providing a renewable energy alternative for cooking and heating water,
4. Reducing electrical demand in an area by providing an alternative means of cooking and heating,
5. Benefiting local economic development in an area by creating a small, sustainability based SMME.

5.3.9 Statements

5.3.9.1 Projected Profit & Loss

Table 5.3 displays the projected financials for the business case described.

Table 5.3: Projected profit and loss for business plan no. 1

	FY2018	FY2019	FY2020
Revenue	**R103,400**	**R141,000**	**R141,000**
Direct Costs	**R77,704**	**R105,960**	**R105,960**
Gross Margin	R25,696	R35,040	R35,040
Gross Margin %	**25%**	**25%**	**25%**
Operating Expenses			
• Salary			
• Employee Related Expenses			
• Mobile phone expense	R600	R600	R600
Total Operating Expenses	**R600**	**R600**	**R600**
Operating Income	R25,096	R34,440	R34,440
Interest Incurred			
Depreciation and Amortization			
Income Taxes	R0	R0	R0
Total Expenses	**R78,304**	**R106,560**	**R106,560**
Net Profit	**R25,096**	**R34,440**	**R34,440**
Net Profit / Sales	**24%**	**24%**	**24%**

5.4 Business plan No. 2: Biomass pellet stoves

Stove Seller

Biomass Pellet Stoves and Wood Pellet for cleaner, cheaper, more efficient and environmentally friendly cooking.

Business Plan

Prepared November 2016

Contact Information

Michael Smith

mikesmith@live.co.za

5.4.1 Business plan No. 2: Key data summary

5.4.1.1 Brief concept

The Biomass Pellet Stove business summarised in this business plan essentially aims to sell both wood pellet stoves and wood pellets to a community. The assumptions within this plan are that a single business owner can sustain him/herself and five sales agents if each are able to sell 120 stoves (10 stoves per month for the first year) and supply these stove users with 20 kg of wood pellets per month.

5.4.1.2 Sustainability contribution

- Job creation.
- Reduction in use of natural vegetation for cooking/heating.
- Improved cooking means
    - Better efficiency than open cooking fires
    - Cleaner burning than many alternatives (i.e. reduced IAP and improved household health)

5.4.1.3 Financing and assistance required

Funding: ~R300 000 over first 4-months of operation to provide 600 biomass pellet stoves at a subsidised price to the end user.

Financing: ~R5 000 for 250 bags of wood pellet starting stock on consignment.

Assistance: Business support and training.

5.4.1.4 Potential job creation

Table 5.4 shows the potential job creation for business plan no. 2.

Table 5.4: Potential job creation for business plan no. 2

Job	Job type	Quantity of jobs	Monthly earning potential
Business owner	Full time	1	R3 500
Sales agent	Part time	5	R1 680
	Total	6	R11 900

5.4.2 <u>Opportunity</u>

5.4.2.1 Problem & Solution

5.4.2.1.1 Problem Worth Solving

In Mahlabathini, and many Drakensberg based rural communities, energy for cooking is both scarce and expensive. In Mahlabathini, wood has traditionally been used for cooking and spatial heating in homes. The Drakensberg area is typically devoid of suitable trees for fuel wood, and households are required to purchase 'bakkie' loads of wood – costing in the region of R600 to R800 per load, with research conducted under WRC Project K5/1955 showing that this can sometimes last households only one month in winter.

The Mahlabathini community has more recently received electricity. It has been noted at WRC Project K5/2423 community research workshops and surveys, that electricity is an unfavourable method for cooking and heating, as it is expensive.

5.4.2.1.2 Our Solution

The Biomass Wood Pellet / Biomass stove is an efficient cooking stove that offers the ability to improve the efficiency of biomass based cooking, and an alternative "high energy" fuel source (wood pellet).

The Isitofu can either be used with small pieces of wood or with a purchased wood pellets (Plate 5.4). In both cases it provides a much cleaner burning, efficient cooking and heating solution for rural households. Wood pellet is a compressed sawdust which provides a highly dense energy (i.e. high energy value per kg of pellet) – and where affordable and available, households can use this fuel for their daily cooking and heating requirements (approximately 1 kg of wood pellet per 1.5 to 2 hours cooking per day).

Plate 5.4: Biomass pellet stove and wood pellet (source: Kopernik Solutions, 2015; RuralKing, 2016)

5.4.2.1.3 Target Market

The target market for this cooking solution is poor rural communities that generally do not have easily accessible cooking fuels (like wood). Additionally, the Biomass stove is applicable to areas that have electricity which is either (i) too expensive for households to use regularly for high energy demand activities (cooking/heating), (ii) unreliable for continuous use.

5.4.2.2 Competition

5.4.2.2.1.1 Current Alternatives

The Biomass Pellet stove's competition is essentially any other stove that can provide cooking energy delivery. These include (i) paraffin, (ii) electricity, (ii) charcoal, (iii) coal, (iv) wood, and (v) dung.

5.4.2.2.2 Our Advantages

One of the primary advantages of the Biomass Pellet Stove is that it is capable of both cooking and spatial heating at the same time.

Additionally, the Biomass Pellet Stove is reliable in the sense that it is not reliant on electricity, or on the possibility that rain has dampened fuel wood or cow dung.

The Biomass Pellet stove, as a result of its Top Lit Up Draft burning technology, is cleaner burning than open fires and other biomass stoves. This means that the Biomass Pellet Stove can benefit user health by dramatically reducing indoor air pollution (IAP) and related illnesses.

5.4.3 Execution

5.4.3.1 Marketing & Sales

5.4.3.1.1 Marketing Plan

One of the difficulties with growing a Biomass Pellet Stove business and wood pellet market is that the Biomass Pellet Stoves are relatively expensive compared to many of the alternative technologies (subsidised paraffin stoves and electric cookers). Two solutions to this problem exist:

(i) **External funding** could be sourced to provide the Biomass Pellet Stoves at a subsidised cost. This funding can be encouraged through a corporate social investment (CSI) programme, and/or the inclusion of branding of the stoves that can be used as disseminated marketing in rural areas. That latter of these, for example, could be in the form of embossing on the stove itself, branding on the stove's box, or inclusion of marketing material or samples in the stove package.

(ii) **A marketing strategy** that specifically demonstrates the dual capability of the Biomass Pellet Stoves as a means of providing cooking and heating solutions – thereby negating the need for purchasing two different items for this purpose.

STOVE MARKETING:

With respect to a specific marketing strategy, it has been identified that physical demonstration is both important in teaching people how to use this technology, and displaying the advanced and novel ability of the Biomass Pellet Stove. It is suggested that the owner of this business, either by his/her own or through the employment of sales agents, go out into a community and demonstrate the technology in people's homes.

In addition, community farming days, pension collection days, and market days can be used as platforms for sales agents to demonstrate the use of a Biomass Pellet Stove by cooking on it.

Business owners could also benefit by providing free demonstration stoves to side walk traders who could use these devices to cook their products in a high foot-traffic area.

WOOD PELLET MARKETING:

Similarly, to stove marketing, demonstration days and door-to-door visits should focus on persuading purchasers that using wood pellet provides a more efficient, preferable option to the use of other biomass fuel sources. Purchasers can be shown directly or told that wood pellet provides a denser energy fuel – i.e. it will provide a longer, hotter burn.

5.4.3.2 Sales Plan

STOVE SALES:

In the case of a small market, a Biomass Pellet Stove seller can act as a sales agent, making direct sales to his/her customers by demonstrating the stove in public areas and/or by doing door-to-door demonstrations and sales.

In the case of larger areas, or cases where a business owner has greater start-up capital, sales agents can be employed to conduct demonstrations and door-to-door visits. Sales agents should be given stock and can earn commission on each sale.

WOOD PELLET STOVES:

Similarly, business owners or sales agents can provide a service whereby wood pellet can be delivered to people on request within a small community. Wood pellet sales provide an extended income for both sales agents and business owners.

5.4.4 Operations

5.4.4.1 Locations & Facilities

The Biomass Pellet Stove and wood pellet business is not limited by activity in a specific location. The one necessity of this business is the need for storage of some stoves and wood pellet (approximately one ton [one pallet in size] to reduce transportation costs). Beyond storage, the sales can either be run from an easily accessible and central shop, and/or the business owner and/or sales agents can conduct business via door-to-door sales and stands at market days.

5.4.4.2 Technology

No advanced technology is required for this business. A simple mobile phone, however, would be required for:

1. Communication with customers who might require a wood pellet or stove delivery.
2. Communication between a business owner and his sales agents.
3. A mobile phone based banking system (e.g. M-Pesa [Plate 5.5]) that could be used for point of sale transaction and purchase of wood pellet from the supplier/factory.

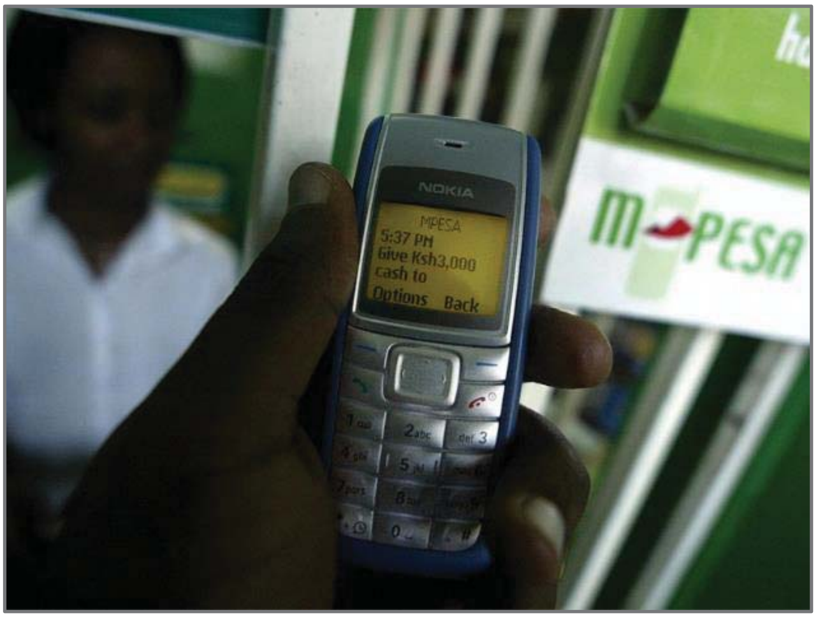


Plate 5.5: Cell phone banking, M-Pesa (source: EuropeanCEO, 2015)

5.4.4.3 Equipment & Tools

No advanced equipment is required to run this business. The sales team and delivery network could, however, be strengthened by:

1. A demonstration kit for the sales agent to demonstrate the stove and biomass pellet to potential buyers (i.e. simply an Isitofu stove and wood pellet)
2. A means of transport that can increase payload capability and ease of travel for pellet deliveries (e.g. a bicycle with a pannier [Plate 5.6]).

Plate 5.6: Pannier bike bag carriers (source: Bike Rumor Media, 2014).

5.4.5 Company

5.4.5.1 Overview

5.4.5.1.1 Ownership & Structure

It is expected that this business model would be formed as an SMME with a single owner – who either conducts the operations of the business himself (with a stove network of minimum 120 stove users), or with the assistance of sales agents (with 5 agents, each having a minimum of 120 stove users under their supervision).

5.4.6 Team

5.4.6.1 Management Team

The management team of this SMME would simply be the owner of the company.

5.4.6.2 Advisors

An owner could take advantage of the vested interest that his suppliers have in his success. Stove sellers and wood pellet producers have an interest in these small businesses working, thereby increasing the demand and sales for their products. Business owners could use this to their advantage to gain their support, in both a monetary, equipment and technology sense, and in the form of advisory.

5.4.6.3 Sales team

Under the assumptions of this model, the team is made up of one business owner and five sales agents who earn a commission on the sale of stoves and monthly sale of wood pellet.

5.4.7 <u>Financial Plan</u>

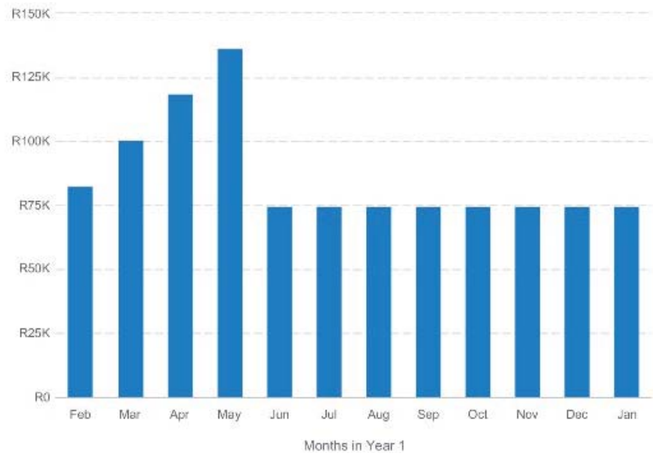
5.4.7.1 Forecast

5.4.7.1.1 Key Assumptions

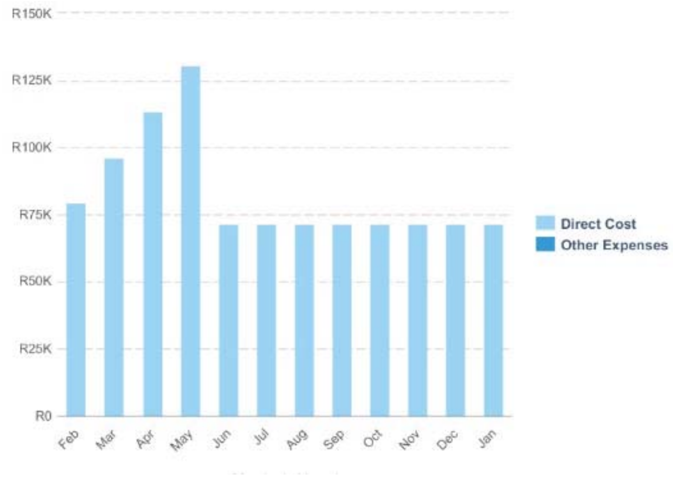
Several key assumptions are used in the development of the following financial assessment. They are namely:

- Product costs:
    - Wood pellet can be bought at R25 incl. VAT per 5 kg bag at the demonstration business location (i.e. this is distance from source dependant), which is then sold at a cost of R30 per 5 kg bag to the end user.
    - Stoves can be bought for R450 incl. VAT per stove and can be sold for R550 per stove.
- Market and business size:
    - It is assumed that the respective community includes approximately 1 000 households (as is the case in Okhombe).
    - We assume here a model where a business owner has 5 sales agents working under him.
- Stove sales:
    - It is assumed that each sales agent is able to sell 30 stoves per month for the first 4 months of operation, and would likely only sell 1 stove per month after this.
- Pellet consumption/sales:
    - It is assumed that each of the stove users purchases 20 kg of wood pellet from his/her sales agent on a monthly basis. This is assumed as reasonably conservative, as a full-time stove user would likely use 1 kg of wood pellet per day.
- Commission structure:
    - Stove agents receive a commission of R75 per stove sale, and the business owner receives R25 per stove.
    - Stove agents receive a commission of R3.5 per 5 kg bag of wood pellet, and the business owner receives R1.5 per 5 kg bag.

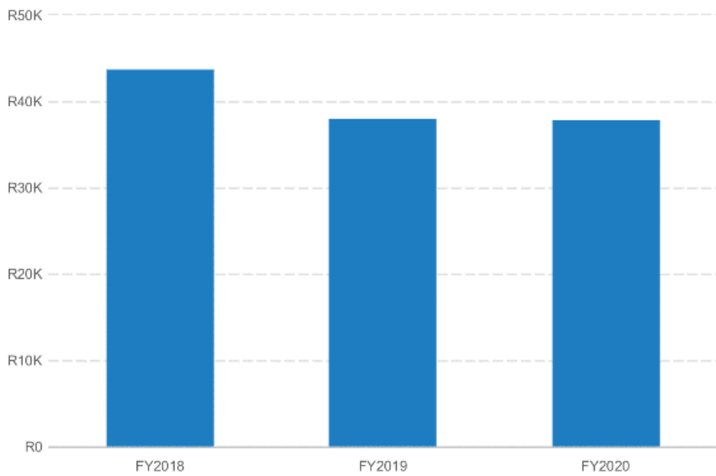
5.4.7.2 Revenue by Month



5.4.7.3 Expenses by Month



5.4.7.4 Net Profit (or Loss) by Year



5.4.8 Financing

5.4.8.1 Use of Funds

Two of the challenges with this business model are:

1. The upfront capital required for the business owner to purchase stoves and wood pellet stock.
2. The relatively high capital cost of the biomass stove for the consumer.

Both these cases require financing/funding either in the form of start-up capital, or in the form of grant funding for the dissemination of biomass stoves (see further below).

Start-up capital would be used to purchase stove and wood pellet stock, while grant funding would be used to provide stoves and demonstration pellet at a subsidised cost. Even in the case where stoves could be provided at no cost, practical research (Watkins and Dankert, pers. comm., 2015) has shown that a nominal charge is necessary in increasing people's value assessment of the product. Further, a small charge is necessary to provide commissions to the sales agents and business owner.

5.4.8.2 Sources of Funds

Funding is most likely to come from government sources and/or corporate and/or grant funding institutions that have an interest in:

1. Improving the health of rural people by providing a technology that reduces indoor air pollution (IAP),
2. Providing corporate social investment (CSI) funding to rural populations,
3. Reducing environmental damage in the form of deforestation, by providing a more efficient biomass cooking options,
4. Reducing electrical demand in an area by providing an alternative means of cooking and heating,
5. Benefiting local economic development in an area by creating a small, sustainability based SMME.

5.4.9 Statements

5.4.9.1 Projected Profit & Loss

Table 5.5 displays the projected financials for the business case described.

Table 5.5: Profit and loss for business plan no. 2

	FY2018	FY2019	FY2020
Revenue	**R1,036,000**	**R897,000**	**R897,000**
Direct Costs	**R985,800**	**R852,300**	**R852,300**
Gross Margin	R50,200	R44,700	R44,700
Gross Margin %	**5%**	**5%**	**5%**
Operating Expenses			
• Salary	R1,800	R1,980	R2,178
• Employee Related Expenses	R360	R396	R432
• Mobile phone costs	R3,000	R3,000	R3,000
• Banking costs	R1,200	R1,200	R1,200
Total Operating Expenses	**R6,360**	**R6,576**	**R6,810**
Operating Income	**R43,840**	**R38,124**	**R37,890**
Interest Incurred			
Depreciation and Amortization			
Income Taxes	R0	R0	R0
Total Expenses	**R992,160**	**R858,876**	**R859,110**
Net Profit	**R43,840**	**R38,124**	**R37,890**
Net Profit / Sales	**4%**	**4%**	**4%**

5.5 Business plan No. 3: Low-tech biogas manufacturing and service industry

Low-tech Biodigester Business

An affordable biogas solution to provide cooking energy and fertiliser for crop production.

Business Plan

Prepared November 2016

Contact Information

Michael Smith

mikesmith@live.co.za

5.5.1 Business plan No. 3: Key data summary

5.5.1.1 Brief concept

The Low-Tech Biodigester business involves the manufacture and maintenance of lower cost, simple biodigesters. A community entrepreneur would need to be trained how to make biodigesters. The entrepreneur would then manufacture and sell the biodigesters, supporting his network of customers with maintenance and servicing.

5.5.1.2 Sustainability contribution

- Job creation.
- Re-use/recycling of waste materials.
- Provision of renewable energy
  - Energy consumption reduction and money saving for product users.
- Production of liquid slurry fertiliser for crop production and soil fertility improvement
- Local and wider environmental benefit through reduced use of other fuels and energies.

5.5.1.3 Financing and assistance required

Funding: ~R4 500 for start-up capital: simple manufacturing equipment and materials for the first biodigester.
~R2 000 for more advanced equipment to increase the speed of manufacturing (ideal but not a necessary requirement).

Community funding: Subsidisation of biodigester cost to end users.

Assistance: Business support and training.

5.5.1.4 Potential job creation

Table 5.6 shows the potential job creation for business plan no. 3.

Table 5.6: Potential job creation for business plan no. 3

Job	Job type	Quantity of jobs	Monthly earning potential
Business owner, manufacturer, sales person	Full/part time	1	R2 749
	Total	1	R2 749

5.5.2 Opportunity

5.5.2.1 Problem & Solution

In Mahlabathini, and many Drakensberg based rural communities, energy for cooking and water heating is both scarce and expensive. Households typically use fire wood and electricity for most of these energy requirements, and both fuels are high monthly costs.

In addition to fire wood being scarce, it's use as a fuel in open fires can be damaging to people's health through the generation and consumption of indoor air pollution (IAP) – one of the highest burdens to disease in Sub-Saharan Africa (Legros *et al*, 2009: 23). Further, in areas where fire wood can be found, environmental damage can take place with the deforestation of indigenous species.

As well as being expensive, households also report that electricity can be highly unreliable often leaving households without a means for cooking (WRC K5/2423 Community Workshops, July 2016).

5.5.2.1.1 Our Solution

Although biogas is not a solution to all energy needs, it can provide a valuable alternative energy that can reduce monthly energy costs for rural households (Smith *et al*., 2014).

A low-tech biodigester can be made from a combination of reused/recycled materials and can be made with relative ease by a trained community member (see Plate 5.7).

The biogas digester should be fed daily with water, cow manure and/or vegetable waste, and can provide gas for cooking (and potentially lighting, refrigeration, heating)[45] and a nutrient rich slurry that can be used as a fertiliser for growing crops.

After the initial cost of establishment, a biodigester costs the household only in time and effort to maintain its operation – and occasional maintenance that can be provided by the low-tech biodigester service provider in the area.

Plate 5.7: A low-tech biodigester made by Mr Tony Lopes and the WRC K5/2423 Community Research Group.

[45] Given sufficient availability of gas and the correct, biogas specific apparatus.

5.5.2.1.2 Target Market

The target market for a biodigester is any household in a rural community that meets the following criteria:

- Has access to cow manure and/or other suitable organic waste of sufficient quantity (2-5 kg wet waste per day).
- Has sufficient water (waste water) to feed the biodigester daily (approximately 10 litres per day).
- Has the man-power to feed the biodigester with waste and water daily.

A biodigester can provide valuable biogas for energy and nutrient rich slurry for gardening, and is therefore likely to appeal to a wide audience who have an interest in reducing their energy costs or improving the quality of their crops.

5.5.2.2 Competition

5.5.2.2.1 Current Alternatives

Any other form of energy, traditional or renewable in nature, that can provide energy for cooking, heating and lighting should be considered as competition to biogas.

In addition, prefabricated biogas digesters and digesters made of brick and mortar are also competing technologies to this business model.

