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Department of Agriculture and Rural Development

A FEASIBILITY STUDY AND AN IMPLEMENTATION PLAN OF ALTERNATIVE ENERGY TECHNOLOGY OPTIONS FOR UNELECTRIFED INFORMAL SETTLEMENTS IN GAUTENG PROVINCE

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ACRONYMS

ARI	Acute Respiratory Infection
BEE	Black Economic Empowerment
BnM	Basa njengo Magogo
CBO	Community Based Organisation
DEA	Department of Environmental Affairs
DoE	Department of Energy
ERC	Energy Research Centre, University of Cape Town
FBAE	Free Basic Alternative Energy
FBE	Free Basic Electricity
GDARD	Gauteng Department of Agriculture and Rural Development
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIZ	German Development Cooperation with South Africa - Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
INDC	Intended Nationally Determined Contribution
LPG	Liquefied Petroleum Gas
LPGASA	Liquefied Petroleum Gas Association of Southern Africa
MCA	Multi Criteria Analysis
MJ	Megajoule
NAAQS	National Ambient Air Quality Standards
NCCRWP	National Climate Change Response White Paper
NGO	Non-governmental Organisation
PV	Photovoltaic
SEA	Sustainable Energy Africa
SDG	Sustainable Development Goal
SMME	Small Medium and Micro Enterprise
Stats SA	Statistics South Africa
SWH	Solar Water Heater
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change

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INTRODUCTION

Project Background

The Gauteng Department of Agriculture and Rural Development (GDARD) commissioned a Feasibility Study and the development of an Implement Plan, in order to address issues related to safe, reliable and affordable clean energy and technologies, targeted at households in unelectrified informal settlements in Gauteng.

This initiative is a response by Province, in alignment with its Air Quality Act, National Air Quality Framework, Gauteng Air Quality Plan and the Province's 10-Pillar Programme[1] of radical transformation and modernisation of Gauteng, to curb the harmful levels of indoor and ambient air pollution prevalent in dense low-income settlements in Gauteng.

Gauteng Province – Overview

Gauteng Province is the smallest province in South Africa by land area (18,178 km^2 – 1.5% of total national area), but it is the most populous with a total population of 12.3 million (making up 24% of the national population) and contributing over a third (36%) of national wealth measured by GDP.

The provincial economy is largely driven by the finance (27%), community services (22%), manufacturing (19%) and trade (14%) sectors. The province contains three metros (City of Johannesburg, City of Tshwane and Ekurhuleni Metropolitan Municipality) and two District Municipalities (West Rand and Sedibeng). West Rand contains four local municipalities (Randfontein, Westonaria, Mogale City and Merafong) and Sedibeng District contains three (Emfuleni, Midvaal and Lesedi) local municipalities (See Figure 1).

The province is highly urbanised, with the metros being home to the majority of the province's population (86% - 9.5 million people). Gauteng experienced the highest average provincial population growth rate between 2001 and 2011 (2.7%). In comparison, the national average annual population growth over the same time period was 1.5%. The household growth in Gauteng (3.4%) has surpassed population growth (2.7%).

The fastest growing component of the residential sector in Gauteng is informal housing, where close to a fifth of Gauteng's households are informal (19%, including backyard dwellers) (Stats SA 2011). This proportion accounts for over third of the country's informal households (Figure 2).

[1] Among the objectives of the 10 Pillar Programme, Gauteng Provincial Government (GPG) aims over the next five years to revitalise and mainstream the township economy by supporting the development of township enterprises, cooperatives and SMMEs that will produce goods and services that meet the needs of township (http://www.gautengonline.gov.za/Documents/10%20pillars.pdf)

Figure 1: Map[2] of Municipalities in Gauteng Province

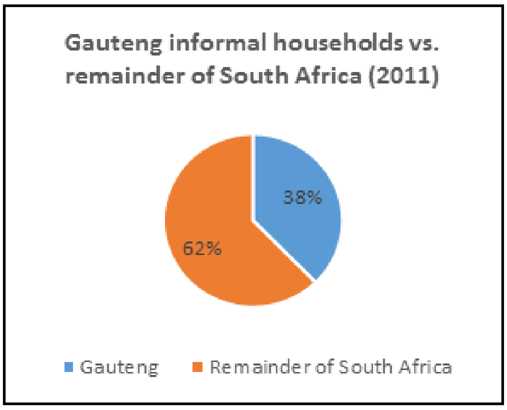

Figure 2: Total number of informal households in Gauteng and South Arica

The informal households are predominantly located in the three metros – 87% of households living in informal settlements are found in the 3 metros. Ekurhuleni metro is estimated to have 137 informal settlement areas, Johannesburg 157 and Tshwane is estimated to have between 108 informal settlement areas (HDA 2013).