5.5.2.2.2 Our Advantages

Although it is noted above that other energies are competition to biogas, they can and should be seen as complimentary, and the main advantages of biogas are:

1. Once established, biogas requires time for feeding, but is otherwise free.
2. Biogas provides instant heat through a biogas burner (i.e. quicker and more efficient than open wood fires, for example).
3. Biogas burns cleanly, thereby decreasing indoor air pollution and related illnesses.
4. A biodigester not only provides an energy fuel, but also a nutrient rich slurry that can be used as a fertiliser for growing crops.

With respect to other biogas technologies, the main attraction of the low-tech 1000 litre food tank biodigester is that it is substantially cheaper and easier to make. This type of digester is also 'modular', meaning that more tanks can be established in series to provide more biogas. Being above ground, leaks and faults can also easily be found and rectified.[46]

5.5.3 <u>Execution</u>

5.5.3.1 Marketing & Sales

5.5.3.1.1 Marketing Plan

In a small community like Mahlabathini (and the wider Okhombe village) marketing will be conducted largely through word of mouth. The business owner could also demonstrate his technology at some prominent, well located homes in the community.

---

[46] Note: the above ground nature of the low-tech biodigester may be cause for concern as it is exposed to fluctuation air temperatures.

Following the sale of biodigesters, buyers should be encouraged to use the business as a service provider to attend to any maintenance of the biodigester.

5.5.3.2 Sales Plan

This business is likely to remain small for some time. The business owner and his/her family would therefore be responsible for direct sales to end users. Manufacturing of the low-tech biodigester is best conducted at the end user's household, and therefore requires that the owner's equipment and sales plan be dynamic.

5.5.4 Operations

5.5.4.1 Locations & Facilities

The manufacturing of these low-tech solutions does not require significant machinery and need not be limited to a specific location. The owner could therefore conduct manufacturing at his home, and or preferably at the house of an end user / product purchaser.

5.5.4.2 Technology

No advanced technology is required for this business; however, a mobile phone could be of assistance to communicate with potential and existing customers, and is advised as a means to provide mobile banking ability.

5.5.4.3 Equipment & Tools

No advanced equipment is required to run this business or the manufacturing of the biodigesters, although simple tools would be required for manufacturing.

Necessity tools include:

- Hacksaw
- Paint brush and associated equipment
- Spanners, screwdrivers and pliers.

Speed of manufacturing could be greatly increased by:

- Cordless drill.

5.5.5 Company

5.5.5.1 Overview

5.5.5.1.1 Ownership & Structure

It is expected that this business model would be formed as an SMME with a single owner – who either conducts the operations of the business himself. Depending on the size of the local market and demand for the products made, the business owner could either employ sales agents on a commission basis, or could employ someone to assist with the manufacturing of units while he conducts sales activities him/herself.

5.5.6 Team

5.5.6.1 Management Team

The management team of this SMME would consist of the owner of the company.

5.5.6.2 Advisors

The low-tech biodigester, although relatively simple in technological terms, still requires key design features which need to be taught by an experienced manufacturer. A business owner would need to be taught how to make the biodigester (see Plate 5.8 training at Mahlabathini).

In addition, an entrepreneur, unless already familiar with business operations, should be taught business development and running skills. The nature of the low-tech biodigester business does require a relatively high up-front capital outlay (approximately R4 000) and it is therefore important that an entrepreneur understand the need for re-investment of sales in the form of new material purchases.

Plate 5.8: A low-tech biodigester manufacturing at Mahlabathini village during a WRC K5/2423 training workshop.

5.5.6.3 Sales team

Under the assumptions of this model, this small business would be owned and run by one individual, who would also act as the sales person for his products.

5.5.7 Financial Plan

5.5.7.1 Forecast

5.5.7.1.1 Key Assumptions

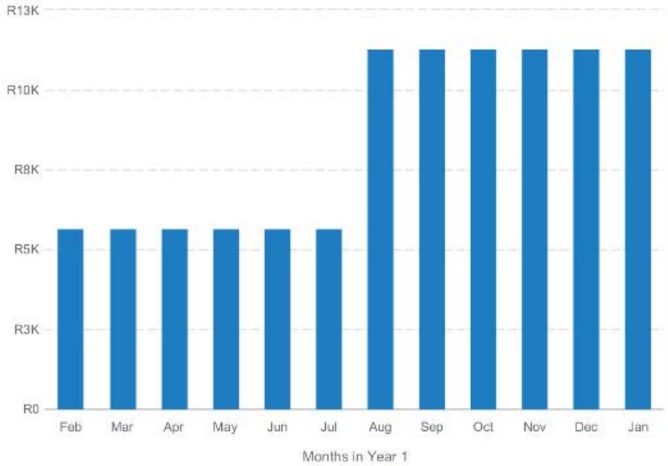
Several key assumptions are used in the development of the following financial assessment. They are namely:

- Product costs (Table 5.7):
  - The costs of a building a low-tech biodigester are likely to vary greatly by area and quantity in production. Specifically, the transportation of bulk 1000 litre tanks is likely to vary greatly and would be decreased by the delivery of multiple tanks at a time.
  - Furthermore, the ability to use recycled materials could greatly aid in cost reduction.
  - The costs of a biodigester manufactured in the Mahlabathini village are presented in Table 5.7 and are estimated at R3 769 per biodigester.
- Expected sales
  - It is expected that a single business owner will be able to make and sell one low-tech biodigester per month for the first 6-months of operation, increasing to two biodigesters per month for the following 12-months, and declining back to one digester per month after that.
  - It is expected further that purchasers, within walking distance of the business owner (i.e. within the village) will require minor maintenance support on a monthly basis after the first year of operation.
    - A call out fee is charged here at R50.
    - It is expected that one call out will be required per year per digester sold.

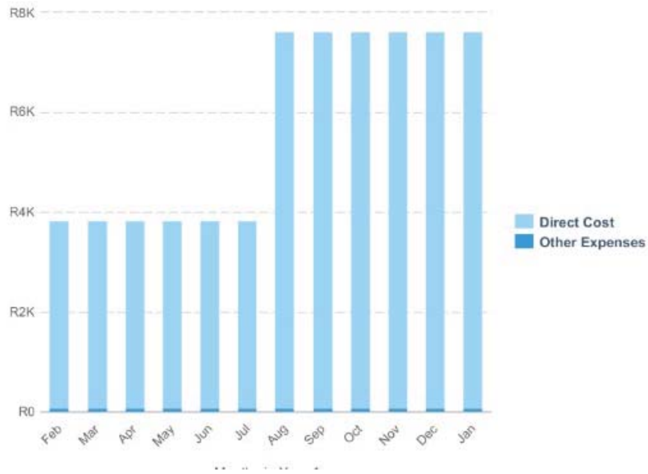
Table 5.7: Estimated material cost for the manufacture of low-tech biodigester at Mahlabathini village

Low-tech biogas digester			
Item	**Quantity**	**Cost**	**Total**
1000 L square tank	1	R1 650	R1 650
PVA protective paint	1	R226	R226
Gas line and fittings	1	R393	R393
20 inch tractor tyre tubes	3	R100	R300
Gas plate	1	R200	R200
Travel for material collection	1	R1 000	R1 000
Time for manufacturing (compensation in sale price)	24	R0	R0
		Total	**R3 769**

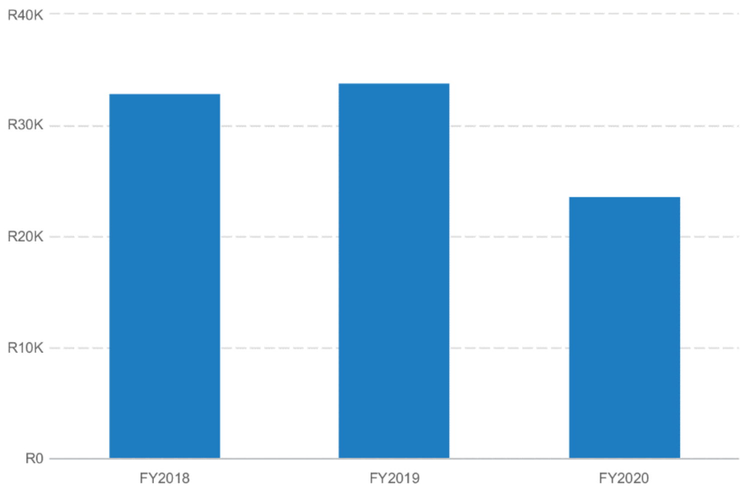
5.5.7.1.2 Revenue by Month



5.5.7.1.3 Expenses by Month



5.5.7.1.4 Net Profit (or Loss) by Year



5.5.8 Financing

5.5.8.1 Use of Funds

One of the challenges with establishing this business is the requirement for some start-up capital to manufacture the products:

- Equipment – a once off purchase for basic manufacturing equipment (hacksaw, wood saw, spanner, screwdriver) to the value of approximately R400.
- Equipment – a once off purchase of more advanced manufacturing equipment for quicker processing (cordless drill and jigsaw) to the value of approximately R2 000.
- Materials for the construction of two stoves and geysers (value of approximately R1 800) which can then be sold to purchase the next round of material.
    - Ideally, grant funding to develop this business could provide the first month's material – a cost value of approximately R4 500.

Total start-up capital required: R5 000.

5.5.8.2 Sources of Funds

Funding is most likely to come from government sources and/or corporate and/or grant funding institutions that have an interest in:

1. Improving the health of rural people by providing a technology that reduces indoor air pollution (IAP) (i.e. by reducing the need for open cooking fires),
2. Providing corporate social investment (CSI) funding to rural populations,
3. Reducing environmental damage in the form of deforestation, by providing a renewable energy alternative for cooking and heating water,
4. Reducing electrical demand in an area by providing an alternative means of cooking and heating,
5. Benefiting local economic development in an area by creating a small, sustainability based SMME.

5.5.9 Statements

5.5.9.1 Projected Profit & Loss

displays the projected financials for the business case described.

Table 5.8: Profit and loss for business plan no. 3

	FY2018	FY2019	FY2020
Revenue	**R101,700**	**R102,600**	**R69,600**
Direct Costs	**R67,842**	**R67,842**	**R45,228**
Gross Margin	R33,858	R34,758	R24,372
Gross Margin %	**33%**	**34%**	**35%**
Operating Expenses			
• Salary			
• Employee Related Expenses			
• Mobile Phone Costs	R600	R600	R600
• Mobile Phone Banking Charges	R270	R270	R180
Total Operating Expenses	**R870**	**R870**	**R780**
Operating Income	**R32,988**	**R33,888**	**R23,592**
Interest Incurred			
Depreciation and Amortization			
Income Taxes	R0	R0	R0
Total Expenses	**R68,712**	**R68,712**	**R46,008**
Net Profit	**R32,988**	**R33,888**	**R23,592**
Net Profit / Sales	**32%**	**33%**	**34%**

5.6 Business plan No. 4: Sale of support of various renewable energy technologies in rural villages

Through the course of the project it has become apparent that many simple renewable energy technologies are not available for purchase within rural communities. Community workshops and surveys have identified that there is significant interest in these, and it is therefore assumed ease of availability of these technologies would likely result in greater up-take in rural areas.

The details of this business and an assessment of it is not carried out here as the plethora of available technologies and variables involved in the concept are too great for valid review.

It is assumed, however, that such a business would likely take structure in an existing retail outlet (e.g. a 'Spaza Store'), as the capital outlay for various technologies is likely to be high.

Given the development of such a retail business, and the increase of various technologies within a community, it stands to reason that an entrepreneur could take advantage of a need for assistance in (i) establishing various technologies in people's homes, and (ii) providing service and maintenance for those technologies. A solar photovoltaic (PV) system, for example, requires some technical experience for connection and maintenance.

Some of the renewable and efficiency technologies that are expected to be of value and demand in rural areas, like Mahlabathini are displayed in Table 5.9:

Table 5.9: Various renewable energy and efficiency technologies that could potentially be sold in rural areas [47]

Solar PV and battery systems	

[47] Image sources from top to bottom: (Hirsch, 2013; EurocosM UK, 2016; SFGate, 2013; Scinet, 2015; ACE, 2016; Ndebele Stoves, 2016).

Low energy consuming LED lights	
Wonderbag	
Solar cookers	

Biomass and biomass pellet stoves	
Closed biomass/wood stoves	

It should be remembered that while these above mentioned technologies (Table 5.9) are likely to benefit the communities in providing renewable energy and energy savings, they are imports to the community and will not necessarily promote job creation and local economic development. Where possible, locally available resources, and people, should be used preferentially to develop renewable energies and efficiency options.

This noted, it should be recognised that in many communities all existing energy is imported. Electricity and fossil fuel derived fuels are all imported to rural South African villages. Wood and other forms of biomass are also often imported into a village, as is the case in Mahlabathini.

5.7 Report on outcomes of business model testing

As has been described in this chapter, four potential business models were identified for the greater Okhombe village.

1. Low-tech solar cooker and solar geyser: Manufacture and sale
2. Biomass pellet and pellet stoves: Sale
3. Low-tech biogas digester: Manufacture and sale
4. Renewable and efficiency energy technologies: Sale and support.

The aim in this aspect of the project, as was employed with the technology use, was to train community members, and then allow them to pursue further actions in their own time and manner. The intention of this process was to mimic real-world scenarios, where researchers did not bias outcomes by directing the communities actions each step of the way. The outcomes of this process have been met with limited success, but have been highly useful in identifying the areas of need in developing local economic development (LED) models. The following experiences, related to the specific models tested and/or explored, highlight the learning of this research.

5.7.1 Low-tech solar geyser: Manufacture and sale

As described in Section 4.2.1, training was conducted with a group of community members to teach them how to build low-tech solar cookers and solar geysers (see Plate 5.9). In an effort to give impetus to the development of this micro-enterprise, the research team commissioned the development of a group's first low-tech, coke bottle solar geyser. The parties who expressed an interest in developing a micro-enterprise to manufacture and sell these products were asked to:

- (i) locally source the materials required;
- (ii) keep records of the costs of these materials and their acquisition of them;
- (iii) manufacture the low-tech solar geyser as they had been taught during the capacity building training days;
- (iv) use this unit to demonstrate the technology to the broader community and,
- (v) sell units to interested parties.

Plate 5.9: Two of the solar geyser production team with the solar geyser that was commissioned by the research team

A follow-up survey was conducted with Mrs Hlatshwayo (Appendix 10.4.2) and Mrs Msomi (Appendix 10.4.3) who were involved in this pilot micro-enterprise, the key points of feedback are summarised as follows:

Training and manufacturing ability:
Both respondents agreed that the training had been sufficient to provide them with the know-how to manufacture the solar geysers. However, despite this, the group manufacturing the geyser had not had all the tools they required, and they had employed a local man to make the required holes in the bucket. The man had made these holes an incorrect size for the pipes they had been given by the hardware store, and the geyser bucket had leaked from the onset.

Expense of the materials:
The respondents noted, with proof, that the materials had cost them R967, with a further transport cost to get them to Bergville to purchase the materials. These costs were significantly higher than the material costs that had been calculated by trainer, Tony Lopes, after his purchases of materials in a larger city (Johannesburg) (see Table 5.2).

The respondents noted that they had had to use money from a group of eight ladies, who had further assisted in manufacturing the first unit.

It was noted that these costs were prohibitive for a micro-enterprise to absorb before selling any units, and further that they would make the units far too expensive for purchase.

Local market for the solar geyser:
Both respondents, who were also users of the technology noted that the solar geyser was very beneficial to their daily needs, but did not provide hot water the whole time. It was noted that it did not perform as well in the cold winter months, and that it did not deliver hot water on cold or overcast days. On sunny, warm days, the geyser was very effective and was believed to save time and money, and to provide extra hot water where they previously would have only had a small kettle or pot of hot water to use for bathing. For these reasons, the respondents believed people would definitely be willing to buy the technology, but not for as much as R1 500, which they believed they would need to sell it for.

The stated sale price was a result of the high cost of materials from local sources, and both respondents believed they if they were able to get the unit down to a price of between R500-R700, that the local community would be willing to buy it.

Mrs Kunene, whose home is located centrally and along the main village road, noted that she had had significant interest in the solar geyser, and had been asked to show many people how it worked. She believed this interest showed further proof that people would be interested in buying the technology, at the right price.

Would the micro-enterprise be able to support a family?:
Both respondents agreed that there was a market for the technology locally, and that a business could certainly be made out of the manufacturing and sales enterprise if more affordable materials could be sourced. They also, however, agreed that the business would only be able to make extra money for a household, not sustain them in its solidarity.

On further discussion, Mrs Hlatshwayo expressed sincere interest in making the business a reality. She believed that some initial success would lead to further diversification of the type of products that they could manufacture, and it would later be necessary for them to find a location where they could store and display various products.

Requirement for support or training:
The respondents were asked what support, capacity building or resources would be required to realise the success of a micro-enterprise of this type. Both respondents reported that assistance in sourcing materials was the major requirement of the team – and would be critical in making the product more affordable and attractive to the community.

Although training was not noted as a required support item, with both respondents stating they understood well how to manufacture the product from the initial training given, the failure of the first unit identifies that some refresher training would be beneficial. Mrs Hlatshwayo also noted that it would be helpful to train "helpers" who could assist them with the manufacturing of the units.

Mrs Hlatshwayo made reference to the fact that they had had to use the money of the eight people involved to purchase the materials for the first unit, and some financial support would be beneficial in allowing them to make units for display and selling.

The interviews also identified that tooling would be beneficial, as the team would not need to rely on external sources to make holes in the geyser buckets.

5.7.2 Low-tech solar cooker: Manufacture and sale

A different approach, to that of the solar geyser business development (Section 5.7.1), was taken for the solar cooker. The whole community research group (30+ people) who attended the training day (see Section 4.2.1) were shown a home-made solar cook box, and were told how one could be made. In contrast to the solar geyser training, the interested parties were not asked to partake in the actual construction of a demonstration unit. The intention of this process was to establish (i) the difference in these training approaches, (ii) the community's initiative to further explore this type of technology if they saw it to be beneficial.

Mrs Msomi (see Appendix 10.4.4) was interviewed about the uptake of the solar cook box training. She reported that no one had pursued the manufacturing of the solar cook box. Although she acknowledged that the community had been shown how to make the solar cook box, she felt that the training was not sufficient for them to attempt making their own. She explained further that they were not aware which materials should be used, and had not tried to find any of them.

The result of this experience shows clearly that further training, preferable with active participation, is required to initiate a manufacturing project of this nature.

5.7.3 Biomass pellet and pellet stove: Sales

An entirely different business model approach was followed with the biomass pellet stove (Isitofu). Given the short term nature of the project, and the anticipated need for stove users to need regular access to wood pellet – it was decided that an existing enterprise would be used to test the stove sale and pellet sale model.
A team from Renen Energy Solutions made three additional trips to the Mahlabathini community to train and disseminate stoves to the community. It was decided that a package, including a pellet stove, two bags of pellet and a Wonderbag, would be sold to the community for a highly subsidised price of R50 (cost price in excess of R600). The intention was to ensure that there was significant uptake of stoves in the area, to support the sale of pellet from a local store. Over one hundred stoves were sold to the local community, training was provided widely, and the participants were told that stoves and pellet would be available at the local store at the full retail price.

Following this process, the local “Spaza” store was approached and offered free pellet and stove stock on the premise that the stock would be sold to the community at the correct price, and that they should re-order (and pay for) stock when the levels dropped low. The Spaza store was given 10 stoves and 200 bags of 5 kg pellet.

The research team received no requests for stock over the eight-month period. The outcome of an interview with the Spaza store owner (see Appendix 10.3.2) indicated the following:

Stove and pellet sales:
Only two stoves (R600 each) and 20-30 bags of pellet were sold. It was noted that no stoves or pellet were visible in the store, and further that two community members had told the research team that they were unable to get pellet from the store as they were out of stock. When asked where the remaining pellet was, the respondent said that his family had used all of it.

After further questioning, the respondent stated that he believed it had not been bought because there were so few people who had pellet stoves in the village, and the few that did have, had come back a number of times. The owner was told that over 100 people had been given stoves in the area, to which he did not have a response.

Cost of pellet:
The store owner stated that he believed the pellet was too expensive at R30/bag (5 kg), and that people would only buy it for R10/bag. It is noted that the cost price of pellet in Pietermaritzburg (200 plus km away from Mahlabathini) is approximately R15 per bag – making it infeasible to charge less than R30 after reasonable sales mark-ups and transport costs.

The outcomes of this research showed self-centred intent from the store owner. The store had been chosen for two primary reasons: (i) it was open regularly, and would allow people to access the pellet conveniently, (ii) it was believed the store owner would have knowledge of how to run a business, maintaining stock levels and earnings to re-purchase product. The owner’s responses were contradictory – showing his family had used and benefited from the stoves – to his efforts to sell and promote a product that *could* potentially better the lives of the local community. Although multiple follow-up visits were made during the initial period, to ensure the owner understood the product, it appears that further training and explanation needs to be done to ensure ‘buy-in’ from such individuals.

5.7.4 Low-tech biodigester: Manufacture and sale

An interview with Mr Shezi, the owner of the pilot low-tech biodigester and a member involved with the training of its manufacture, was conducted and is included as Appendix 10.4.5.

Mr Shezi’s biodigester has not been successful. This technology was new to the research team, and despite bringing an expert in to conduct the training and manufacture, the team has been unable to rectify the problem. Mr Lopes, who constructed the digester, returned after the cold winter period – in which basic biodigesters often lie dormant – to check the system and even installed a second, in-parallel digester. The system appeared to be making gas, although this production was not being captured or was not sufficient to provide cooking ability.

When asked about his belief of a market for biodigesters in Okhombe, Mr Shezi explained that there would definitely be a market as energy was expensive and biomass inaccessible. He emphasised that people would, however, have to see the technology working for them to believe its abilities and especially if they were to invest in it. He believed people would be willing to pay R1 500 or more if they could be assured that it would provide all of their cooking needs, noting that he understood the gas would be 'free' once the initial investment had been made.

The experience with this model emphasised the need for demonstration units in rural communities. Although this is an example where the technology was not working, it appears necessary for all technologies to be demonstrated effectively before people are willing to invest in them, or even transition to them where they are donated.

The research team will continue to work with the pilot household to establish why the technology is not working.

5.7.5 Renewable and efficiency energy technologies: Sale and support

The research project did not have the time or resources to establish a sale and support model for a host of renewable energies, but rather set out to establish which technologies were most relevant to the community.

In an effort to understand the status quo of this potential retail/service industry the research team interviewed the local Spaza store to develop an understanding of (i) what, in this category of merchandise, was already available, and (ii) what they believed might be beneficial to the community (see Appendix 10.3.2).

The store owner was asked which technologies he sold, why he did or did not, and whether he thought there was a market for these goods. The responses to the various technologies were as follows:

Solar products:
The store did not sell solar products and the owner said he did not think there was a market for them, because most people had electricity.

The experience of the project researchers suggests that this belief was inaccurate. The solar products implemented in the community had been widely regarded as extremely useful, mainly in their capacity as a secondary source of energy, and due to the unreliability of electricity in the area.

Energy efficient lights:
The store did not sell energy efficient (LED or CFL) light bulbs, but the owner believed these would be sought after and his reason for not selling them was that he did not know where he would get them.

The research of the project supports the suggestion that these would be valued in the community, but only in cases where training – like that conducted in this project – had educated the local people of the significant savings possible from these technologies.

Clean cook stoves (pellet cookstoves):
As discussed in Section 5.7.4, the store owner was not displaying the stoves or pellet that had been given to them, and he stated that he did not think there was a market for these products.

The research suggests that these technologies were highly regarded as a back-up option for cooking, but not as a primary source of cooking. In an area with significant electricity outages, it stands to reason that wood pellet would be, albeit infrequently, a purchased commodity in a local store. The research does, however, agree with the store owner that the pellet stoves were more expensive than people are willing to pay in the area – although it is noted that two stoves were sold at full retail value.

Wonderbag:
The store owner did not sell the Wonderbag and stated that he would not sell, and didn't believe a market for it existed, as his family had not had any success using this technology.

The findings of Wonderbag usage has been highly contradictory in the research community, with some people praising the Wonderbag for its benefits and others being wholly unimpressed – despite the latter reporting similar methods of use. It appears training is key for the successful application of this technology, and it is suggested that any resellers be carefully guided, with supporting printed instructions, to educate potential purchasers.

Solar cooking oven:
The store owner was not aware what this technology was and was unable to answer whether it would have any use or demand in the community.

Again, as described in the case of Mr Shezi's biodigester (Section 5.7.4), it appears pivotal that demonstration technologies be employed in rural communities to ensure people develop trust in them, and an understanding of how they work from actual experience and word-of-mouth exposure.

In general, the broader research suggests that renewable energy technologies would certainly have a market in a local store. It is understood, however, that the lack of knowledge of these technologies would need to be addressed before demand arose for them, or before local stores would risk stocking them.

CHAPTER 6. CLIMATE CHANGE RELATED SURVEYS

6.1 Introduction to climate change

It was in 1988 that the Intergovernmental Panel on Climate Change (IPCC) formed a coalition to assess evidence of climate change; however, the organisation only released its first report in 1990 where it cited the increasing temperatures amid the claims of sky rocketing carbon emissions which had reached six billion tonnes per year. Hegerl and Zwiers (cited in Kpadonou *et al*., 2012) warn that climate is already changing due to anthropogenic greenhouse gas and aerosol emissions, which affect average climate conditions as well as climate extremes. Reports continue to signal that climate change is attributed directly or indirectly to human activities, which eventually alters the composition of the global atmosphere, in addition to the naturally variable climate occurring over a comparable time (Midgley *et al*., 2005).

While the previous chapters of this report focused on green economy, which is a social justice programme which tackles the adverse effects of multiple-human activities on the environment, this chapter illustrates the linkages of renewable energy initiatives with sustainability and climate change. While green economy has recently gained momentum leading to national implementation, to mitigate carbon emissions reduction by 34% and 42% by 2020 and 2025 respectively (National Treasury, 2013) the research programme on water adaption and mitigation strategies to climate has long existed. In South Africa an estimate of R30 million was spent on more than 30 research projects in the field of hydroclimatology (The Water Wheel January/February 2009).

The green village concept focuses on green energy as a critical intervention, however, other components have a direct link and are as critical if maladaptation is to be avoided. At the core of Hoff's (2011) nexus is the debate that there are natural resource scarcities and the recognition that water, energy, food and other resources are interlinked in a web of complex relations where resource use and availability are interdependent (Leck *et al*., 2015).

In this report the impact of climate change in South Africa on water resources, essential for production of food and generation of energy is discussed. Rural livelihoods are described within the context of their dependence on water for farming and securing of food. The impact of climate change in Okhombe is presented, based on in-depth interviews, household surveys and transect walks. Further, to illustrate community agency, community strategies used to expand the inadequate water supply were traced. Finally, the report presents the communal garden and bio-digester as two sites to indicate linkage as well as dependency of energy on water availability (i.e. the expansion of the current water supply systems in Okhombe). The recommendations are drawn to show how adaptability can be sustained using the nexus instead of focusing on one sector.

6.2 The impact of climate change on South Africa's water resources

Global struggles to manage natural resources existed in the ancient times (Western *et al*., 1994) although no direct link was made to climate change. Critchley and Netshikovhela (cited in Zuma, 2003) for instance, indicate that soil and water crises appeared in Africa as early as the 1920's. At the start of the millennium and almost a decade after the IPCC report was published, the World Bank projected that 20 countries would have 1000 m^3 of available water per capita per year or less. The centuries-long history of rainfall fluctuations and droughts of varying lengths and intensities meant that twelve of the countries were in Africa, with nine in Sub-Saharan Africa (World Bank, 1997). Sub-Sahara has subsequently acquired a water-poor status (Swatuk, 2008; SADC, 2005), with South Africa befitting the 29th place as one of the driest countries, with an estimate of 1110 m^3 of water per person (Muller *et al*., 2009:9). This means South Africa lacks large, fast flowing rivers and huge underground reservoirs which other countries have. Moreover, high levels of evaporation exacerbate the scarce rainfall.

While the IPCC report led to the evolution of the global community to integrate climate change into their policy agenda, the South African government only took critical steps to deal with climate change after the COP17 (like many other policy makers and practitioners of developing countries) where the green economy gained momentum, (DFID, 2006a; DFID, 2006b; UNDP, 2007). The paradigm shift was perhaps the acknowledgement of complications posed by climate change on the commodified water, which is a result of "modifications in water vapour, runoff, and soil moisture" (Rosenzweig and Hillel, 1995).

Meanwhile studies on adaptation continued in support of adjustment in natural or human systems to a new or changing environment (Midgley *et al*., 2005). As a result, numerous adaptation strategies have been proposed to mitigate the negative effects of climate change (Leary *et al*., 2012; Mukheibir, 2008; Mukheibir and Sparks, 2005; Midgley, 2005). There is however, a call for long-term strategies to ensure that future supply of water matches demand, even in times of reduced availability (Makhebir and Sparks, 2005).

6.3 Rural livelihoods dependence on water for food security

The IPCC (2007) had already warned that poor communities particularly in sub-Saharan Africa will be most vulnerable because of their low adaptive capacity and great dependency on high climate sensitive resources such as water resources and ecosystems. Albeit these pessimistic reports, rural communities continue to depend on water and land use for their livelihoods (Allouche, 2016; McCusker and Oberhauser, 2006:326). A *livelihood* encompasses one's ability to use existing capabilities and to freely access communal, allocable natural resources, local strategies, rules, and local knowledge.

Crop production remains the best vehicle in the reduction of food insecurity in rural communities (Machethe, 2004). However, although rural communities and farmers represent 75% of the population, they live on 13% of the most water-short land (SAHRC, 2006:2; Earle *et al*., 2005:3). As water is already a limiting resource for development in South Africa, this implies that further changes to water supply will lead to drastic implications, especially in the agriculture sector. In fact, studies have already shown that periodic droughts remain a threat to agricultural production (South Africa Yearbook 2003/04). It is not surprising that food insecurity continues (Pauw and Mncube, 2007) alongside water-deprivation which by its very nature affects the well-being of humans (Hellegers and Leflaive, 2015).

Mjonono *et al*. (2009) and Hendriks (2005) argue that households can employ strategies (i.e. conscious assessment of alternative plans of action) to help them cope with food insecurities and vulnerabilities. Sheckleton and Lukert (2015) articulate that livelihood strategies form heterogeneous livelihood systems which shift amid transformation of nature, which ends up producing new socioenvironmental conditions (Swyngedouw, 2003). Adjustments to livelihood systems tend to indicate a combination of production systems and management of resources available, to construct an ongoing livelihood for the household (Baro, 2002).

However, the tragedy created by historical injustices of the apartheid system further renders rural communities even more prone to environmental shocks such as climate change. For example, over-allocation of water to downstream commercial farmers and inequitable land acquisitions and distribution

(Goldin, 2005: 83)[48] reflects continuation of structural domination embedded in the political and administrative systems. Research has shown that such practices of water over-allocation is not only limited to commercial farmers; but that it extends to the mining sector where access to controlled water resources is one of the inputs for the production purposes (Earle *et al*., 2005).

6.4 Water Allocation Reform (WAR)

Despite the adverse impact of climate change in the region (Swatuk, 2008), the government has placed *access to water resource use* for economic, social and environmental benefits (DWA, 2013:2) as one the developmental and management goals.

Alongside streamlining of climate change interventions (i.e. mitigation and adaptation strategies), the Department of Water and Sanitation (DWS) revived the 2005 Water Allocation Reform (WAR) to implement fair water allocation as a commitment to redressing the apartheid regime's past racial water injustices to historically disadvantaged individuals (DWAF, 2005)[49]. One of the *equity targets* which directly addresses the issue of livelihoods of domestic water user is: *access to the benefits from water resource use through economic, social and environmental development and management* (DWA, 2013: 12). One of the functions of Catchment Management Associations is ensuring fair water allocation as a commitment to redress the apartheid regime's past racial water injustices towards the historically disadvantaged individuals (DWAF, 2005).

Water allocation is used to (re)distribute available water resources to legitimate claimants (Hellegers and Leflaive, 2015: 273; Bird *et al*., 2009[50]). The process supports livelihoods, economies and social life within an ecological framework (Bird *et al*., 2009).

The DWS adopted a developmental approach to water to promote good governance and ensure that resources are effectively managed, while increasing productivity and to meet the food needs of the growing population (Zuma, pers. comm., 2017). The decentralised water allocation function is a mandate of Catchment Management Agencies who facilitate Catchment Management Forums which are supposed to be at a proximity to the stakeholders, including rural communities and respective water service providers. Figure 6.1 illustrates the relationship between various water institutions and water users in the Catchment Management Forums.

[48]Goldin, J. 2005. Trust and Transformation in the Water Sector, Doctoral Thesis, Department of Political Studies, University of Cape Town.
[49]A Draft Position Paper for Water Allocation Reform in South Africa: Towards A Framework For Water Allocation Planning (Discussion Document). DWA, Pretoria; 5
[50]Bird, J., Arriens, W.L., and van Custodio, D. (2009). Water rights and water allocation: Issues and challenges for the region. Asian Development Bank, The Philippines.

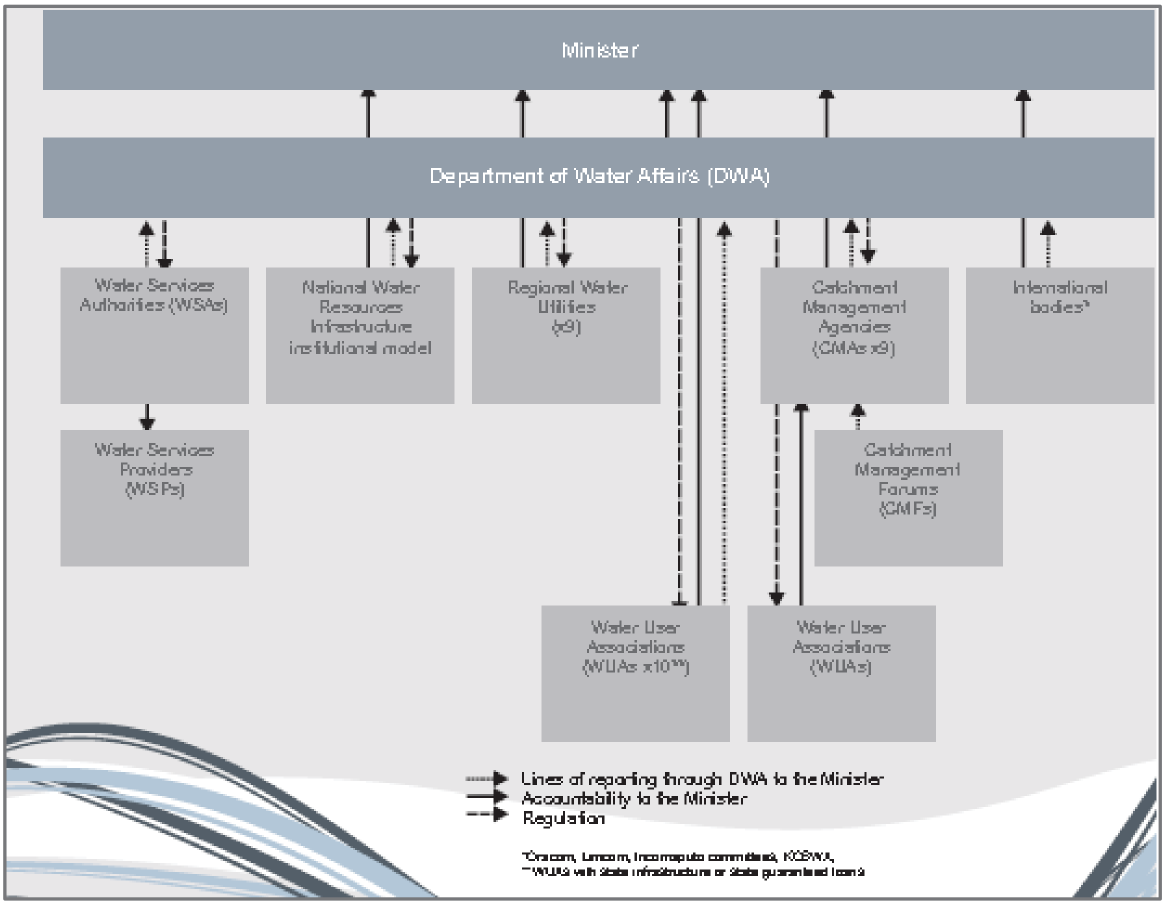


Figure 6.1: An institutional relationship between water management and water use (DWA, 2013)

6.5 The impact of climate change on food security systems in Okhombe

This section presents the results of research interviews of community members of Okhombe on the following three questions: what is their knowledge of climate change, what is the impact of climate change on community members' livelihoods, and lastly, what are the individual and communal adaptation strategies adopted to cope with climate change impact on water and food security? The results were collected from seven individuals from three categories (farmer, household and communal) using a mixture of in-depth interviews and household surveys. While five individuals resided in Mahlabathini, two members were representatives of the Enhlanokhombe Water Committee.

6.5.1 Local knowledge of climate change (perceptions and indicators)

A study by Dollar and Goudy (1999) indicated that Okhombe summer rains which occur between October and March, make up to 82% of the total rainfall per year. It is not surprising that 25% of South Africa's water is generated in this area (Everson *et al*., 2007). However, water scarcity might alter this; for instance, community members often point out that the rainfall pattern has changed drastically over the years, causing a delay in the crop production (Table 6.1).

While some people may deny the existence of local knowledge about climate change, Diaw (cited in Kpadonou *et al*., 2012) argued that the local rules formed by local communities in their protection of natural resources implies that grassroots communities are able to deal with their own environment.

Table 6.1: An illustration of community understanding of climate change

	Knowledge of climate change	
Name of participant	**Do you understand what climate change is?**	**How can you define climate change?**
Mrs Mkhonza	Yes, those who read weather forecast explain it on TV and radio	"Usually we see delayed rains, sometimes cattle die of diseases we do not know. The spring might even feel like winter, like now the grass has the brownish colour. Nothing grows"
Mrs Hlatshwayo	"Yes"	"I think it the change in the weather. For example, less rainfall"
Mr Shezi	"Yes. It affects us farmers"	"Everything living creature struggles. Cattle, people and crops suffer in this area"
Mr Masengemi	"Yes"	"It is when the weather behaves differently than we know"
Mrs Msomi	"I know it from the radio"	"Sometimes it gets too hot and sometimes it rains heavily"

All five people interviewed agreed that they were familiar with climate change. However, how they found out about it differed. For instance, while three participants mentioned symptoms, Mrs Mkhonza and Mrs Msomi indicated that they also heard about the concept from the South African Weather Service. Mrs Mkhonza further explained that she has already been observing the changes in rainfall pattern over the years.

6.5.2 How climate has affected community livelihoods

The specific question asked was: How does climate change present itself in the community?
The following are some of the ways community members have been affected by climate change:

- Drying up of streams and cattle dying
- Extremely hot conditions
- Spontaneous, unexpected heavy rains
- Less crop production as crops wilt
- Less land cultivated to avoid losing more seeds due to low rainfall
- A limited supply of firewood

While all other participants mentioned symptoms of climate change, Mrs Mkhonza reminisced about the rainfall patterns and how these have changed local livelihoods and strategies.

Mrs Mkhonza reminiscing about the rainfall patterns, crop production and community livelihoods
"When I was growing up it used to rain in June but these past 7-8 years we were starting to get used to rains occurring in September. However, this has also changed; in the last two years, the rain gets delayed. This year, we had unexpected rain in August but now we are experiencing a drought period again. This means we might have to wait before we can start planting anything in our gardens and fields. Right now, the grass is drying up and has a brownish colour as if it is winter season. Even with the delays the indigenous seeds still grow well, taking on three months to grow and be ripe. By December families are already eating their crops. However, most people have non-indigenous seeds, and this becomes a problem. This change in weather does not only affect us; our livestock too. Under extreme conditions the livestock dies in hundreds in the community. And this will mean another problem as we will not have the labour to plant as we use cattle for crop production. Our current crop production schedule is that we plant in November, provided the rain is good. This means we then harvest in May. Before planting, in October, the cattle would still be grazing, until end of May, eating the leftovers from harvesting. But as the rains are delayed, we are already

concerned because the cattle voluntarily leave the grazing camps and get into the fields even when they are not released. So as you can see the climate change has confused our livelihoods and the strategies we use to survive."

6.5.3 Community's adaptive and communal strategies to water and other food systems

Mrs Hlatshwayo: "When the water does not come out of the boreholes, which happens regularly, most people fetch water from the reservoir close to the community garden".

Mrs Mkhonza: "We are suffering in upper Mahlabathini. People forget us here. Even when the tanker arrives they do not tell us. We have a ward committee and a councillor, and they are supposed to alert us. However, they don't. My husband and I decided to protect the spring across the river from our house (Plate 6.1). It works sometimes but then five more families use it, so it is not enough. So we have also purchased a JoJo tank like most families in the village".

Plate 6.1: Mrs Mkhonza showing the researcher where the protected spring is located

Mr Shezi: "For me I wanted to use this biogas-digester I have to see if I can use the by-product from biofuel as manure for my garden; this way I would save on watering by combining using the already made solution. In the meantime, I would be generating energy for my household. I am really looking forward to seeing the technology work. I need a lot of water for producing the gas. However, it is good that I don't really have to use clean water. But I still need water for these two big containers. In the meantime, I have two Jojo tanks, just in case of rain" (Plate 6.2).

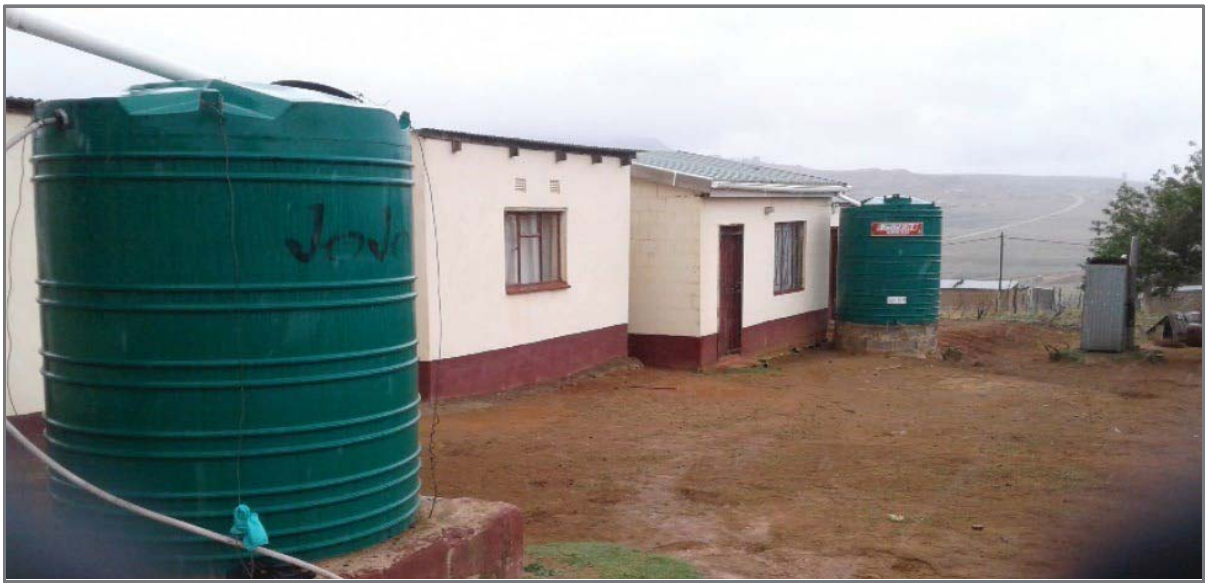


Plate 6.2: Two of Mr Shezi's Jojo water tanks

Mr Masengemi: "There is not much to do really. We either use barrows to fetch water from the leaking reservoir close to the community garden or we wait for the water tanker from uThukela District".
Mrs Msomi: "People usually go the communal garden, or they wake up very early to fetch water from the small spring that Mr Mkhonza protected. However, it is very far and getting back from there carrying a bucket is not easy. For me I also harvest the rain water (Plate 6.3), but it is not always there".

Plate 6.3: Mrs Msomi's rainwater harvesting container

6.6 Bottlenecks in securing adequate water supply

Owing to a close link between water availability and rural poverty (Thompson *et al*., 2001) institutionalising water allocation would improve the livelihoods of the marginalised domestic water users, using equity targets (DWA, 2013). However, findings from Okhombe indicate that formal water institutions generate complexities and divergence from achieving equity – a social justice.

6.6.1 The limited water sources and broken boreholes

A transect walk showed that there are four boreholes in Mahlabathini (Plate 6.4). However, only three operate serving over 200 households. Two to three times a month the boreholes are completely dysfunctional, requiring maintenance from uThukela District. However, in most cases technicians do not respond to the community request to service the infrastructure.

Plate 6.4: One of the boreholes in Mahlabathini

In Plate 6.4 Mrs Hlatshwayo can be seen turning the handle, to propel water into her bucket while other people place their containers next to hers signalling for her to step out of the way.

6.6.2 Lack of institutional support to communal agency – the case of Enhlanokhombe Water Development Committee

During one of the household interviews (i.e. Mrs Mkhonza) and again in Mr Masengemi's view (a representative of the communal garden) it was highlighted that one of the ways the community will be able to continue planting vegetables in their gardens is if the community was permitted to protect reliable springs which the Mahlabathini community already heavily relies on due to limited and often dysfunctional boreholes. The community gave the example of Enhlanokhombe Water Development Committee; subsequently two committee members were interviewed to establish the objective and the inspiration for initiating the project.