Rapid urbanisation, driven by employment[3] and resource opportunities, has resulted in the increased need and demand of basic services and has contributed to the

[2] Source: Map of Gauteng with municipalities labelled (2011)" by Htonl. Licensed under GFDL via Commons - https://commons.wikimedia.org/wiki/File:Map_of_Gauteng_with_municipalities_labelled_(2011).svg#/media/File:Map_of_Gauteng_with_municipalities_labelled_(2011).sv;2g

[3] The official unemployment rate for the Province is high (26%), but in relative terms, when compared to other provinces, it has one of the lowest unemployment rates, second only to the Western Cape (21%). National unemployment sits at 30%.

growth of the informal sector (HDA 2013). The informal housing sector is characterised by extreme poverty and a lack of access to a range of basic services including energy.

In 2011, 87% of Gauteng's households were electrified as determined by the use of electricity for lighting as a proxy for electrification (Stats SA 2011). The use of electricity for cooking is slightly lower, at 84%, indicating multiple fuel use to meet household energy needs. In comparison, electricity use for both lighting (85%) and cooking (74%) at the national level is lower.

In terms of the informal sector, the recent National Department of Energy (DoE) study on 'Energy Related Behaviour and Perceptions in South Africa's Residential Sector' indicates that 73% of informal households in Gauteng have access to electricity including both formal and illegal electrical connections. Therefore over a quarter of informal households located in densely populated low income communities remain unelectrified and even where there is access to electricity it is clear that: (i) households are multiple fuel users in order to satisfy their energy needs; and (ii) the fuels used are largely polluting and unsafe for human health (DEA 2013, DoE 2013).

In view of this, there is a clear need for Gauteng Province to address the energy needs of informal settlements, in particular those households without access to electricity. It is unlikely that universal access to electricity will be achieved within the Province by 2025 which is the target date set for the entire country by the National Department of Energy (DoE). This warrants urgent attention by Province, to seek clean household energy alternatives for the poor, as indoor and ambient air pollution from domestic fuel-burning in densely populated low income communities will persist into the future at dangerously high levels.

Gauteng Air Quality and Household Energy Use Overview

Gauteng has been identified as one of the key air pollution "hotspots" in the country, because its air pollution levels have far exceeded national ambient air quality standards, posing a threat to human health and the environment[4]. Within the residential sector, domestic fuel burning to meet primary household energy needs in densely populated low income communities has been identified as a major source of air pollution, impacting human health and wellbeing in the Province (DEA 2013). This is due to the level of release of these emissions within the breathing zone of people. Moreover, the impact of emissions from fuel burning is often amplified by poor ventilation in low-income households.

[4] National Ambient Air Quality Standards (NAAQS) have been set for criteria pollutants (such as sulphur dioxide, oxides of nitrogen, ozone, lead, particulate matter specifically PM_{10}, carbon monoxide and benzene) which have known health impacts. The permissible level of these pollutants in ambient air has been informed by the World Health Organisation Guidelines. Where ambient air for a specified pollutant exceeds its NAAQS, health is potentially compromised. (DEA, 2009)

Households in these poor communities, out of necessity and lack of access to affordable clean energy, are compelled to use harmful and unhealthy fuels such as coal, wood and paraffin for their daily survival. The main pollutants of concern associated with domestic fuel burning in combination with the use of inefficient technologies/appliances are: fine particulate matter (PM_{10}), sulphur dioxide, carbon dioxide and carbon monoxide. Domestic fuel burning presented the most significant source of respiratory hospital admissions in Gauteng (Scorgie *et al* 2004). Particulate matter (PM)[5] in studies has been selected as the pollutant most accountable for premature deaths from exposure to polluted air (Mduli *et al* 2005).

Indoor air pollution levels caused through dirty fuel combustion exceeds the World Health Organisation's recommended level by up to 10-15 times in parts of the Highveld urban areas of Gauteng, particularly during the winter months when thermal needs are greatest (Poggiolini 2007). Moreover solid fuels such as firewood and charcoal, due to their low heat transfer and efficiency, generate 10-100 times more respirable PM per meal than modern cooking fuels like LPG (Nathan & Kelkar 1997). The exposure of household members to harmful indoor air pollutants is thus severe. Health impacts from exposure to these pollutants include acute respiratory infections (ARI's) and chronic obstructive pulmonary disease[6]; low birth weight; stillbirths, cataracts; persistent headaches; and frequent eye and ear infections. ARIs are recognised as the 6th largest killer of children under the age of four in South Africa (Poggiolini 2007). Such impacts place a substantial economic and social burden on families and in turn the broader South African economy.

The use of safe, affordable, clean burning energy technologies and energy sources not only substantially reduce the risk of fires and indoor air pollution, but will also contribute significantly to improved ambient air quality, human health and well-being, and will provide long-term economic benefits, ultimately impacting on poverty reduction.

Purpose of Report

As a first step towards developing a plan to improve both indoor and ambient air qaulity, this study assesses the suitability and appropriateness of alternative clean energy technologies for use in densely populated unelectrified informal settlements in Gauteng Province. The technologies considered fulfil the primary household energy requirements of cooking, lighting, water heating and space heating. The key factors considered in this study for the improvement of air quality levels include: safety, affordability and efficiency of clean technologies as well as the sustainablitiy of fuel supplies.

The feasiblity study is made up of four key components:

[5] A mixture of solid particles and liquid pollutants suspended in the air that are inhaled.

[6] A collection of chronic lung conditions characterized mainly by a persistent blockage of airflow from the lungs.

Part 1 presents an analysis of a survey exploring **household energy use patterns**, conducted in four selected unelectrified informal settlements in the Gauteng Province. The purpose of the survey was to gain an understanding of current energy use demands and needs as well as perceptions prevalent among informal households in Gauteng. The survey provides quantifiable and indicative data on household energy use and their social acceptance among densely populated low income informal settlements in Gauteng. The survey results provided the basis for identifying appropriate alternative clean energy technologies and energy sources that reduce air pollution while meeting the major household energy requirements of informal households, notably cooking, space heating and lighting.

Part 2 provides a comprehensive review of energy technologies and associated energy sources available in the market that are cleaner, appropriate, applicable and more sustainable and those that are currently available and used by informal households in Gauteng. This review also includes a range of potential suppliers/distributors of clean energy technology and energy options. Key issues, notably the main technical pros, cons, risks and impacts for the each of the alternative technologies and energy sources are highlighted. These serve as a cost-benefit and emissions analysis by which technology options can be compared against each other.

Part 3 develops a decision-making framework to determine the most appropriate household energy technologies for use in dense informal settlements in Gauteng Province. A multi-criteria analysis (MCA) was conducted to assess the most suitable technology options based on a number of criteria. Technology options for an alternative energy mix were identified for: (1) Cooking and heating applications; and (2) Lighting and Charging applications. This assessment was to provide a range of technologies, evaluated based on criteria developed with experts from GDARD and driven by an air pollution reduction agenda, rather than to provide a restrictive list of ‘ideal’ technologies.

Part 4 provides a high-level implementation plan for the rolling out of alternative clean energy technologies to informal households in Gauteng.