6.7 The role of local institutions in supporting local agency to expand water supply

The most pressing contemporary challenges addressed by the green economy are ecological/economical, intellectual, political and moral. Hence, for green economy technologies to succeed in Okhombe, the political environment, which is one of the four elements of green economy (Kennet and Heinemann, 2006:1797) required investigation to identify gaps which are often indicated in interventions (Davies and Mullin, 2011:794), to include and support the community in mitigating effects of climate change on water and by extension, food security and energy.
However, in addition to the negative impact of climate change on the natural resources and livelihoods of people, institutional control of water resources and services, and ecological marginalization of local people affected access to and use of water and other natural resources. These dynamics ultimately affect the success of technology up-take.

The case of Enhlanokhombe Water Committee

The two members interviewed in Enhlanokhombe indicated that the committee had been established in 2014 to explore possible diversification of water sources and the potential use of local springs to increase water supply. The committee consisted of eight members (two of which had previously been involved in similar projects) and which had initially received support from the uThukela District Municipality Technical Services. However, the committee was disbanded after being informed by the local Council to stop operating on the water infrastructure. This was in spite of the fact that the project had already implemented a water system of 2 km in Enhlanokhmbe using pipes which had been donated by the uThukela District Municipality. There was no explanation provided for the abandonment of the project. However, the project has not been finalized yet. The local council has changed twice since the water committee was established and the project was initiated. This has made it difficult for the committee members to establish any contacts with politicians who have an interest and willingness to support the project. The community also indicated that the uThukela District stopped giving support to the Committee without providing any explanation.

Irregularities of UThukela water service provision

i) Non-representation of Okhombe on the Bergville Catchment Management Agency Forum (BCMF) and other local structures dealing with water.

The role of Catchment Management Associations is to support the local government in its service provision role to the community (e.g. by identifying issues for discussion during catchment management forums). However, none of the officials of uThukela District attended three of the meetings of the Bergville Catchment management Agency Forums (BCMFs) that the researcher attended. Instead, “formal” water resources users (namely, commercial farmers) were often on the main agenda.
Okhombe emerging farmers can present their needs to the Phongolo-Umzimkhulu Catchment Management Agency in the presence of neighbouring commercial farmers. While the community was not aware of the BCMF, the closest institution would be the Integrated Development Planning (IDP) forums. The interviews and focus group discussions further indicated lack of awareness amongst the community (individual households and the Water Committee itself) of the existence and representation of the community in the IDP forums. These forums, were initiated by the uThukela District Municipality to identify water allocation requirements for Water Service Development Plans.

ii) Dysfunctional water infrastructure

One of the sources of renewable energy, biofuel technology, falls under the water management sub-programmes of the Department of Public Works. This ties in with the two households in Mahlabathini that are testing different biogas digesters for the purposes of renewable energy. For the sustainable production of energy, the biogas digesters have to be fed one bucket of manure or vegetable waste and one bucket of water. However, access to water has been a major problem at Mahlabathini. A transect walk in Mahlabathini, subsequent to in-depth interviews with farmers and individual households, showed that many communal borehole taps are non-functional and villagers have to walk, sometimes over three kilometers to collect water for drinking. Investigations conducted into the non-responsiveness of officials from the uThukela District Water Technical Services to fix existing water infrastructure and to devise other water supply mechanisms in Okhombe led to the following:

a) The interview of a total of ten community members from four sub-wards (Mahlabathini, Sigodiphola, Mpameni and Enhlanokhombe) has pointed to the possibility that it could be that the borehole water infrastructure is already aging, hence it consistently requires maintenance which is a service only offered by technicians from uThukela District Municipality. However, the technicians do not always respond to the community request to service the boreholes. In a recent interview with Mrs Hlatshwayo from Mahlabathini, it had been confirmed by the technician who last came to fix the borehole in August that the borehole parts were not available anymore as the infrastructure was outdated.
b) Meanwhile the Okhombe community continues to struggle for water supply and are currently using unreliable boreholes and scattered jojo tanks. In Mahlabathini which has a population of approximately 665, only three boreholes were found to be functioning properly. As a result of the extreme water shortage these boreholes are often shared with people from the neighbouring sub-wards of Mpameni and Ngubhela.
c) Since about three years ago uThukela had also promised to connect one of the three water tanks close to the communal garden. However, communal garden members indicated that they have to irrigate using buckets. Water in the two other water tanks was often used by the community for drinking water, but these have been leaking for months. In Plate 6.5, Mr Masengemi stands in this garden plot pointing at one of irrigators which were donated to the members, but which are aging and rusting.

Plate 6.5: Mr Masengemi describes how a donated irrigator would help water his garden plot

6.8 Discussion of findings

While climate change has undoubtedly constrained the livelihoods in Okhombe, due to the substantial effect on water availability, the community is fortunate to have groundwater at a level which produces adequate springs for easy accessibility.

However, while water infrastructure (boreholes) exist, these are usually not enough for the number of people in each sub-ward leading to individuals spending a lot of time queuing instead of performing other household activities. In addition, some of the boreholes are situated more than 2 km away from the homestead, which contradicts the DWS standard. Moreover, the boreholes are not regularly maintained which in other rural communities is a responsibility that the local government allocates to the village water committees (Mvula Trust, 2009).

The spring protection project which the Okhombe Water Committee implemented in Enhlanokhombe and the three water tanks erected in Mahlabathini for communal garden use and drinking water for households indicate the potential to secure adequate water for energy production and other household activities which all contribute towards Okhombe livelihood systems.
The dwindling support of uThukela District in maintaining the boreholes as well as the withdrawal from support to the Enhlanokhombe water committee project indicate lack of support from local institutions which is critical to ensure that the vulnerable social groups adapt to climate change (Agrawal *et al.*, 2009).

Green economy as a development agenda has already earned a complicated status due to efforts to integrate a wide range of concerns: economic, environmental, and social (Davies and Mullin, 2011). However, ensuring good governance and participation of local institutions will uphold regulation of enterprise activities.

Meanwhile, lack of knowledge of existence of the Bergville Catchment Management Forum, as well as the distant venues (45 km), presents the possibility for continuity in a persistent hardship in accessing locally available water services and resources. Thus, inadequate water supplies, and dysfunctional water infrastructure limit the households' production of food as well as production of biofuel energy which are dependent on water availability. It is this institutional gap that Ostrom (cited in Bailey and Caprrotti, 2014) warns against and is apparent in Okhombe with poor systems of accountability for ensuring consistency between higher level visions of the green economy visions and green economy strategies on the ground.

6.9 Recommendations

The expansion of water supply and maintenance of functional boreholes has a potential to support the upscaling of green economy technology in Okhombe. However, the integration of adaptation into government and governance across levels and scales is critical to ensure long term sustainability of the green economy. On the other hand, giving equal attention to interlinked components of the green economy instead of singling out one component will avoid maladaptation.

CHAPTER 7. POTENTIAL MODELS FOR INCREASING ACCESS TO ENERGY IN RURAL AREAS

7.1 Potential models for increasing access to energy

The importance of 'access to energy' in promoting sustainable development in rural areas is well acknowledged. An outcome from the "Global Conference on Rural Energy Access" (Addis Ababa, December 2013) was general agreement that "lack of clean, affordable and reliable energy is at the heart of a range of interconnected problems faced by the energy poor in rural areas" (UN-DESA, 2014).

It is important to establish rectification of the misinterpretation that 'energy' means access to grid-provided electricity. Rugumayo (2010) points out that this is an inadequate view, as has been identified by the community-based research of this project. Energy services can be made available by different fuels and technologies (Rugumayo, 2010) and even where grid-electrification is in place, it is often not reliable and subsequently undependable (Research Workshop Feedback, 2017; IIED, 2012; Oyuke *et al*., 2016).
In accordance with these findings, this research has identified the need for stand-alone, decentralised renewable energy technologies (RETs) for areas of South Africa that either has no access to grid-electricity, or is halted by poor supply thereof. This report investigates various mechanisms for the dissemination, or roll-out, of "green toolbox" technologies – and evaluates them within the research context.

7.1.1 <u>An investigation of models proposed for increasing energy access</u>

Three key sources, and their respective findings, have been identified as offering potential mechanisms for increasing energy access in rural areas. It should be noted that this report views these models in light of the broad Green Toolbox identified, and does not limit its application to *energy access*.

7.1.1.1 Bundschuh and Chen (2014)

Bundschuh and Chen (2014) focus on three major drivers for the promotion of energy access: (i) Regulations, (ii) Funding and subsidies, and (iii) Business models related to rural energy service companies (RESCOs).

(i) Regulations
Although the topic is broad, the need for regulation, even in the off-grid, stand-alone RET arena is summed up by the following statement: "The lack of a proper regulatory framework deters investors from investing in rural areas" (Monroy and Hernandez, 2008: cited in Bundschuh and Chen, 2014: 421). Similar to many other sectors of the economy, non-stifling, stable and consistent policy is required to ensure good practice and a secure environment for investment.

(ii) Funding and subsidies
The renewable energy arena, especially within the rural domestic setting, is unattractive to the 'financial system' that is typically reluctant to finance projects or technology that is unproven or considered risky to implement (Bundschuh and Chen, 2014: 424). Subsidies can be an effective, and possibly necessary, method of stimulating a pioneering concept of industry.
(iii) Business models related to rural energy service companies (RESCOs)

Bundschuh and Chen (2014: 427) acknowledge that large-scale (conventional) utility companies rarely have the capacity to initiate and maintain small-scale renewable energy technology (RET) systems. Rather, they consider a "network of small enterprises specialized in the installation and maintenance of RET systems" (2014: 427) better placed to service the rural market. The three large-scale dissemination mechanisms are cited as:

Cash purchases:	Modular ('bit-by-bit') purchase of RET systems from retailers (i.e. to avoid high up-front capital outlay.
Micro-credit model:	An end-user purchases a system using the service of a loan to pay it off over months (Figure 7.1).
Fee-for-service:	Systems are installed and maintained at the cost of the provider, who charges an on-going fee for the delivery of the service (Figure 7.1).

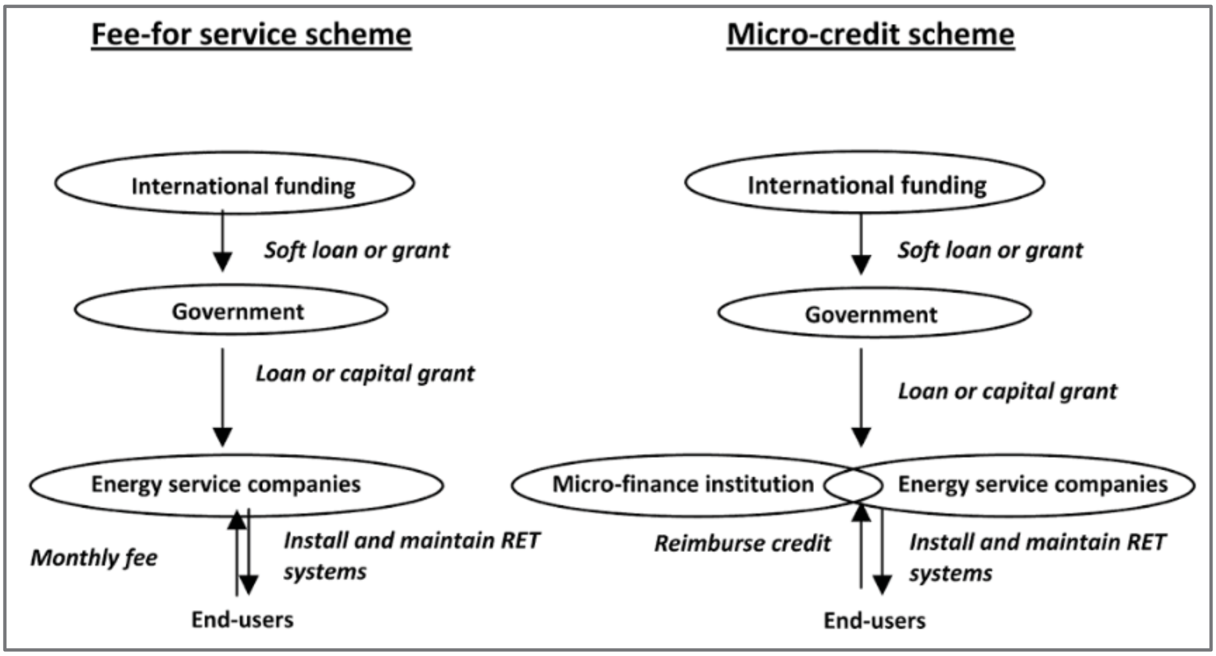


Figure 7.1: Comparison of the micro-credit and fee-for-service models (source: Bundschuh and Chen, 2014).

7.1.2 United Nations – Economic and Social Commission (UN-E&SC) (2005)[51]

The UN-E&SC provide various channels of approach which can be used in increasing energy services in a rural area through policy instruments. The broad categories of approach are: (i) Financial intermediation, (ii) Technical intermediation, (iii) Social intermediation, (iv) Organizational intermediation.

(i) Financial intermediation
Development of a financial package and support system to build and operate RESCOs (UN-E&SC, 2005: 122).

(ii) Technical intermediation
Improvement of the technical options (i.e. the RETs and systems surrounding them) through research and development and/or the import of technology and support capacity (UN-E&SC, 2005: 122).

(iii) Social intermediation
Involves the enrolment of communities identifying needs and projects, conceptualising their design and assisting with their management (UN-E&SC, 2005: 123). Specifically, the UN-E&SC notes the importance of identifying "socio-economic status" – a notion that was itemised as being important by one of research contributors, in the context of his experience with community based RET projects (Lopes, pers. com., 2017)[52].

Market based models:
With respect to marked based models, the UN-E&SC (2005: 123) note that few have been effective in increasing access to energy. The researchers point to the need for distributed service and limited profit as the reason for failure. The market based models introduced are:

- **Seed funded market-based ideas:**

Market-based ideas that are seed funded by aid agencies, and then must rely on the attraction of commercial bank financing and the establishment of service companies (RESCOs).

- **Concession subsidisation:**

Subsidies for RETs are provided by the government or aid agencies, and subsequent service must be provided by a maintenance or service company.

- **Rental based:**

A model described previously, by Bundschuh and Chen (2014), as a fee-for-service model. While the models differ on a case-by-case basis, the rental based models typically provided equipment to people on a loan basis or purchase of energy basis.

[51] Abbreviated for ease of reading – United Nations Economic and Social Commission for Asia and the Pacific.
[52] Tony Lopes was interviewed as an industry professional with experience in disseminating low-tech RETs in South Africa. One of concepts he believed to be key to securing the participation of a great rural community, was that of finding respected community members, and first securing their adoption of the programme and/or technology.

7.1.3 United Nations Industrial Development Organisation (UNIDO) (2006)

The United Nations Industrial Development Organisation (UNIDO *et al*., 2006) identify similar methods for increasing energy service in rural areas to those identified above. Their findings are neatly categorised into four types: (i) Market-based models, (ii) Government led models, (iii) Private company participation, (iv) Subsidies.

(i) Market-based models

UNIDO *et al* (2006: 10.29) repeat the sentiments of UN-E&SC (2005) in saying that the success of market-based models in delivering increased energy access is very limited. The distribution of service required and low profit margins are also cited as the main reason. UNIDO *et al*. (2006) note that a number of models have been established and can typically be explained by Figure 7.2.

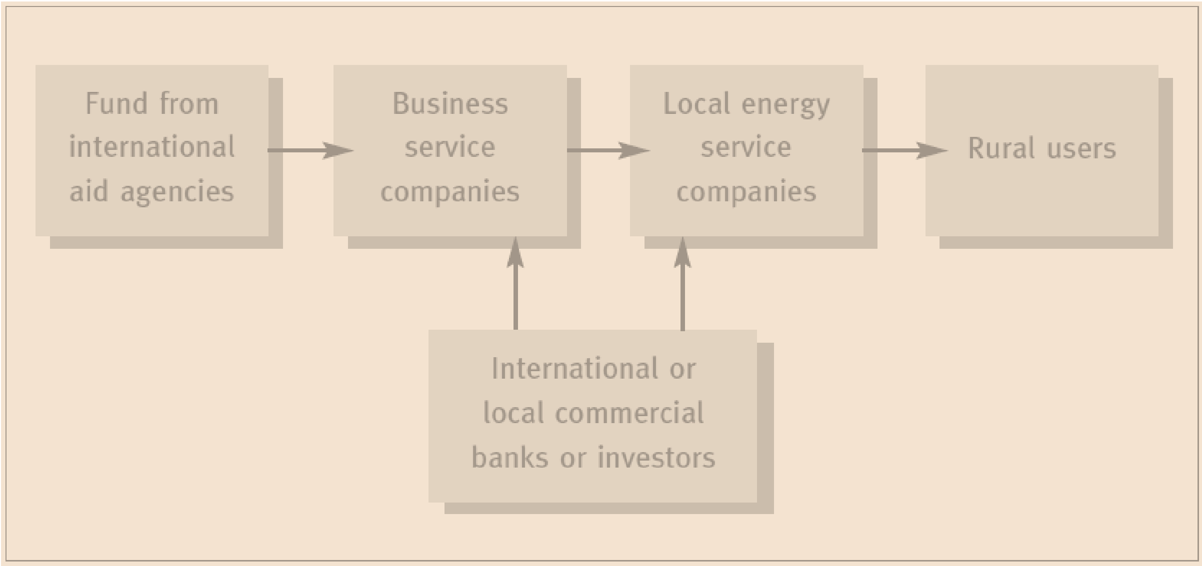


Figure 7.2: Implementation flow of market based models (source: UNIDO *et al*, 2006: 10.29)

Business service companies are said to play a key role in these models (i) identifying a key need (or market-based idea), and (ii) sourcing seed financing to develop the business. The continuation of these models is then pivotal on the development of local companies that can service the community’s technology (i.e. RESCOs) (UNIDO *et al*., 2006).

UNIDO *et al*., (2006) also note the “concession approach” and “rental approach as discussed under Section 2.5.2 and well-illustrated by Figure 7.3.

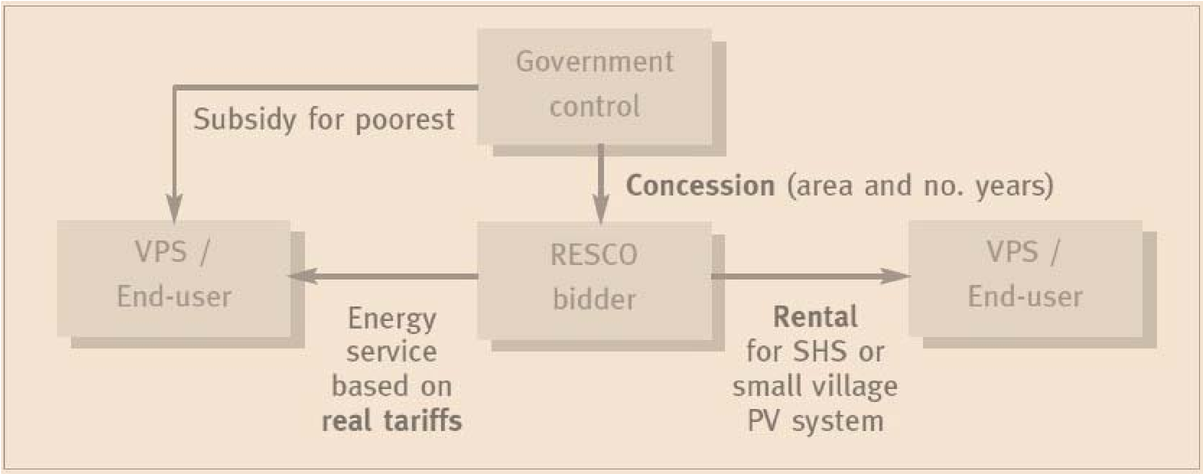


Figure 7.3: Concessional and rental market-based models (VPS – Village Power Supplier)) (source: UNIDO *et al*., 2006: 10.30)

(ii) Government led models

Government models (Figure 7.4) are described as being formed in multiple ways.

- For governmental control of systems with the private sector being contracted only as vendors of goods and services. Typically a bottom-up approach through community participation and awareness building.
- A subsidy approach to support the investment of the initial infrastructure, which is then serviced by the private sector with rates which are able to accommodate the necessary operations and maintenance.

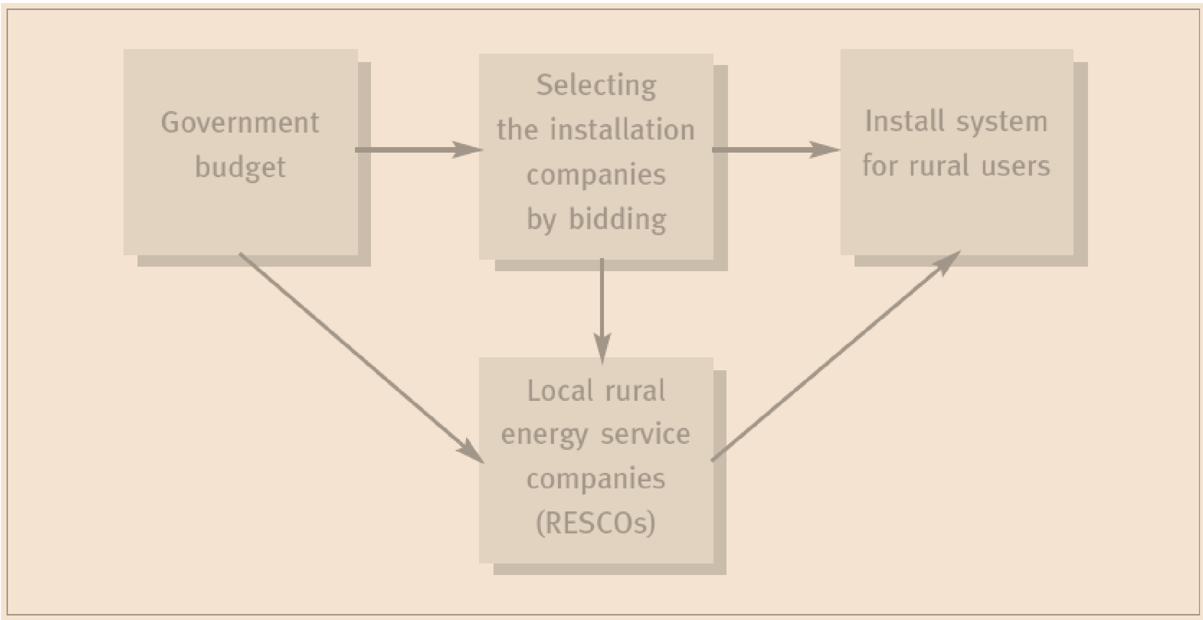


Figure 7.4: An example of a government led model applied in China (UNIDO *et al*., 2006: 10.32).

(iii) Private company participation

Private company participation can come in a multitude of forms, and the case of rural energy provision is not dissimilar to other business models being applied in the private sector. UNIDO *et al*. (2006: 10.32) point out the key importance, however, of well-defined contractual relationships between such businesses and the state. Absence of such is likely to lead to exploitation of uneducated rural populations and neglect of systems. Especially in the case of new, unknown technologies, with minimal market penetration, exploitation can come in the form of delivery of sub-standard products and then the absence of post-sale service.

An example of a successful private utility model, SELCO in India, has been based on the fundamentals of:

Product: Delivering the right product (i.e. in terms of need and quality).
Service: Continued commitment to servicing products, in this case at people's homes.
Finance: Appropriate finance models to aid communities in purchasing products within their means.

(iv) Subsidies

Subsidies are noted by UNIDO *et al*. (2006: 10.35) as being one of the most common and popular forms of increasing energy access. The subsidy models reviewed are:

- **Management and administration**: the subsidisation of agencies that manage the planning and regulation of rural energy programmes.
- **Direct cost for Research and Development**: funding of research for (i) technologies, (ii) models of implementation, (iii) exploratory testing. A valid use of funds where private enterprise is not driven by profit expectation to fund research and development – and, the basis on which this research is being delivered.
- **Project subsidies**: through multiple channels, the funding of RESCO development and/or the subsidisation of technologies to the end users.

7.1.4 Summary of models presented

In summary, there are many models in theory and practice that have delivered varied success on increasing access to energy. It appears factual that different models are applicable to, and have varied success rates, in different scenarios – and it is therefore important to understand the local setting before choosing and rolling out a model.

One fundamental that appears consistent throughout, is that understanding the consistent operation and maintenance (O&M), through skilled, trained and locally based service companies, is pivotal to longer term success of stand-alone, decentralised RETs. This view is shared by the authors of this research and has been seen to be true in practice, even with a minimal number of pilot RETs deployed in a small geographical location. While this is a shared view of researchers, it does not appear to be understood by many decision makers and key stakeholders in the South African setting. The false notion that RETs can be deployed and then ignored (presumably because they are renewable and therefor self-sufficient) is prevalent among the stakeholders this research team has come into contact with. This finding is key, and a mindset change is pivotal to the future success of any model being employed in South Africa. Like grid-connected water and electricity, RETs require continued support and maintenance, and a well-orchestrated network of service providers to deliver it.

7.1.5 The case of Okhombe

The community based research at Okhombe (Mahlabathini Village), conducted over the past two years of this project and augmented by prior projects, has indicated several key findings that are important in proposing potential models for improving energy access:

Current challenges:

- **Despite grid-electrification people are desperate for alternative options**: largely due to the inconsistency of supply from grid-electricity, and the expense of pre-paid electricity.
- **Willingness to pay up-front capital is limited**: either as a result of a lack of capital availability (indicated as likely by questionnaires conducted), or perception of worth or value is low and therefore doesn't warrant a 'fair price'.
- **Technical ability to 'up-take' technology is lacking**: even the simplest of technologies, deployed with one-on-one training, have often failed by user error. The need for technical assistance and training is great.
- **Local capability to service equipment is non-existent**: even in cases of minor fault and system disturbance, no local service providers or communal know-how is currently available.

Identified needs: These key findings point to the need for a model that can:

- Provide more **reliable and affordable** energy options than the local grid. That is, correct selection of a "**Product**" – as defined by UNIDO *et al*. (2006: 10.32).
- **Subsidisation** will be necessary given the low purchasing ability and willingness to pay.
- **A service network**, a rural energy service company (RESCO – as it has been defined), will be critical to ensuring the continued operation and longevity of any RET that is put in place. Additionally, such RESCOs will be key in developing community awareness and providing user training to ensure the appropriate and efficient use of technologies.

The proposed model:

Although many options are in existence, the case of Okhombe (and many other similar, rural villages), is likely to be best served by a hybrid model, which administers various support at different stages of development.

The absence of private company financing and interest in the rural energy service arena means that government and/or aid agency subsidisation will be critical in (i) disseminating and deploying appropriate RETs in people's homes, and (ii) supporting the development of a service industry to operate and maintain a supportive network.

Until such a point as this type of model is locally proven, it is unlikely that private companies will invest appropriately, effectively and to the scale that is required from mass roll-out of decentralised energy options. A longer-term intention should certainly be to promote such development, and supportive, stable regulatory framework will be critical in ensuring that the private sector supports and does not exploit rural populations.

This model is summarised as follows and presented in Figure 7.5:

- Research and development: to investigate the needs of rural populations and select the right products for those needs (as is the intention and exploration of this research project, WRC K5/2423)
- Subsidisation: of (i) research to select the right products, (ii) RETs delivered to end-users, (iii) development and maintenance of RESCOs until such a point as they are profitably sustainable.

- Service: development of a service network to support the energy systems (RESCO).
- Move to sustainability: by way of proving concepts, establishing good-practice operating environments and providing supportive regulation; the market can be opened and made attractive to private investment and companies.

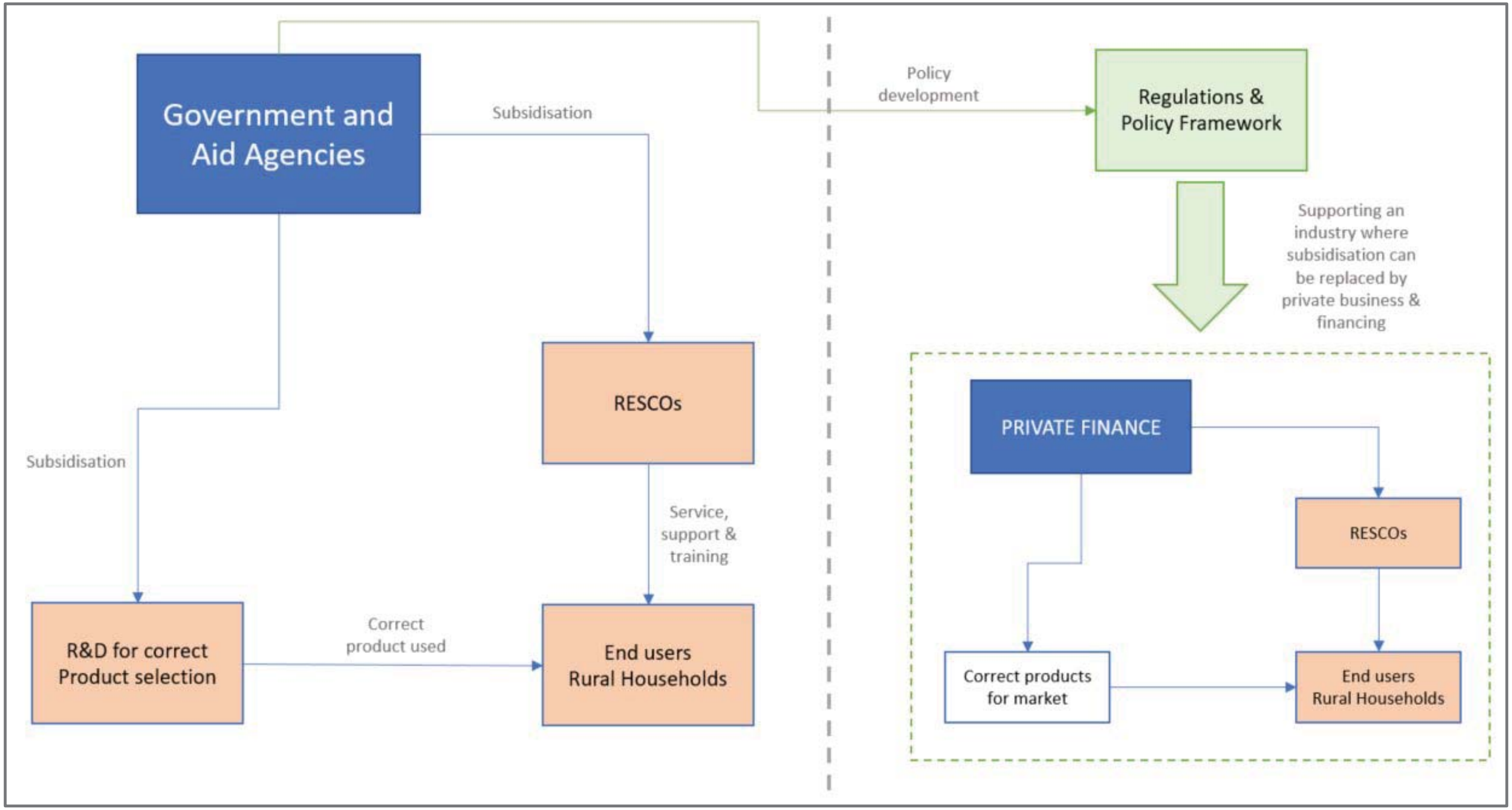


Figure 7.5: Model proposed for Okhombe and similar rural areas in South Africa

CHAPTER 8. RECOMMENDATIONS AND CONCLUSIONS

One of the aims of this project was to improve the economic conditions of communities in the Upper Thukela district through demonstrations of how green innovations and technologies can be integrated into their rural livelihoods. This was achieved by demonstrating and implementing modern technologies on renewable energy that focused on efficiency, reliability and affordability. Since these initiatives are only likely to succeed if they are adapted to local conditions, the current project focused on building the capacity of community members to test the effectiveness of renewable energy technologies at the household level. Community members reported on both the technical and socio-economic impacts of the technologies at several community workshops. A number of opportunities and challenges that were identified are outlined below.

8.1 Opportunities

- Raising the level of awareness of community leaders, youth, and community members on issues such as renewable energy.
- Community members learning about new environmentally friendly and sustainable technologies relating to energy.
- Ensuring conservation of existing energy resources (e.g. indigenous forests), by maximising alternative energy sources.
- The project resulted in a better understanding of energy and water use which can be used to assist the community in developing alternative means to meeting their needs.
- Community capacity building in biogas production (use of biodigesters), solar and other energy as an interim or long-term solution to minimizing carbon emissions and expensive electricity /energy generation infrastructure in rural areas.
- Developing the potential for a SMME facility to develop a small business at the village relating to energy.

8.2 Challenges

- Lack of natural resources such as water.
- Extreme poverty resulting in under-utilization of existing electricity infrastructure.
- High capital cost of renewable energy equipment for households (e.g. biodigesters).
- Lack of communication and co-operation between relevant government departments for energy, water and sanitation.
- Potential that climate change will limit the available water resources and other natural resources that people and livestock depend on for survival.
- Lack of local economic development opportunities.
- Lack of business skills to take advantage of local economic development opportunities that do exist.

8.3 Integrating the Okhombe experience into government core line activities and the private sector

The next step to spread the best of these technologies is to upscale the initiatives to village and national level. The stakeholders who will play a key role in this upscaling were identified, and the potential links and partnerships that will make upscaling happen were determined.

The main objective in linking renewable energy initiatives with sustainability is to ensure that in the long term they increase the productivity of agro-ecosystems, improve resilience to environmental variability, including climate change, and at the same time prevent degradation of natural resources (Liniger *et al*., 2011). This was achieved by integrating the green solutions tool box and business framework with core line function government departments to ensure sustainability of the intervention and to forge partnerships with all key stakeholders.

8.4 Sustainability

Sustainable development in South Africa is supported by its environmental policy. In particular, the National Environmental Management Act (NEMA) has strong links with sustainable land management (Mudhara *et al*., 2016). One of the key factors in promoting a long-term strategy to address environmental issues is the development of the National Action Programme (NAP) within NEMA. The vision of the NAP is to promote sustainable land management through "effective and efficient institutional arrangements at national, provincial, local and community levels; the establishment of effective and efficient partnerships between government departments, the private sector, civil society, overseas development partners and owners and managers of land; and the alleviation of poverty by promoting sustainable livelihoods and enhanced land management" (Mudhara *et al*., 2016). The investigation and demonstration of how integrated green innovations and technologies can be utilized to create entrepreneurship/jobs that improve the economic conditions of communities in the upper Thukela falls directly under the NAP at the community level. Communities have been provided with a knowledge base for renewable energy technologies which, if adopted, will result in a reduction of the harvesting of indigenous trees for fuelwood, and at the same time alleviate degradation and poverty. The South African Government's strong commitment to the roll-out of renewable energy, raises questions as to how the growing spatial extent of renewable energy development in South Africa can be upscaled and managed sustainably. Since the use of alternative energy for heating and cooking falls under the Department of Agriculture, Forestry and Fisheries's (DAFF's) vision to increase the ecological sustainability of natural resources such as indigenous forests, DAFF should be included in all efforts to upscale.

One of the key questions which needs to be asked about the different green energy technologies is "Is the technology sustainable"? To determine if the renewable energy technology is sustainable it is recommended that the TEES-test (Technically effective, Economically valid, Environmentally friendly, Socially acceptable), described by Mudhara *et al*. (2016), be applied to each technology. The TEES test determines whether a technology is Technically effective, Economically valid, Environmentally friendly and Socially acceptable.

To determine if the technology is technically effective the community members need to assess whether the technology is better than current alternatives, and whether it works well. To determine whether the technology is economically valid the following questions which have been adapted from Mudhara *et al*. (2016), need to be assessed by the stakeholders:

- Do the benefits generated by the technology outweigh the costs?
- Is the technology affordable to the target group?

- What type/levels of investments are required?
- Is the economic performance of the technology as good as or better than current alternatives?

The environmental aspects of the technology should outline whether the technology has any negative or positive environmental impacts. This could include the impacts on land degradation, carbon stores, biodiversity and ecosystem services. The environmental impact of the technology should be compared to available alternative technologies. The social acceptability of the technology will depend on whether it benefits women and more vulnerable people. Such benefits could include improvements to livelihoods, increased food security and social recognition. The technology should have good potential to spread to other households and upscale to higher levels.

8.5 Guidelines to upscale to village level.

One of the first steps to upscale from household to village scale is to implement cross-learning. Cross-learning was defined by Tuijp *et al*. (2016) as "a process whereby individuals or groups exchange knowledge and information, and share ideas with each other, resulting in increased knowledge amongst those involved". In the current project, cross-learning was achieved by cross or exchange visits whereby villagers from Mahlabathini visited the different households which were testing the renewable energy technologies. The aim of the cross visits was to build the capacity of the people by enabling them to learn from others who have gained experience in renewable energy. This household-to-household approach is an effective way of promoting communication with people with similar problems and demonstrating the potential of the different renewable energy technologies. Members of the households demonstrated the technology that they were testing and gave feedback on the positive and negative aspects of each technology. They also reported on the potential savings of the technology, the practical aspects and feasibility of uptake by the wider community. The question- and answer session that followed enabled community members to participate in an open exchange of ideas and practices. Cross visits can also include organizing awareness-raising activities and providing support to neighbouring communities towards developing a sustainable management system. The cross visits also provide a good platform for communities to strengthen their relationships and discuss common problems in land management. In terms of upscaling, cross visits should occur at different scales. In the household cross visits carried out in the current project, it was clear that some community members were inspired by a specific technology and encouraged other community members to adopt the technology. It is recommended that village, regional, provincial and national cross visits take place to promote the sharing of both technical and social knowledge.

8.6 Guidelines to upscale to national level

8.6.1 Identification of stakeholders

To extend the positive impact of the research at a national level in South Africa it is necessary to identify the potential stakeholders and determine their involvement in guiding the upscaling of renewable energy technologies. The value in collaborating with government departments and non-governmental organisations cannot be under-estimated as this will assist in determining potential co-funding for upscaling. Collaboration will also enable organisations to facilitate knowledge sharing that will promote infrastructure development for a sustainable future.

8.6.2 Potential points of contact for governmental collaboration

Four tiers of government have been identified as potential points of contact for governmental collaboration. These are national, provincial, district and local levels.

- At national level, five government departments were identified as key stakeholders for upscaling this project. These include: Ministry of Rural Development and Land Reform, Department of Energy, Ministry of Agriculture, Forestry and Fisheries, Ministry of Environmental Affairs, and Ministry of Water and Sanitation;
- At provincial and regional levels stakeholders who have already been approached include: Department of Agriculture Extension Office in Ladysmith; Department of Water and Sanitation in Bergville and Durban; Department of Economic Development, and Environmental Affairs in Pietermaritzburg and uThukela District Municipality;
- The research team continues to present progress on renewable energy technologies to the Amazizi Tribal Council, with support of individuals at sub-ward and village levels. Mr Masengemi (the tribal council representative for Mahlabathini) was an active member of project. Other key members were Mr Xaba and Mr Hlatshwayo who are both community elected members and are the main contacts for the Inkosi in Okhombe. The research team also presented progress at the community level using the support of other community projects involved in environmental management such as the Okhombe Monitoring Group.

8.6.3 Linking renewable energy initiatives with sustainability and climate change

Socio-ecological research was conducted in the community through interviews of household members and focus group sessions of project members and local farmers to determine the main effects of climate change. The results indicated that the main effects of climate change which have negatively impacted the Mahlabathini community livelihoods include: limited supply of firewood and a decrease in rainfall which ultimately restricts the area of land that farmers can cultivate for crops.

In addition to the negative impact of climate change on the natural resources and livelihoods of people, institutional control of water resources and services, and ecological marginalization of local people affected access to and use of water and other natural resources. These dynamics ultimately affect the success of technology up-take.

(i) Institutional control of water resources and services (scale issue)

One of the sources of renewable energy, biofuel technology, falls under the water management sub-programmes of the Department of Public Works. This ties in with the two households in Mahlabathini that are testing different biogas digesters for the purposes of renewable energy. For the sustainable production of energy the biogas digesters have to be fed daily with one bucket of manure or vegetable waste and one bucket of water. However, access to water has been a major problem at Mahlabathini. In-depth interviews held in the community showed that many communal borehole taps are non-functional and villagers have to walk up to three kilometers to collect water for drinking. Investigations into the non-responsiveness of officials from the uThukela District Water Technical Services to fix existing water infrastructure and to devise other water supply mechanisms in Okhombe indicated three institutional issues:

a. A total of 10 individual members from four subwards in Okhombe (Mahlabathini, Sigodiphola, Mpameni and Enhlanokhombe) reported that the borehole water infrastructure is already old and hence consistently requires technical operation and maintenance which the District does not provide anymore.
b. A report compiled from the interviews of members of the community and two members of a community-led water initiative showed that a committee had been established in 2014 to explore possible diversification of water sources and the potential use of local springs to increase water supply.
c. The committee which consisted of eight members (two of which had previously been involved in similar projects) and which had initially received support from uThukela District Municipality Technical Services was disbanded after being informed by the local Council to stop operating on

the water infrastructure. This was in spite of the fact that the project had already implemented a water system of 2 km in Enhlanokhmbe using pipes which had been donated by the uThukela District Municipality. There was no explanation provided to abandonment of the project. However, the project has not been finalized yet. The local council has changed twice since the water committee was established and the project was initiated. This has made it difficult for the committee members to establish any contacts with politicians who have an interest and willingness to support the project. The community also indicated that the uThukela District stopped giving support to the Committee without providing any explanation.

d. Meanwhile the Okhombe community continues to struggle for water supply and are currently using unreliable boreholes and scattered jojo tanks. In Mahlabathini which has a population of approximately 665, only two boreholes were found to be functioning properly. As a result of the extreme water shortage these boreholes are often shared with people from the neighbouring sub wards of Mpameni and Ngubhela.
e. The socio-ecological research clearly indicated that while water is critical in biofuel and biogas production, a significant threat to the upscaling of the technology is the instability of support from the district and local authorities for water access. Strong institutional powers need to be established to provide access to an adequate water supply which could include building infrastructures on springs which community members have identified in the catchment.

(ii) Non-representation of the Okhombe community in water support structures

The interviews and focus group discussions further indicated lack of awareness amongst the community (individual households and the Water Committee itself) of the existence and representation of the community in the Integrated Development Planning Forums. These forums were initiated by the uThukela District Municipality to identify water allocation requirements for Water Service Development Plans. For example, the Bergville Catchment Forum facilitates communal projects directly using water resources. In addition, emerging farmers can present their needs to the Phongolo-Umzimkhulu Catchment Management Agency in the presence of neighbouring commercial farmers. It is clear that one of the processes in upscaling is to ensure that communities are aware of the institutional support that is available to aid access to basic services.

(iii) Community organisation:

Amid climate change effects and institutional and ecological decisions which negatively affect household livelihoods, the Okhombe community showed a willingness to rehabilitate their local environment and adopt green economy technology options as adaptive strategies to sustain their livelihoods. The following technology options were piloted and adopted by the community:

i. Solar PV,
ii. Solar PV installed system,
iii. Solar-hot water,
iv. Solar Cooker,
v. LED lights,
vi. Biogas thermal,
vii. Stoves.

These options are in support of the South African Government's National Infrastructure Plan which was adopted in 2012. The aim of the plan is to transform South Africa's economic landscape while simultaneously creating significant numbers of new jobs, and strengthen the delivery of basic services. To achieve this a Strategic Integrated Project (SIP) has been proposed which comprises 18 projects. The current project falls under (SIP 8), which aims to ensure green energy of South African economy through two broad programmes:

A. Support sustainable green energy initiatives on a national scale through a diverse range of clean energy options as envisaged in the Integrated Resource Plan (IRP, 2010)

The national development plan proposes that gas and other renewable resources like wind, solar and hydro-electricity will be viable alternatives to coal and will supply at least 20 000 MW of the additional 29 000 MW of electricity needed by 2030. It is in relation to this proposition that Okhombe Green Economy Project can forge partnerships with existing government initiatives. Identified partnerships are with the following departments:

Department of Public Works

The Okhombe Project falls under the Greening of public and private buildings and environment vision which is part of the Environment and Economic sustainability components of the Sustainable Building and Construction framework. In Okhombe the use of energy-efficient stoves contributed to the environment sustainability whereas the solar cooker and solar water heaters contributed towards economic sustainability. Similarly, entrepreneurial benefits from the local construction of solar water heaters contributed to local economic development.

Comprehensive Sustainable Green Economy Programme

The Comprehensive Sustainable Green economy programme of the Department of Environment Affairs is a key opportunity to promote uptake and upscaling of the solar technology options tested in the Okhombe project. The outcomes of the Okhombe Project can be used in this programme through working through the Clean Technology Fund. This can support municipalities and the private sector in a large-scale program to deploy solar water heaters (SWH), with a target of achieving 50 percent of the Government’s ambitious goal of converting 1 million households from electric to solar water heating over the next five years.

This further supports SWH market penetration and development of a domestic SWH industry by buying down high installed cost, market development, and demonstrating business models.

Specific sub-programmes of strategic importance include:

a) Clean energy and energy efficiency programme which drives expansion of off-grid options in rural and urban areas. The programme is also responsible for up-scaling of Solar Water Heater rollout.
b) Sustainable waste management practices programme includes – under the two sub-programmes on Waste beneficiation and Zero waste community programme for 500 000 households.
c) Water management programme includes alternative technology for effluent management.
d) Environmental sustainability programme includes research, awareness and skills development and knowledge management.

Department of Energy

The Department of Energy (DoE) is another key partnership that needs to be developed for upscaling green energy technologies. The DoE aims to broaden electricity supply technologies to include gas and imports, as well as nuclear, biomass and renewable energy resources (wind, solar and hydro), to meet the country’s future electricity needs and reduce its carbon-dioxide emissions. The current small-scale energy project at Okhombe indicates that in rural areas there is an option to supplement existing energy with solar and LED technology and that this can be upscaled to many villages where energy is limited to unreliable and expensive electricity supply.

Department of Environmental Affairs

The Department of Environmental Affairs (DEA) has committed to contribute to the implementation of the National Development Plan and National Infrastructure Plan by undertaking Strategic Environmental

Assessments (SEAs) to identify adaptive processes that integrate the regulatory environmental requirements for Strategic Integrated Projects (SIPs) while safeguarding the environment. The first iteration of the wind and solar photovoltaic (PV) SEA was accordingly commissioned by DEA in 2013, in support of SIP 8, aimed at facilitating the implementation of sustainable green energy initiatives.

B. A second strategic programme of SIP 8 is to support bio-fuel production facilities

The use of bio-fuels as a renewable energy source presents the potential for numerous environmental, energy security and efficiency benefits to the South African economy (Gilder and Mamkeli, 2014). The bio-fuels are used as part of the energy mix in response to Eskom electricity shortages and Department of Environmental Affairs' alternative energy for effluent management. Although the current project did not test bio-fuel production, the recommendations from WRC Report 1955/1/15 (Improving rural livelihoods through biogas generation using livestock manure and rainwater harvesting) can be used to support the upscaling of bio-fuels production.

8.7 Conclusion

The implementation of the renewable energy project in Mahlabathini contributed to multiple spheres of the WRC Knowledge Tree:

- **Inform policy and decision-making**

Business plans were developed for each of the green energy technologies implemented in Mahlabathini. These plans will inform policy and decision-making on their potential for local economic development and job opportunities. The plans can be taken to funders and potentially rolled-out to multiple areas and for up-scaling to a Green Village.

- **Develop new products and services for economic development**

The project tested innovative green technologies (e.g. solar cookers, solar geysers, wood pellet stoves) that reduced workloads for women and resulted in savings for household incomes through reduced consumption of fuelwood and electricity.

- **Enhance Human Capital Development (HCD)**

Two PhD students are currently registered on the project and aim to submit their theses in 2018.

- **Empower Communities**

Community members were trained on the implementation of green technologies, data collection, monitoring, and reporting. One of the community members (Mrs Msomi) who attended the training session on the construction of the solar geyser, expressed an interest in opening a small business to make and sell solar geysers to the community. She stated that her unemployed son, Nhlanhla, who participated in the training would be able to help and would like to earn an income.

The education and training carried out in this project was both a scientific and a social process, bringing people together, and contributing to the development of the community as a whole.

- **Promote transformation and redress**

This was achieved through the implementation of renewable energy technologies (e.g. solar, biomass) which provided economic, environmental, and social benefits to the people living in these rural areas. The business plans developed provide opportunities for job creation which has potential to redress the high unemployment in the area.

- **Drive sustainable development solutions**

The project has led to more income and more economically sustainable livelihoods (e.g. most households testing the wood pellet stoves reported that they used to buy R100/month of electricity and now they only buy R50/month). Increased well-being was reported by the women testing the solar cooking box as they said it saves money and time. If it is not cloudy it is very effective and it cooks samp quicker than the electric stove. The women were able to heat water and cook porridge quickly for the children before they went to school. The solar system promoted well-being as it enabled people to have light and charge their cell phones when there was no electricity. The new technologies have reduced vulnerability as households are no longer vulnerable to the unreliable electricity which was reported to go off for days at a time due to winds, electrical storms and load-shedding. The technologies contributed to more sustainable use of the natural resource base as households had a reduced dependency on fuel wood.

Water shortage was identified by the community as a critical factor hindering sustainable development. Building the capacity of community members on the need for adaptation to climate change has encouraged the community to address the problem of limited access to water for household use and food security. However, institutional problems at Mahlabathini with respect to water access is a critical factor that needs to be addressed for sustainable development.

The implementation of the green energy project in Mahlabathini achieved the following outcomes in relation to the objectives of this solicited project:

1. **Identify drivers of poverty, opportunities offered by natural ecosystem, and develop a community based vision of a Green Village using a bottom up approach**

The baseline survey in which 110 community members in Mahlabathini were surveyed, identified limited employment opportunities, poor resources (especially water and firewood) and poor infrastructure as the main drivers of poverty.

Of the 40 community members who attended the workshop on "Community visioning of a green village in Mahlabathini ", only one had heard of a green village. The participants collectively reached a consensus that "amadlelo aluhlaza" (greener pastures) best described how they envisioned the green village with the following**:**

- People had water that was piped to their households;
- The cattle were grazing the plentiful grass;
- People were working in community gardens which produced enough food to eat and sell to make money;
- Fields were ploughed by livestock for crops;
- Erosion gullies were fixed;
- Trees were grown for firewood;
- There was enough firewood to be harvested by women for energy; and
- People were talking to each other indicating that they were happy.

2. **Through integration of indigenous knowledge, green innovations, research, and technology, develop a tool box of green solutions that can address the impact of climate change and help communities or sectors to adapt to climate change**

The following tool box of green solutions was developed following a process of need identification and practical applicability of the various technologies:

- Basic solar PV lighting and charging kits.

- Two varieties of wood pellet / biomass stoves, (i) one fan driven with a small solar panel, charger and light, (ii) one non-fan driven Top Lit Up Draft stove.
- A more advanced solar PV back-up system (to be wired into a home).
- Low-tech solar geyser (coke bottle geyser).
- Low-tech 1 000 litre biodigester.
- Two types of solar cookers: (i) a bought parabolic dome cooker, (ii) a self-build solar oven box.
- LED lights.
- Wonderbags.

The technologies were implemented in the community selected research households, and the following provides a brief summary of the users' experience:

Basic solar PV lighting and charging kits

The experience of these systems was generally positive with users noting that they had used them extensively to charge their phones. Initial misunderstanding regarding the amount of time the system needed to be charged had resulted in one user not using the solar-kit for several months, until realising that a full-day of solar charging was necessary. Recognition was made of the fact that the technology was portable, and could therefore be stolen, so charging of the system could only take place under the vigilance of the user or family members.

While the systems were regarded highly, grid-electricity provided light was still used as a primary energy with the solar systems providing back-up when grid-electricity failed. It was reported that this was a frequent occurrence in Okhombe, and the system had therefore provided much appreciated energy security, although acknowledgement was made of its inability to cook, heat and provide energy for other high-energy-demand needs. In combination with a pellet stove, one of the research households noted that she had sufficient, basic energy needs when electricity was unavailable – a situation her neighbours had keenly noted.

Pellet cookstoves

Two pellet cookstoves were tested by research households, the ACE cookstove (fan driven) and the Isitofu (no-forced air).

Although perceptions about each of the stoves usability varied, the technology was regarded positively as a back-up energy when electricity was unavailable. Pellet consumption data, and pellet sales at the local Spaza Store, supported the fact that these technologies were used infrequently as back-up technology.

The ACE cookstove was generally preferred as it was quicker to start and allowed for a degree of heat control with changes of the fan speed. The battery powered light and charging ports were also considered valuable additions – which the Isitofu did not offer.

It was noted unanimously that the stoves smoked, and tended to blacken pots. All households commented that the stoves were easy to use, although project experience had shown the researchers that continuous training was required to ensure the systems were used correctly and the commentary that the systems smoked was indicative that they were still not being used optimally.

During the course of the project over 130 stoves were disseminated to the surrounding community. The stoves were provided with 10 kg of wood pellet (approximately 10 hours of use time) and users were advised that they could purchase more pellet from the local Spaza Store. An audit of purchases from the store revealed that only 20 to 30 bags had been purchased by a handful of customers over a full year.

Despite the positive reviews from households interviewed, the use data at these households and from the local store suggest that usage was minimal – supporting the conclusion that these technologies were used only when necessary as a back-up option.

Installed solar PV system

The feedback from the household who was recipient of the installed solar system was positive and encouraging for highly-remote households without any access to grid-electricity. The household reported that the system had worked consistently, providing them with lighting. It should be noted that the system provided DC-electricity and therefore could not support the use of appliances such as a TV which was an AC-user. The availability of DC appliances proved to be significantly limited and even more so in these rural areas. An AC based solar PV system was identified as being significantly more expensive than the system tested under this project, and the technologists consulted identified that such a system would be prone to abuse – via the use of high-demand electrical equipment which it was incapable of supplying.

Low-tech solar geyser (coke bottle geyser)

Two households were recipients of the coke bottle geyser systems. Both households noted that their systems had operated with varying success based on the environmental conditions, especially the air temperature and amount of sunshine. The research households were not insulating the water storage bucket in any way, which explained the poor delivery of heat on cold, sunny days (which would otherwise have provided hot water).

Follow-up research with the technology designer (Mr Tony Lopes) identified the key importance of insulating the hot water storage bucket with a blanket during cold periods, and his research identified that the system should result in water temperatures of between 40-45°C in summer with ambient temperatures of 18-30°C, and water temperatures of 30-34°C in winter with ambient temperatures of between 5-20°C.

The households explained that they had used the systems to provide hot water for children's baths and washing dishes, and had often used the warm water for pre-heated cooking uses. It appeared that the systems had afforded them hot water use (e.g. bathing) that they would otherwise have not had available or would have had significantly less hot water for.

The technology users noted significant community interest in their hot water systems, and concluded that people would buy the system, but they would not be willing to pay more than R600 because of the 'seasonal' usability (as described above, and to be mitigated with insulation systems).

Low-tech 1 000 biodigester

The low-tech biodigester was installed at the beginning of the cold winter period and the researchers' expectations were low as poor gas production results had been seen in the area with submerged biodigesters (which are less affected by ambient temperature). As had been predicted, the low-tech digester was not able to begin gas production with the extreme winter temperatures. When warmer conditions arrived, the digester began to operate but only provided minimal, captured gas. The system remains under investigation, and although gas production is evident, it is minimal and has not been captured effectively.

The hypothesis was confirmed that externally exposed digesters of this type are not suitable for areas that experience extreme conditions. Further, as has been noted in this report, that local expertise is essential for technologies of this type. Despite the evident problem being minor (i.e. a leak in the gas lines or storage mechanisms), the local community were unable to identify the problem, nor repair it, without the help of the researchers who were based over 200 km away from the project site.

In their WRC funded pilot green village (biogas focused) project Everson and Smith (2015) stated, with reference to 6 000 litre buried biodigesters, that a biodigester would be a valuable addition to an off-grid rural home – providing energy for cooking, waste management and slurry fertiliser for crop and fodder production. However, pilot households reported that the available biogas was not always sufficient for all their cooking needs, especially during winter months when biogas production decreased. One option to increase the temperature in the digester and thus increase potential biogas production in winter is to add warm water to the digester. However, heating ten litres of water daily is not a financially viable solution for rural households. The current project addressed this issue through the development of a solar water geyser which generated warm water. It is therefore recommended that when upscaling to a green village that households with biodigesters should also operate a solar water geyser. This supports the notion that sustainable solutions should be developed with a combination of various, supporting technologies.

Solar cookers

Two types of solar cookers were implemented at research households, a parabolic solar cooker and a low-tech solar oven box which could be manufactured fairly simply by a local tradesman. The parabolic cooker was evidently quite cumbersome to set up and initial concerns were raised about the need to take this device in and out of the house, and leave it out in the garden where it may be exposed to theft. Similarly, the solar box would also need to be left in the open.

Reports of the technology experiences were similar to those of the low-tech geysers with users appreciating their ability greatly, but noting that they were not appropriate for all weather conditions. It was also identified by the researchers that careful planning needed to be implemented by the households to make effective use of the solar ovens, as preparation needed to take place well before normal time of cooking.

The users acknowledged that the systems worked very well on hot, sunny days, and could be used either to cook items or pre-heat water or food before finishing off a cooking process. Savings associated with this process were noted by the users although they believed that community members might be reluctant to purchase the technology as it could only be used during good weather conditions.

Efficient lighting (LEDs)

Predictably the LED lights revealed savings for houses who implemented them. The LEDs replaced incandescent and compact-fluorescent bulbs with a known energy saving of between 50% and 90%. The research identified that these options were scarce in the area, despite offering these savings, and the local store owner claimed that he did not know where he could purchase any to stock in his store.

Wonderbag (insulated slow-cookers)

The Wonderbags received extremes in popularity with some users exclaiming how useful and valuable they had been to their cooking processes, and others claiming that they were entirely useless. Further research and user trials identified that the Wonderbag system, and any similar post heat insulative cooker, provides significant opportunity for efficiencies. If used correctly, it appears that these systems can save people time and money in the cooking process.

Like many of the technologies implemented, the key factor of success was identified as user training and transfer of experiential knowledge. While the process of use can be clearly articulated or demonstrated to future users, it appears that successful implementation is most notably dependent on the sharing of successful application by community members. Capacity building on a technology like the Wonderbag needs to be placed within the specific cultural and livelihood experiences of the users – and is dependent on success stories for wider uptake.

3. **Identify and develop a business (economic) framework that poor and local communities can use to improve their livelihoods without furthering land use degradation**

A set of concept projects and business plans were developed for each green energy technology for implementation in rural areas. The intention of these plans was to provide a means of local economic development, with an integral focus on sustainability – of both the job and/or business created, and of the natural resources and environmental nature housed within that venture**.** Each plan or concept was designed to include local economic development, natural resource and environmental sustainability and a net export trade balance between the local community and the external surrounds. Each plan is a standalone document that can be taken to funders and/or communities for implementation.

The business models were tested on a pilot scale by some of the community research group and a number of challenges arose. While the training on how to develop the low-tech solar geyser was successful and the group successfully produced their own geyser, the cost and availability of materials posed significant challenges. Assistance, in the form of supporting the group to source more affordable materials, was highlighted as the major need, with a general agreement that the community would not purchase the geyser at the price it had been made for. Additional outcomes identified that business support and training would be critical to ensure that good, sustainable business practice was followed. It was also identified that any renewable energy business would need to be supported by technical knowledge and technology support to service the local market.

4. **Develop and test practical and appropriate mechanisms, manuals and guidelines for landscape development and management that will protect the infrastructure and improve ecosystem services**

This objective was more specific to the Tsitsa catchment and is outlined in Volume 1.

Following the testing of eight green energy technologies, manuals and guidelines were developed for three technologies which could feasibly be made within the limitations of a rural community's resources: (i) Solar geyser using recycled coke bottles, (ii) Biogas digester (1000 litres) and (iii) Solar Oven (see Appendix 10.2).

5. **Train communities (mainly the youth) on appropriate skills/capacity necessary to sustain the businesses and ecosystem services that transform the poor community to be more self-sufficient**

The capacity-building component of this project gave training to community members on appropriate green energy technologies to grow business opportunities and promote the sustainable use of natural resources. In addition to the technical aspects of the training, community members were trained on monitoring, evaluation, reporting and data recording. The project also initiated the building of research capacity with two community members who showed potential to carry out experiments.

As part of the capacity building process regular workshops were held to enable community members to share best practices and give their insights on their experiences. This shared approach was critical for assessing the technological update of specific energy technologies. Seven training workshops were held to build capacity and enable community members to share their experiences. These were:

- Community workshop on presentation of energy technologies held at Mahlabathini on 13 March 2016
- Community training workshop on energy systems held at Mahlabathini on 06 June 2016
- Community feedback training session on energy systems held at Mahlabathini on 24 June 2016
- Community feedback and business development workshop on energy systems held at Mahlabathini on 16 September 2016

- Mahlabathini pellet cook stove hand-out and training with community research group on 17th November 2016
- Mahlabathini pellet cook stove hand-out and training with community on 25th November 2016 and 9th December 2016
- Green Village community workshop on business opportunities and experiences held at Mahlabathini on 18 January 2017.

6. **Integrate the green solutions tool box and business framework with core line function government departments in order to ensure sustainability of the intervention and to forge partnerships with all key stakeholders**

An expert workshop was held with industry experts and government representatives to gain professional insight into the range of available technological options for testing, how best to implement and test these technologies, and how to mitigate any potential risks with the community-based research. The project identified existing government initiatives that can be used to forge partnerships for upscaling the project. The identified partnerships are with the following: Department of Public Works**,** Comprehensive Sustainable Green Economy Programme**,** Department of Energy and the Department of Environmental Affairs.

7. **Develop models on how to expand the green tool box of solutions and business framework utility, from household/village to the national or country-wide scale**

Four models were identified for increasing energy service from household/village to national and country-wide scale: (i) Market-based models, (ii) Government led models, (iii) Private company participation, and (iv) Subsidies. These different models are applicable to, and have varied success rates at different scales – and it is therefore important to understand the local setting before choosing and rolling out a model. A critical factor in selecting a model is that skilled, trained and locally-based service companies are pivotal to longer term success of stand-alone, decentralised renewable energy technologies.

In the case of Okhombe (and many other similar, rural villages), it is likely to be best served by a hybrid model. This model is summarised as follows:

- Research and development: to investigate the needs of rural populations and select the right products for those needs (as was the intention and exploration of this research project, WRC K5/2423)
- Subsidisation: of (i) research to select the right products, (ii) rural energy technologies delivered to end-users, (iii) development and maintenance of rural energy service companies until such a point as they are profitably sustainable.
- Service: development of a service network to support the energy systems (rural energy service company).
- Move to sustainability: by way of proving concepts, establishing good-practice operating environments and providing supportive regulation; the market can be opened and made attractive to private investment and companies.

The business and economic analysis reviewed a variety of projects and business models that could aid in improving community livelihoods in poor rural areas. The aim of these business models was to:

- Achieve the development goals of green technology deployment and rehabilitation of degraded land
- Create jobs
- Develop and sustain small, medium and micro enterprises (SMMEs) in rural areas.

The business models proposed for Mahlabathini targeted the local manufacture and servicing of the Green Technology solutions that were tested in the village which included:

- Low-tech, community-made renewable technologies from recycled materials
- Biomass pellet stoves
- Low-tech biogas manufacturing and service industry
- Sale of support of various renewable energy technologies in rural villages.

8.8 Path forward in developing and testing a 'Green Toolbox' for Okhombe

The findings of the community workshops and survey conducted in Mahlabathini, Okhombe have aided the team in understanding the current situation faced by the community and therefore provided a better position from which to investigate various solutions.

Key findings of both the survey and workshop showed that energy, water and food security are of real concern for the people of this village. With respect to energy security, it was clear that access to energy, the cost of energy and the reliability of energy are major challenges that people face each day. The absence of energy has been further exacerbated by successful alien plant (namely wattle) removal programmes which have left few biomass options for fuel wood. The lack of reliability of the electricity supply was described clearly, with community members noting how it would likely go out at any time and could remain unavailable for days. The general energy security problems are highlighted by the fact that households tend to use multiple energies, largely due to changing levels of accessibility, cost and reliability.

Although the focus of the Okhombe research was predominantly centred on identifying various renewable and sustainable options for energy provision, food and water security were also taken into account in developing the Green Village concept. Although the survey did not exemplify the water security problems in Mahlabathini as clearly as the community workshop, the latter revealed the significance of this problem in the area. People highlighted the seriousness of the problem saying that they were sometimes without access to water from the communal tap for up to 10 days. One of the Green Village visions raised by a community member was that of a physically green Mahlabathini – comprising of green pastures and abundant crops for humans and livestock. This vision highlighted the importance of water in the greater picture.

In general, it was clear from the results of both the community survey and the community workshops that the community was interested in and supportive of developing a Green Village. Much of the interest and excitement in the topic was founded in the belief that renewable energy could provide an alternative means to strengthening energy security and alleviating the cost of living. Specifically, it became clear that 'off-grid' options for energy would alleviate pressure by providing alternatives to electricity (which has proven to be unreliable), wood and other fuels (which are both expensive and often inaccessible). Although the community's support of and interest in alternative options was apparent, the research identified that it was directed at identifying secondary or back-up options and was neither considered nor used at the research households as a primary option. Electricity remained the preferred primary energy at all research households, and it was evident that the implemented technologies, although extremely useful and appreciated during electricity outages, were sub-ordinate in their ability to serve peoples' advancing needs and chosen secondarily even where monetary savings had been experienced. While alternative and low-tech options serve a purpose, especially where no grid electricity is available, the technologies tested were not capable of meeting all the peoples' energy needs, and therefore, more advanced off-grid and/or mini-grid electricity options need to be further investigated.

CHAPTER 9. REFERENCES

9.1 Citations

ACE (African Clean Energy). 2016. ACE Cookstove. Available at: [http://www.africancleanenergy.com/] (Accessed 29 January 2016).

Adams, J., Bratmna, J., Chartier, Y. and Sims, J. 2009. Water, sanitation and hygiene standards for schools in low-cost settings. World Health Organisation: Geneva.

Agarwal, B. 1983. Diffusion of rural innovations: Some analytical issues and the case of wood-burning stoves. *World Development* 11 (4): 359-376.

Agrawal, A., Kononen, M. and Perrin, N. 2009. The Role of Local Institutions in Adaptation to Climate Change. *Social development working papers*, Paper No. 118.

Allouche, J. 2016. The birth and spread of IWRM – A case study of global policy diffusion and translation. *Water Alternatives* 9(3): 412-433.

Amon, T., Amon, B., Kryvoruchko, V., Zollitsch, W., Mayer, K. and Gruber, L. 2007. Biogas production from maize and dairy cattle manure—Influence of biomass composition on the methane yield. *Agriculture Ecosystems & Environment* 118: 173-182.

Bailey, I. and Capriotti, F. 2014. The green economy: functional domains and theoretical directions of enquiry. *Environment and Planning* 46: 1797-1813.

Baro, M. 2002. Food insecurity and livelihood systems in Northwest Haiti*. Journal of Political Ecology* 9: 1-34*.*

Bike Rumor Media. 2014. Super Tough Chrome Knurled Welded Pannier-Rack Bags & Backpacks. Available at: [http://www.bikerumor.com/2014/02/18/super-tough-chrome-knurled-welded-pannier-rack-bags-backpacks-now-available/]. (Accessed 13 November 2016).

Bio2Watt. 2014. What is biogas? [Bio2Watt]. Available at: [http://www.bio2watt.com/what-is-biogas.html] (Accessed 29 January 2016).

Bird, J., Arriens, W.L. and van Custodio, D. 2009. Water rights and water allocation: Issues and challenges for the region. Asian Development Bank, The Philippines.

Bole-Rentel, T. and Bruinsma, D. 2013. Doing business in South Africa – Bioenergy. Available at: [http://southafrica.nlembassy.org/binaries/content/assets/postenweb/z/zuid_afrika/netherlands-embassy-in-pretoria/import/the_embassy/economic-affairs/bioenergy-intro.pdf]

Bundschuc, J. and Chen, G. 2014. Sustainable Energy Solutions in Agriculture. Taylor & Francis Group: Abingdon.

Chaurey, A. and Kandpal, T.C. 2010. Assessment and evaluation of PV based decentralized rural electrification: An overview. *Renewable and Sustainable Energy Reviews* 14: 2266-2278.

Cornwall, A. and Jenkins, R. 1995. What is participatory research? *Social Science and Medicine* 41 (12): 1667-1676.

Davidson, O. and Winkler, H. 2006. Energy policy. In Winkler H (ed) Energy policies for sustainable development in South Africa. Energy Research Centre, University of Cape Town.

Davies, A.R. and Mullin, S.J. 2011. Greening the economy: interrogating sustainability innovations beyond the mainstream. *Journal of Economic Geography*, 11: 793-816.

DEA. (Department of Environmental Affairs). 2014. SIP 19: Ecological Infrastructure for Water Security. Ministers approved draft for Submission to the Presidential Infrastructure Coordinating commission. Revision 6.1 Friday 31 October 2014. Available at: [https://www.environment.gov.za/sites/default/files/docs/sip19_ecologicalinfrastructure_watersecurity.pdf] (Accessed 21 July 2017).

DFID. 2006a. Key Sheets on Climate Change and Poverty, Department for International Development, London, Available at: [http://wwwdfid.gov.uk/pubs/files/climatechange/keysheetsindex.asp.]

DFID. 2006b. White Paper: Making Governance Work for the Poor, Department for International Development, London.

DOE. (Department of Energy). 2013. A Survey of Energy Related Behaviour and Perceptions in South Africa – The Residential Sector. Available at: [http://www.energy.gov.za/files/media/Pub/DoE-2013-Survey-of-EnergyRelated-Behaviour-and-Perception-in-SA.pdf. 2013]

Dollar, E. and Goudy, A. 1999. Environmental change. In: Fox R and Rowntree K (eds) The geography of South Africa in a changing world. Oxford University Press. Oxford.477pp.

DWA (Department of Water Affairs). 2012. Report on the Status of sanitation services in South Africa. DWA: Pretoria.

DWA (Department of Water Affairs). 2013. National Water Resources Strategy: Water for equitable and sustainable future. June 2013 (second edition). Department of Water Affairs. Republic of South Africa.

DWAF (Department of Water Affairs and Forestry). 2005. A Draft Position Paper for Water Allocation Reform in South Africa: Towards A Framework For Water Allocation Planning (Discussion Document). DWA, Pretoria.

Earle, A., Goldin, J. and Kgomotso, P. 2005. Domestic Water Provision in the Democratic South Africa – Change and Challenges. Pretoria: AWIRU, CiPS, University of Pretoria. pp 1-40.

ETC UK. 2007. Promoting Biogas Systems in Kenya: A feasibility study. ETC Group: Ottawa.

EurocosM UK. 2016. Home Solar Power 240V Kit. [EurocosM UK]. Available at: [http://www.eurocosm.com/Application/Products/solar-powered/Solar-Home-Power-Station-GB.asp] (Accessed 14 November 2016).

EuropeanCEO. 2015. Vodafone launches M-Pesa mobile payment service in Europe. Available at: [http://www.europeanceo.com/business-and-management/vodafone-launches-m-pesa-mobile-payment-service-in-europe/] (Accessed 13 November 2016).

Everson, T.M. and Smith, M.T. 2015. Improving rural livelihoods through biogas generation using livestock manure and rainwater harvesting. Water Research Commission: Pretoria, South Africa. WRC Report No. 1955/15

Everson, T.M., Everson, C.S. and Zuma, K.D. 2007. Community based research on the influence of rehabilitation techniques on the management of degraded catchments. Water Research Commission: Pretoria, South Africa. WRC Report No. 1316/1/07.

Geis, D. and Kutzmark, T. 2006. Developing Sustainable Communities: the future is now. Available at: [http://freshstart.ncat.org/articles/future.htm] (Accessed 05 September 2015).

Gilder, A. and Mamkeli, M. 2014. South Africa: Biofuels in South Africa. Available at: [http://www.mondaq.com/southafrica/x/297616/Renewables/Biofuels+in+South+Africa].

Goga, S. and Pegram, G. 2014. Water, energy and food: A review of integrated planning in South Africa. Understanding the Food Energy Water Nexus. WWF-SA, South Africa.

Goldin, J. 2005. Trust and Transformation in the Water Sector, Doctoral Thesis, Department of Political Studies, University of Cape Town.

Hellegers, P. and Leflaive, X. 2015. Water allocation reform: what makes it so difficult? *Water International* 40(2): 273-285.

Hendriks, S.L. 2005. The challenges facing empirical estimation of food (in) security in South Africa. *Development Southern Africa*, 22(1): 1-21.

Hirsch, W. 2013. Two Things You Need To Know Before You Buy LED Lights. [Designing Your Perfect House]. Available at: [https://www.designingyourperfecthouse.com/two-things-need-know-buy-led-lights/] (Accessed 14 November 2016).

Hoff, H. 2011. Understanding the Nexus. Background Paper for the Bonn 2011 Conference. The Water, Energy and Food Security Nexus. Bonn. Stockholm Environment Institute, Stockholm.

Howells, M.I., Alfstad, T., Victor, D.G., Goldstein, G. and Remm, U. 2005. A model of household energy services in a low-income rural African village. *Energy Policy* 33 (14): 1833-1851.

HowStuffWorks. 2009. [HowStuffWorks]. Available at: [http://science.howstuffworks.com/ How solar cooking works environmental/green-science/solar-cooking1.htm] (Accessed 29 January 2016).

IIED (International Institute of Environmental and Development). 2012. Improving people's access to sustainable energy. [IIED]. Available at: [https://www.iied.org/improving-people-s-access-sustainable-energy] Accessed: (2017/07/21).

IPCC. 2007. Climate Change 2007, Fourth Assessment Report: Summary for policymakers, Intergovernmental Panel on Climate Change, Geneva. Available at: [http://www.ipcc-wg2.org/index.html].

IRENA (International Renewable Energy Agency). 2012. Renewable energy technologies: Cost analysis series: Hydropower. IRENA: Masdar.

IRP (Integrated Resource Plan). 2010. Integrated Resource Plan (IRP2010. Integrated resource plan for Electricity 2010-2030. Available at: [http://http://www.energy.gov.za/IRP/irp%20files/IRP2010_2030_Final_Report_20110325.pdf].

Jones, G.J. and Thompson, G.T. 1996. Renewable energy for African development. *Solar Energy* 58(1-3): 103-109.

Kalogirou, S.A. 2004. Solar thermal collectors and applications. *Progress in Energy and Combustion Science* 30: 231-295.

Karekezi, S. and Kithyoma, W. 2002. Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa? *Energy Policy* 30: 1071-1086.

Kennet, M. and Heinemann, V. 2006. Green Economics: setting the scene. Aims, context, and philosophical underpinning of the distinctive new solutions offered by Green Economics *Int. J. Green Economics*, 1: 68-102.

Kopernik Solutions. 2015. Prime Cylindrical Biomass Cookstove. Available at: [https://kopernik.info/technology/prime-cylindrical-biomass-cookstove] (Accessed 13 November 2016).

Kpadonou, R.A.B., Adegbola, P.Y. and Tovignan, S.D. 2012. Local Knowledge and Adaptation to Climate Change in Ouémé Valley, Benin. *African Crop Science Journal*, 20(2): 181-192.

Krantz, L. 2001. The Sustainable Livelihood Approach to Poverty Reduction: An Introduction. Swedish International Development Cooperation Agency. Available at: [http://www.sida.se/contentassets/bd474c210163447c9a7963d77c64148a/the-sustainable-livelihood-approach-to-poverty-reduction_2656.pdf].

Leck, H. Conway, D., Bradshaw, M. and Rees, J. 2015. Tracing the Water-Energy-Food Nexus: Description, Theory and Practice. *Geography Compass,* 9(8): 445-460.

Legros, G., Havet, I., Bruce, N. and Bonjour, S. 2009. The Energy Access Situation in Developing Countries. World Health Organization: New York.

Léna, G. 2013. Rural Electrification with PV Hybrid Systems (IEA PVPS Task 9, Subtask 4, Report IEA-PVPS T9-13:2013 CLUB-ER, Thematic Paper). International Energy Agency: Paris.

Liniger, H.P., Mekdaschi Studer, R., Hauert, C. and Gurtner, M. 2011. Sustainable Land Management in Practice – Guidelines and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO).

Lopes, T. 2016. Solar Oven. [Lowtech.co.za]. Available at [http://www.lowtech.co.za/solar-oven]. (Accessed 13 November 2016).

Macaulay, A.C., Commanda, L.E., Freeman, W.L., Gibson, N., McCabe, M.L., Robbins, C.M. and Twohig, P.L. 1999. Participatory research maximises community and lay involvement. *British Medical Journal* 319: 774-778.

Machete, C.L. 2004. Agriculture and poverty in South Africa: Can agriculture reduce poverty? Paper presented at the Overcoming Underdevelopment Conference in Pretoria, 28-29 October.

McCusker, B. and Oberhauser, A.M. 2006. An assessment of women's access to natural resources through communal projects in South Africa. *GeoJournal* 66: 325-339.

Midgley, G.F., Chapman, R.A., Hewitson, B., Johnston, P., De Wit, M., Ziervogel, G., Mukheibir, P., Van Niekerk, L., Tadross, M., Van Wilgen, B.W., Kgope, B., Morant, P., Theron, A., Scholes R.J. and Forsyth, G.G. 2005. A status quo, vulnerability and adaptation assessment of the physical and socio-economic effects of climate change in the Western Cape, Report to the Western Cape Government, Cape Town, South Africa. Report No. ENV-S-C 2005-073. Stellenbosch, CSIR.

Mjonono, M., Ngidi, M. and Hendriks, S. 2009. Investigating Household Food Insecurity Coping Strategies and The Impact of Crop Production on Food Security Using Coping Strategy Index (CSI). *Farm Management*. 17th International Farm Management Congress, Bloomington/Normal, Illinois, USA.

Mudhara, M., Critchley, W., Di Prima, S., Dittoh, S. and Sessay, M. 2016. Community Innovations in Sustainable Land Management – Lessons from the field in Africa. Routledge, Abingdon.

Mukheibir, P. 2008. Water resources management strategies for adaptation to climate-induced impacts in South Africa. *Water Resources Management* 22 (9): 1259-1276.

Mukheibir, P. and Sparks, D. 2005. Climate variability, climate change and water resource strategies for small municipalities. Water resource management strategies in response to climate change in South Africa, drawing on the analysis of coping strategies adopted by vulnerable communities in the Northern Cape province of South Africa in times of climate variability. Pretoria: Water Research Commission.

Muller, M., Schreiner, B., Smith, L., Van Koppen, B., Sally, H., Aliber, M., Cousins, B., Tapela, B., Van der Merwe-Botha, M., Karar, E. and Pietersen, K. 2009. Water security in South Africa. Development Planning Division. Working Paper Series No.12, DBSA: Midrand.

Mvula Trust. 2009. Annual Report 2008/2009, Republic of South Africa.

National Treasury. 2013. Carbon tax policy paper: Reducing greenhouse gas emissions and facilitating the transition to a green economy. Policy paper for public comment, May 2013. Pretoria, Republic of South Africa. Available at: [http://www.info.gov.za/view/DownloadFileAction?id=189311].

NDA (National Department of Agriculture). 2002. Policy on Agriculture in Sustainable Development – 8th Draft. Available at: [http://www.nda.agric.za/docs/Policy/SustainableDev.pdf] (Accessed on 12 September 2017).

Ndebele Stoves. 2016. New Stoves. [Ndebele Stoves]. Available at: [http://www.ndebelestoves.co.za/newStoves.htm] (Accessed 28 January 2016).

NREL (National Renewable Energy Laboratory). 2014. Solar photovoltaic energy basics. [NREL]. Available at: [http://www.nrel.gov/learning/re_photovoltaics.html] (Accessed 26 January 2016).

Okhahlamba Independent Development Plan review 2014/15. 2014. Available at: [http://www.okhahlamba.org.za/docs/idp/2014/okhahlamba%20municipality%202014_2015%20version%202%20_20%20june%202014.pdf].

Oyuke, A., Penar, P.H. and Howard, B. 2016. Off-grid or 'off-on': Lack of access, unreliable electricity supply still plague majority of Africans. *Afrobarometer*: Dispatch No. 75, 14 March 2016.

Pauw, K. and Mncube, L. 2007. The impact of growth and redistribution on poverty and inequality in South Africa. Available at: [http://www.commerce.uct.ac.za/research_units].

Rengasamy, S. Undated. Introduction to Livelihood Promotion-Madurai Institute of Social Sciences. Available at: [https://www.scribd.com/doc/16343533/Introduction-to-Livelihood-Framework] (Accessed 14 November 2016).

Ringler, C., Bhaduri, A. and Lawford, R., 2013. The nexus across water, energy, land and food (WELF): potential for improved resource use efficiency? Current Opinion. *Environmental Sustainability* 5: 617-624.

Rosenzweig, C. and Hillel, D. 1995. Potential impact of climate change on agriculture and world food supply. *Consequences*, 1: 23-32.

Rugumayo, A. 2010. *Energy Access for Rural Communities in Sub Saharan Africa*: Presented at ASADI 6th Annual Meeting 7-11 November 2010, Cape Town South Africa. Available at:[https://www.assaf.org.za/files/2010/11/Energy-Access-for-Rural-Communities-in-Sub-Saharan.pdf] (Accessed 22 December 2017).

RuralKing. 2016. Wood Pellet Fuel 40 LB. Available at: [http://www.ruralking.com/hardwood-wood-pellet-fuel-40lb.html] (Accessed 13 November 2016).

SADC. 2005. Climate Change Adaptation: Perspectives for the Southern African Development Community (SADC). Report No.1 for the Long Term Adaptation Scenarios Flagship Research Programme (LTAS). Available at: [https://www.environment.gov.za/sites/default/files/docs/ltasphase2report1_adaptation_sadc.pdf].

SAHRC. 2006. Sixth Economic and Social Right Report 2003-2006. Pretoria: SAHRC.

Salomon, M. 2009. Research into keeping cattle in a changing rural landscape. Centre for Environment, Agriculture and Development (CEAD): Pietermaritzburg.

SANEDI. 2017. SANEDI strategic plan 2016-2017. Available at: [http://www.sanedi.org.za/img/Bids%20and%20Notices/Sanedi%20Strategic%20plan%202016_17_d1.pdf] (Accessed 01 December 2017).

Scinet. 2015. How solar cookers work. Available at: [http://solarcooking.wikia.com/wiki/How_solar_cookers_work] (Accessed 29 January 2015).

SFGate. 2013. Wonderbag insulated cooker helps African women. [SFGate]. Available at: [http://cached.newslookup.com/cached.php?ref_id=325&siteid=2266&id=4286822&t=1388788507] (Accessed 31 January 2015).

Shanan, Z. 2014. Which solar panels are most efficient. [Clean technica]. Available at: [http://cleantechnica.com/2014/02/02/which-solar-panels-most-efficient/] (Accessed 26 January 2016).

Sheckleton, S. and Luckert, M. 2015. Changing Livelihoods and Landscapes in the Rural Eastern Cape, South Africa: Past Influences and Future Trajectories. *Land* 2015, 4(4): 1060-1089.

Smith, M.T. 2011. The financial and economic feasibility of biodigester use and biogas application for rural households. Masters of Commerce thesis. University of KwaZulu-Natal: Pietermaritzburg.

Smith, M.T. 2015. A study on South Africa's roof-top and ground mounted small-scale solar PV installations: market demand, financing and supply (Report no. REN1504-01.1). Technical assistance facility of the Agence Francaise de Developpement (AFD).

Smith, M.T. and Everson, T.M. (2015). Guidelines report on biogas generation using livestock manure and rainwater harvesting. Volume 2. Water Research Commission: Pretoria, South Africa. WRC Report No. 1955/1/15.

Smith, M.T., Schroenn Goebel, J. and Blignaut, J.N. 2014. The financial and economic feasibility of rural household biodigesters for poor communities in South Africa. *Waste Management* 34 (2): 352-362.

Sookraj, A. 2002. The provision of services in rural areas – with special reference to health and education: A case study of Okhombe Village in the North-West Drakensberg, KwaZulu-Natal. Master of Arts Thesis. University of KwaZulu-Natal South Africa.

SunWater. n.d. What is solar thermal? [SunWater] Available at: [http://sunwatersolar.com/solar-thermal/what-is-solar-thermal] (Accessed: 2016/01/28).

Swatuk, L.A. 2008. A political economy of water in Southern Africa. *Water Alternatives* 1(1): 24-47.

Swyngedouw, E. and Heynen, N.C. 2003. Urban Political Ecology, Justice and the Politics of Scale. *Antipode* 35: 898-918.

Ter Heegde, F. and Sonder, K. 2007. Biogas for Better Life: An African Initiative – Domestic biogas in Africa; a first assessment of the potential and need. SNV: Netherlands.

The Green Age. n.d. Types of solar PV setup. [The Green Age]. Available at: [http://www.thegreenage.co.uk/tech/types-of-solar-pv-setup/] (Accessed 26 January 2016).

Thompson, J., Porras, I.T., Tumwine, J.K., Mujwahuzi, M.R., Munguti, K., Johnstone, N. and Wood, L. 2001. Drawers of water II: 30 years of change in domestic water use and environmental health in East Africa. IIED, London, UK.

Trier, C. and Maiboroda, O. 2009. The Green Village project: A rural community's journey toward sustainability. *Local Environment* 14: 819-831.

Tuijp, W., Dittoh, S., Mahdi, M. and Mudhara, M. 2016. Cross-learning with community initiatives. In: Community Innovations in Sustainable Land Management – Lessons from the field in Africa. Eds: , Mudhara M, Critchley W, Di Prima S, Dittoh S, Sessay M. Routledge, Abingdon.

UNIDO (ed). 2006. *Sustainable Energy Regulation and Policymaking for Africa*. UNIDO, REEEP and IT Power: United Kingdom.

U.S. Department of Energy. 2011. Wind Data Details: Cited in: Centre for Sustainable Systems. 2011. *Wind Energy Factsheet*. [CSS] Available at: [http://css.umich.edu/factsheets/wind-energy-factsheet] (Accessed 11 December 2017).

U.S. Department of Energy. 2016. Animation: how a wind turbine works. [U.S. Dept. of Energy]. Available at: [http://energy.gov/eere/wind/animation-how-wind-turbine-works] (Accessed 28 January 2016).

UNCTED. 2009. Green and renewable technologies as energy solutions for rural development. Paper presented at United Nations Conference on Trade and Development, Geneva.

UN-DESA (United Nations Department of Economic and Social Affairs). 2014. Improving sustainable energy access for rural areas. Available at: [http://www.un.org/en/development/desa/news/sustainable/rural-energy-access.html] (Accessed 20 July2017).

UNDP. 2007. Human Development and Climate Change: preface for Human Development Report. Available at: [http://hdr.undp.org/hr2007].

UN-E&SC (United Nations, Economic and Social Commission for Asia and the Pacific). 2005. Energy services for sustainable development in rural areas in Asia and the Pacific: Policy and Practice. United Nations: New York.

Water Wheel. 2009. Climate Change – Knowledge: The cornerstone of SA's adaptation to climate change. The Water Wheel 8(1): 22-24.

Western, D., Wright, R.M. and Strum, S.C. 1994. Natural Connections: Perspectives in Community-based Conservation. Washington (DC): Island Press.

WHO (World Health Organisation). 2004. Global burden of disease. WHO: Washington DC.

Winkler, B., Lemke, S., Rittera, J. and Lewandowski, I. 2016. Integrated assessment of renewable energy potential: Approach and application in rural South Africa. *Environmental Innovation and Societal Transitions*. Available online.

Winkler, H. 2006. Energy demand. In Winkler H (ed) Energy policies for sustainable development in South Africa. Energy Research Centre, University of Cape Town.

World Bank. 1997. Rural Development: From Vision to Action. A Sector Strategy. The World Bank, Washington D.C., USA.

World Energy Outlook. 2014. *World Energy Outlook: Methodology for Energy Access Analysis*. [World Energy Outlook]. Available at: [http://www.worldenergyoutlook.org/media/weowebsite/EnergyAccess_Methodology_2014.pdf] Accessed (22 December 2017).

Yu, Derek. 2013. Some factors influencing the comparability and reliability of poverty estimates across household surveys. Stellenbosch Working Paper Series No. WP03/2013. Stellenbosch University.

Zuma, K.D. 2003. A social analysis of development process of a community-based monitoring system: a case of soil rehabilitation in Okhombe, South Africa. Wageningen Research University, The Netherlands.

9.2 Personal communications

Gray Maquire	Project 90x2030	January 2016
Luke Dillon	Calore KZN	January 2016
Warren Confait	Renen Energy Solutions	January 2016
Tony Lopes	Lowtech.co.za	January 2016
Toney Lopes	Lowtech.co.za	2017
Amy Watkins	Wonderbag Foundation	29 September 2015
Tanah Dankert	Wonderbag Foundation	29 September 2015

CHAPTER 10. APPENDICES

10.1 Expert Energy Workshop – Farm Inn, Pretoria 25 November 2015

The organizations and individuals invited to the expert workshop were:

Table 10.1: Invitees to the expert workshop

Name	Designation	Contact details	Organisation
Karen Breytenbach	Head DOE	Manila.soobramoney@ipp-projects.co.za 0797442526 0873513026	Independent power producers DOE
Warwick Pierce	Energy Consultant	Warrick.pierce@aurecongroup.com 012 4272839; 073 3212783	Independent power producers DOE
Pico Shomange	Manager	pico.shomange@ipp-projects.co.za	Independent power producers DOE
David Mahuma	Programme manager	david@sanedi.org.za	Working for energy SANEDI
David Tinarwo	Lecturer	dtinarwo@yahoo.co.uk	University of Venda
Gordon Ayres	Managing Director	gordon@biogaspro.com	AGAMA
Cobus Botha	Researcher	BothaC@arc.agric.za	ARC
Kgoroshi Mashabane	Manager	kwmashabane@ruraldevelopment.gov.za	Dept. of Rural Development
Lwandle Mqadi	Specialist	MqadiL@eskom.co.za	ESKOM
Tshilidzi Ramuedzisi	Chief Director	Tshilidzi.ramuedzisi@energy.gov.za	DOE
Karen Surridge-Talbot	Centre Manager	karenst@sanedi.org.za	SANEDI/DEA Renewable Energy Centre of Research & Development
Sara Polonsky	Deputy Director: Strategic Support	SPolonsky@environment.gov.za	DEA
Gray Maguire	Community Engagement Facilitator	project90x2030@gmail.com	Project 90
Simphiwe Nojiyeza	Lecturer	simphiwen@uj.ac.za	University of Johannesburg
Vhalinavho Khavhagali	Director	VKhavhagali@environment.gov.za	DEA
Puleng Mofokeng	Deputy Director	Pulengm@daff.gov.za	DAFF

The response to the workshop was highly disappointing with only four out of the sixteen invitees attending. Since government support is essential for the success of this project, the project team needs to investigate alternative ways to engage with government departments. Nevertheless, valuable input was received from the following people who attended the workshop.

Present: Gordon Ayres (Agama), Dr Simphiwe Nojiyeza (University of Johannesburg), David Tinarwo (University of Venda), Karen Surridge-Talbot (SANEDI), Dr Terry Everson (University of KwaZulu-Natal), Mike Smith (University of KwaZulu-Natal).

Agenda

1. Explanation of workshop purpose and expected outcomes.
2. Presentation of project activities so far, and feedback from workshops and surveys in Okhombe.
3. Implementation options for a small scale pilot study in a rural area. Advice on best practice.
4. Technology options for testing: energy, food and water with a focus on energy for cooking, heating and lighting.
5. Post research planning – how best to deliver findings to the right audience, and who that audience should be. Advice on how to take initiative through to government.

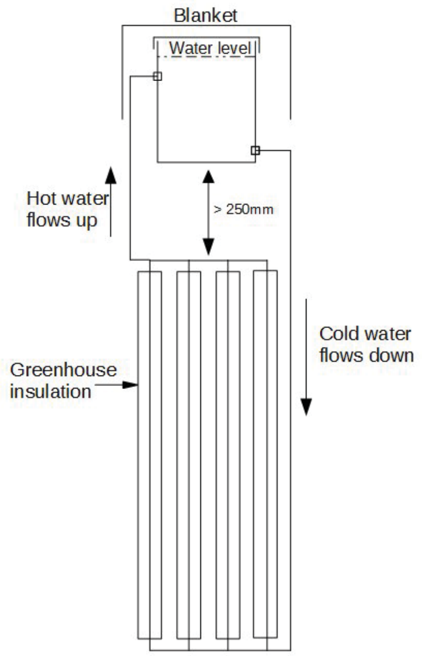
10.2 Guideline manuals

Included here are guidelines, from Lowtech.co.za's Tony Lopes, which are informed the capacity building training that was conducted by Tony and the WRC research team. Sections 10.2.1 to 10.2.3 are still under review as they were received shortly before delivery of the draft final report.

10.2.1 Solar geyser using PET coke bottles

The plastic solar geyser array, was developed by Jose Alano, a retired Brazilian mechanic. It uses 2 L cold drink bottles and long-life milk/fruit juice tetra-pak cartons. He shows you how to build it with PVC pipe. However, the unit below uses 15 mm black LDPE irrigation pipe instead of the PVC pipe. The LDPE is easier to work with and more forgiving to errors. Copper pipe is more efficient but it's also more expensive and prone to theft.

This system needs no electricity to circulate the water. It uses the principle of thermosyphon, a natural law where hot rises and cold sinks. Ensure the solar array is installed below the container, for thermosyphon to work.



When handling recycled material, do wash properly to avoid bad smell and spread of diseases such as Leptospirosis. The tetrapak is cut into the shape of the bottle and placed inside the bottle, behind the pipe. It acts as a reflector to direct the sun rays towards the black 15 mm LDPE irrigation pipe. It can also be painted black, in which case it acts as a heatsink. The 2 L cold drink bottle has the bottom cut off to allow the other bottle to slide in. Use only clear bottles.

The 15 mm T piece sets assembled. The small horizontal pipe sections are 80 mm long and the vertical pipes are 1070 mm long. More columns can be added to speed up heating. Use one bottle per/litre of water in container.

Cut a 20 mm hole at top (hot in) of bucket and bottom (cold out). The 15 mm male elbow fits on the outside, gasket and locknut on the inside.

A frame made of wood/bamboo/steel should be fitted behind the array, to prevent it from sagging. Use 6 bottles per column.

The blanket insulates the heated water.

Ensure that the bucket/container is always full to allow thermosyphon to occur. The distance between the bottom of the bucket and the top of the array, should be around 250 mm.

If small quantities of hot water are removed from the container during the day, cold water should be added using a funnel which directs the water to the bottom and therefore will not cool the water temperature at the top.

	
Nomusa at 633 Denver squatter camp with her 10 column array geyser and 60 litre container. Her paraffin bill has halved.	Precious at Okhombe Drakensberg with 10 column geyser and 50 litre container.

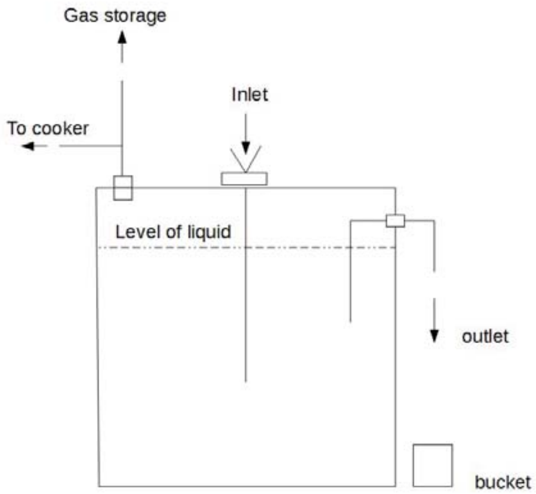
The above system is suited for areas where water is not piped to homes – the water is manually filled. If one has pressurised municipal water to the house, the container can be fitted with a level ball float. The container could then be mounted inside the roof with array on the outside, and the hot water gravity fed into the home.

Although simple, the project does require attention to details, regarding manufacture and its operation. The size of the array needs to be in relation to the container size. If the water gets too hot, the irrigation pipe will soften excessively and then leaks may occur.

10.2.2 Biogas digestor 1000L IBC

When we hear the word biodigesters, we think of messy manure to produce some gas for cooking. For methane production, anaerobic conditions are needed. A container that allows no air inside is required. In this case, we use a second hand 1000L IBC (International Bulk Container).

As the tank is above ground, the quantity of gas produced, is dependent on the ambient temperature. If larger volume tanks were buried in the ground, we would have a more stable and steady supply of gas. To increase the production of gas, additional tanks can be added in parallel.

<table>
<tr>
<td>
</td>
<td>
The tank cap is fitted with a 700 mm long 50 mm wide PVC pipe. The adaptor is 2inch BSP which screws into the red cap. The inside of the thread side of the adaptor, needed to be sanded to allow the 50 mm pipe to fit on the inside and then glued with PVC weld. It has to be airtight. Ensure when cap is screwed on, that the rubber seal is flush with the lip of the tank male side.</td>
</tr>
<tr>
<td>
Drill a 20 mm hole to insert an elbow with locknut on the inside. This is for the gas outlet. Add a T piece to store the excess gas in truck tyres or another tank or thick plastic. Mini valves can be added, which allows for easier maintenance of the system without loss of gas.</td>
<td>
For the outlet of the digestor, fit a 350 mm long 50 mm PVC pipe, with elbow and appropriate fittings that will hold this piece to the wall of the container and be airtight. Note this goes on the inside of the digestor. It is fitted about 70 mm from the top of the tank, on a surface with no ridges – the PVC fittings must fit flush to be airtight.</td>
</tr>
</table>

On the outside of the tank. As feedstock is added and the tank too full, digestate will exit. Also, as the pressure builds up due to gas production, the digestate will push up the pipe and exit. Place a bucket underneath and use as liquid manure.

The gas can be stored in 250 micron plastic, or truck tyres, which must be kept in shade and covered, with a carpet and some weights to create some pressure for the burner ring.

Using a Cadac gas plate, increase the hole size of the jet, to 1.5 mm, due to the lower pressure from the biodigester system.

To activate the digestor, a mixture of about 40 kg fresh cow/horse manure is put into the tank and add about 800 litre of water. Wait until the gas starts to produce, then can add feedstock.

The daily quantity of gas produced, depends on the weather. On cloudy and cold days there is no gas produced. If the sun is shining, the unit produces about 15 min of gas per day. One can use it to boil water for tea or heat up food. To cook longer food items, accumulate gas for 2-3 days. The unit will produce negligible gas over winter months. The above are the results for South Africa, Johannesburg region.

The feedstock for this biodigester is old cooking oil and rotting fruits, and its calorific content is higher than that of manure, roughly 40 times higher. Add 2 litre of feedstock with 20 L of water once or twice a week. Feed the digestor slowly, as feeding too much could cause an imbalance in the chemical reactions and cause gas production to stop.

10.2.3 Solar Oven – Sunstove Organisation

The Sunstove Organisation is a South African section 21 Incorporated Association dedicated to benefiting the environment and women in developing countries. It has manufactured and distributed more than 15,000 Sunstoves. Telephone 0119692818 or sunstove@iafrica.com

The main outer shell is made from recycled plastic which is moulded with the side walls at specific angles to allow as much sun rays into the stove. The inner reflective sheeting, is spent lithograph aluminium sheeting. Between the sheeting and the outer shell, pink aerolite insulation is used, to maintain the trapped heat. The clear plastic cover, is polycarbonate sheeting which can take temperatures up to 150 deg cel. The unit weighs around 5 kg and costs R450.

One could make a sunstove out of wood, glass, carpet underfelt and tinfoil. If the outcomes of a project are to develop skills, it is worthwhile. However, at a cost of R450 for a finished product, the Sunstove is value for cost expended.

When using the solar oven, the sun needs to be shining for more than 30 minutes in every hour. The best time to cook, is between 10am and 3pm. Start cooking at 10am, as solar cooking will take between 2 and 4 hours to cook a meal. Stir the food as little as possible.

Use only black pots and they must not touch the lid. The white plastic covering must be peeled off both sides of the lid or the Sunstove will not cook. Avoid pots with plastic lids as they could melt.

Plate 10.1: Sunstove solar cook stoves

Don't leave the Sunstove in the sun if there is nothing in it and don't use ammonia based cleaners and avoid scratching the lid.

Mealie meal recipe – In the sunstove, preheat the required amount of water, with salt to taste, in a pot. At the same time, pre-heat the correct portion of mealie meal in another pot. When the water is hot, it does not have to boil, add the mealie meal, stir it in and leave it until it is cooked.

10.3 Questionnaire and responses for pilot testing of business models in Mahlabathini

10.3.1 <u>Questionnaire for Spaza store related business</u>

- The local Spaza Store in Mahlabathini was given 10 Pellet Cook Stoves and 1 tonne of wood pellet (5kg bags) to sell at real market value.
- Training days were conducted with 177 people attending over six weeks.
- Over 105 people bought stoves at a highly subsidised price (R50 instead of R650).
- All people attending were told they could purchase wood pellet from the local Spaza store.
- The Spaza store was given a set price list, and contact details to re-order pellet and stoves.
- Each stove should use between 20-40 kg per month (2 100-4 200 kg/month in Mahlabathini) – no pellet has been re-ordered by the Spaza Store by October 2017

This interview must be conducted with the Spaza store to see how many stoves and how much pellet was sold, and to investigate other renewable technologies that they may or may not be selling.

1. **How many bags of 5k pellet have you sold? ________________________________**

2. **How many stoves have you sold? _____________________________**

   [Depending on result (i.e. very little versus lots)]

3.

   3.1. *Very little sold:* **Why do you think you have only sold this many, what has the feedback from the community been?**

   Feedback on stoves:

   ____

   ____

   Feedback on pellet:

   ____

   ____

   3.2. *Lots/all sold:* **Why have you not re-ordered more pellet and stoves?**

   ____

4. **What energy products do you think you could sell (i.e. what do people want locally), do you sell them, why have you not sold them?**

Solar products:

☐ I sell them already
What is the feedback from the community on these products? ____________________

☐ I don't sell them

Do you think there is a market for them ☐ Yes / ☐ No

Why ____________________

Energy efficient lights:

☐ I sell them already
What is the feedback from the community on these products? ____________________

☐ I don't sell them

Do you think there is a market for them ☐ Yes / ☐ No

Why ____________________

Clean cookstoves:

☐ I sell them already
What types do you sell? ____________________

What is the feedback from the community on these products? ____________________

☐ I don't sell them

Do you think there is a market for them ☐ Yes / ☐ No

Why ____________________

Wonderbag (or similar):

☐ I sell them already
What is the feedback from the community on these products? ____________________

☐ I don't sell them

Do you think there is a market for them ☐ Yes / ☐ No

Why
____

Solar cooking oven: ☐ I sell them already

What types do you sell?
____

What is the feedback from the community on these products?
____

☐ I don't sell them

Do you think there is a market for them ☐ Yes / ☐ No

Why
____

Any other renewable energy products sold at the store:

What types do you sell?
____

What is the feedback from the community on these products?
____

____

10.3.2 D. Khoza: Spaza Store for Pellet and Pellet stoves, and other renewable energy technologies

1. **How many bags of 5k pellet have you sold?**

A. 20 to 30 bags were sold.

[Noting that no pellet or stoves were in the store] Where is the remaining 170 to 180 bags of pellet that were given?

A. We used them. [Prompted further], my mother used them at our house.

2. **How many stoves have you sold?**

A. We sold two (2) stoves at R600 each.

3. **Depending on the result of question (2)**

3.1. ***If very few are sold:*** **Why do you think you have only sold this many, what has the feedback from the community been?**

Feedback on stoves: A. The stoves are too expensive. People don't understand why they were given away for R50 at the expo days, but they are now R600.

Feedback on pellet: A. Not many people have the stoves. [Prompted further as it is known that over 105 people have stoves in Mahlabathini] A. There are a couple of people who have the stoves and they have come back to buy the pellet.

3.2. ***If many or all sold:*** **Why have you not re-ordered more pellet and stoves?**

[Question was rephrased to ask if he would get more pellet knowing there were so many people who had the stoves]

A. No, it is too expensive at R30/bag. If you make it R10/bag maybe people will buy it. [The team explained the cost, without transport to Okhombe was approximately R15/bag, so this would not be possible]

4. **What energy products do you think you could sell (i.e. what do people want locally), do you sell them, why have you not sold them?**

Solar products:

☐ I sell them already
What is the feedback from the community on these products? ______________________________

☐ I don't sell them

Do you think there is a market for them ☐ Yes / ☐ No

Why: A. There is electricity.

Energy efficient lights: ☐ I sell them already

What is the feedback from the community on these products? ____

☐ I don't sell them

Do you think there is a market for them ☐ Yes / ☐ No

Why don't you sell them: A. I don't know where to find them.

Clean cookstoves: ☐ I sell them already

What types do you sell? ____

What is the feedback from the community on these products? ____

☐ I don't sell them

Do you think there is a market for them ☐ Yes / ☐ No

Why: As per above commentary on cook stoves.

Wonderbag (or similar): ☐ I sell them already

What is the feedback from the community on these products? ____

☐ I don't sell them

Do you think there is a market for them ☐ Yes / ☐ No

Why: A. No, I don't know how it works. It doesn't work for my family.

Solar cooking oven: ☐ I sell them already

What types do you sell? ____

What is the feedback from the community on these products? ____

□ I don't sell them

Do you think there is a market for them □ Yes / □ No

Why: A. No, I don't know what that is.

Any other renewable energy products sold at the store:

What types do you sell? A. None.

What is the feedback from the community on these products? A. The energy efficient lights.

10.4 Questionnaire for micro-enterprise teams that were trained to make solar ovens, solar geysers and biodigesters

10.4.1 Questionnaire

1. **Name ____ Technology ______________________**

2. **Did you make the ____________________ after the capacity building / training day?**

   □ Yes / □ No

   Why:

   ____

3. **Have you sold any of the _____________________________ that you made?**

   □ Yes / □ No

   Why:

   ____

4. **Do you think there is a local market for the ______________________, and could you make a living out of making and selling them?**

   4.1. (*local market*) □ Yes / □ No 4.2. (*make a living*) □ Yes / □ No

   Why:

   ____

5. **If you were to try and make this business work, what resources or capacity building would you need to help you do that …**

   [Let the interviewee answer openly, and if they are unsure, give some examples (e.g. more technical training, guidance on how to run a business, start-up capital, marketing assistance]

   First answer without prompting:

   ____

   Second answer with prompting:

   ____

10.4.2 T. Hlatshwayo: Low-tech, coke bottle solar geyser

1. **Name** T. Hlatshwayo **Technology** Low-tech geyser

2. **Did you make the ___________________ after the capacity building / training day?**

   ☐ Yes / ☐ No **Yes, but only for WRC Team**

   Why:

   Constructing the first one was easy, because we were familiar with how it was meant to be made. But, it didn't work properly, because we got the pipe sizes wrong, and it leaked.

   Eight (8) people contributed to the making of the first digester.

   Others were not made because they were very expensive to make (R967.00 ex transport costs).

3. **Have you sold any of the ___________________________ that you made?**

   ☐ Yes / ☐ No

   Why:

   I don't think anyone will buy it because it was too expensive to make, even just to make for ourselves. We would probably need to charge people R1 500.

She does see the value in the product, but the technology only works for some of the year (doesn't work in winter), so people would not be willing to pay that much for something that only works part of the year. Also when it is cloudy, it does not provide hot water.

4. **Do you think there is a local market for the ____________________, and could you make a living out of making and selling them?**

4.1. (*local market*) ☐ Yes / ☐ No 4.2. (*make a living*) ☐ Yes / ☐ No

Why:

4.1. Local market, yes. But only if we can make it cheaper. I think people would be willing to pay about R700. But people have very short term

4.2. In Mahlabathini, yes someone could make money out of it, we could, and we would like to do it. But possibly only to make extra money, not to support a family.

5. **If you were to try and make this business work, what resources or capacity building would you need to help you do that …**

[Let the interviewee answer openly, and if they are unsure, give some examples (e.g. more technical training, guidance on how to run a business, start-up capital, marketing assistance]

First answer without prompting:

We didn't have the tools to make the product, so that was the first thing we would need. We had to pay someone to make holes in the bucket.

The materials were also very expensive, we need to find cheaper suppliers.

Second answer with prompting:

Training: If we were to make a business out of it, we would probably want to train some helpers to make the geysers as well, so we would like the professional (original) trainers to teach them.

Money/loan/donation: So that we can make some of the products to sell. We don't have enough money to make the products.

Supplier finding: We need support to find the cheapest suppliers and products to make the geysers. We would need this support continuously.

Final, unsolicited, comment:

If we can make it cheaper, then we really think we can make a business out of it. We would also need to find a place where we can store the products, and show customers the products. We also think that if it starts working, we would be able to start making other similar products.

10.4.3 NN. Msomi: Low-tech, coke bottle solar geyser

1. **Name** NN Msomi **Technology** Low-tech solar geyser

2. **Did you make the ___________________ after the capacity building / training day?**

   ☐ Yes / ☐ No – Yes, but only for the WRC team.

   Why:

   Nobody wanted to contribute any money to making another one. So we weren't able to get the materials to make it.

   We also had trouble making the first one. The wrong sized hole was made in the bucket, so the pipes didn't fit and they leaked.

3. **Have you sold any of the ____________________________ that you made?**

   ☐ Yes / ☐ No

   Why:

   No we haven't.

4. **Do you think there is a local market for the ______________________, and could you make a living out of making and selling them?**

   4.1. (*local market*) ☐ Yes / ☐ No 4.2. (*make a living*) ☐ Yes / ☐ No

   Why:

   4.1 I there is definitely a market for them. Even people who are not from Mahlabathini ask about the geyser.

   4.2 Not to sure. It depends mainly on whether we would be able to get the materials cheaper. We could only sell them if the materials were less, so we could sell them for something that people could afford.

   Maybe if they could be sold from R500 – R600, people would buy them.

5. **If you were to try and make this business work, what resources or capacity building would you need to help you do that …**

   [Let the interviewee answer openly, and if they are unsure, give some examples (e.g. more technical training, guidance on how to run a business, start-up capital, marketing assistance]

   First answer without prompting:

   We need someone to help us find cheaper materials to make the systems. We have the training on how to make them, so we don't need that any more.

   Second answer with prompting:

   None.

10.4.4 NN. Msomi: Low-tech solar box / oven

1. **Name** NN Msomi **Technology** Low-tech solar cooker

2. **Did you make the __________________ after the capacity building / training day?**

   ☐ Yes / ☐ No

   Why:

   No we didn't make it. The training was not sufficient for us to actually know how to make the box. We were shown how to make it, but we didn't know what materials to use after the day.

3. **Have you sold any of the ______ ____________________ that you made?**

   ☐ Yes / ☐ No

   Why:

   n/a

4. **Do you think there is a local market for the ____________________, and could you make a living out of making and selling them?**

   4.1. (*local market*) ☐ Yes / ☐ No 4.2. (*make a living*) ☐ Yes / ☐ No

   Why:

   I don't have actual experience using the solar box, so I can't tell whether people will buy.

5. **If you were to try and make this business work, what resources or capacity building would you need to help you do that …**

   [Let the interviewee answer openly, and if they are unsure, give some examples (e.g. more technical training, guidance on how to run a business, start-up capital, marketing assistance]

   First answer without prompting:

   No, we don't even know what materials to use. So we would need to be shown how to make it, what materials to use.

   Second answer with prompting:

   No, we are not interested in the solar box.

10.4.5 S. Msomi & B. Shezi: Biodigester

Mr Shezi's biodigester was visited and it was established that it was not working. The WRC team had been back to establish a second biodigester to provide extra gas, and despite the fact that gas is clearly being made by the system, it was not sufficient or was not being captured properly.
Mr Shezi and Mr Msomi have not made any of the biodigesters as they needed/wanted to be able to show people the operating system before they could persuade anyone to invest in one.

Mr. Shezi was asked whether he thought the biodigester would have a market in Mahlabathini and how much people might be willing to buy it for?

Mr Shezi said that he thought people would definitely want biodigesters if it worked. He spent a lot of money on gas and electricity for cooking, and said that wood was not easily available and was expensive. He believed that people would buy the systems but was unsure how much people would be willing to pay. [After further prompting] Mr Shezi believed people would be willing to pay R1 500 for the biodigester, if it was able to cover all of their cooking needs. He said they would be willing to pay this as it is a once off cost, and then the gas is free.