A FEASIBILITY STUDY AND AN IMPLEMENTATION PLAN OF ALTERNATIVE ENERGY TECHNOLOGY OPTIONS FOR UNELECTRIFIED INFORMAL SETTLEMENTS IN GAUTENG PROVINCE

1. PART 1: STATUS QUO OF HOUSEHOLD ENERGY USE IN UNELECTRIFIED INFORMAL SETTLEMENTS IN GAUTENG PROVINCE

1.1. INTRODUCTION

As the first phase of this Feasibility Study, a survey exploring household energy use patterns was conducted in four selected unelectrified informal settlements in the Gauteng Province. The purpose of the survey was to gain an understanding of current household energy use patterns, needs and perceptions prevalent among informal households in Gauteng. This understanding is very important for Gauteng's strategy development in terms of managing air pollution emissions in the residential sector. It is important to note that the intention of the survey was to provide quantifiable and indicative data on household energy use and their social acceptance among densely populated low income unelectrified informal settlements in Gauteng. The findings of this survey will form the basis for identifying appropriate alternative clean energy technologies and energy sources, the ultimate aim of which is to improve indoor and ambient air quality of informal communities as they carry out their their principle energy consuming activities, notably cooking, space heating and lighting.

Energy is globally recognised as a basic human need (UNDP 2000). Importantly, energy is not consumed for itself, but for what it can do i.e. the services it provides such as cooking, lighting, heating, cooling and the production of goods and services (UNDP 2000). These energy services are central to human welfare and development. To this end more recently at the United Nations Sustainable Development Summit where world leaders adopted the 2030 Agenda for Sustainable Development included energy for the first time as a stand-alone goal, among the 17 Sustainable Development Goals (SDG). The energy SDG (SDG 7) aims to ensure universal access to affordable, reliable, and modern energy services by 2030 (UN 2015).

Implicit in this SDG is the use of appropriate energy sources that does not impact negatively on ambient air and indoor air quality, health and wellbeing. Therefore, Gauteng Province's intention with this project is firmly in line with current international and national ambitions.

1.2. METHODOLOGY

1.2.1 Overview

Primary research data on energy use was collected for informal households located within the air pollution priority areas of some of Gauteng's largest municipalities. Data collection was undertaken through face-to-face interviews, using a questionnaire developed by Sustainable Energy Africa (SEA) in collaboration with the Gauteng Province and Safe Energy (see ANNEXURE 5). Energy data collected included: (1) appliances and fuels used to meet primary household energy requirements; (2) household energy access and affordability; (3) health impacts from household energy use; (4) energy awareness; and (5) perceptions of appliance and fuels used. This data was captured, collated and analysed using Microsoft Excel software. The survey findings informed the Multi Criteria Analysis (MCA) used to identify the most suitable technologies for informal households (Part 3) and the Implementation Plan (Part 4).

The survey was conducted in 48 households, spread across 4 informal settlements in Gauteng. Sample informal communities were chosen based on: 1) location of settlement in air pollution "hotspots" of Gauteng; 2) a relatively representative geographic spread within Gauteng; 3) settlements with a predominant lack of access to electricity. The four settlements selected are:

a) Ramaphosa Informal Settlement in Ekurhuleni Metropolitan Municipality

Ramaphosa is an unelectrified informal settlement located in Germiston, in Ekurhuleni and had 3,043 informal households in 2011 according to Census 2011 (Stats SA 2011). Residents have resided here for at least 5 years in the hope that they will be moved to a permanent location as promised by government (according to personal accounts). Although not much residential coal burning was evident due to affordability constraints, the informal settlement is located close to an industrial area. At the time of the survey thick plumes of noxious black smoke was observed from the nearby scrap metal companies which tend to regularly burn material. Residents were observed burning rubber tyres and electrical wiring (to extract the copper that is sold to earn an income), releasing noxious emissions.

b) Slovo Park in the City of Johannesburg Metro

Slovo Park is a long established unelectrified informal settlement, situated south of Johannesburg, and had 3 112 informal households in 2011 - the highest number of dwellings of the four study settlements (Stats SA 2011). Many illegal electricity connections were observed emanating from a formal building (that was purportedly legally electrified) and from the neighbouring Eldorado suburb. Households used these weak illegal electricity connections for lighting, charging cell phones, powering their television and radio sets. Observed coal use was minimal among households in the area, while wood and paraffin use were prevalent. Households procured wood from wood vendors as well as a municipal dump site located close to the informal settlement.

c) Bophelong Informal Settlement, Emfuleni Local Municipality in Sedibeng District Municipality

Bophelong Informal Settlement in Emfuleni borders the formal township of Bophelong. It is the smallest of the four study settlements comprising 869 households in 2011 (Stats SA 2011). The township is fully electrified, enabling easy access to illegal electricity connections. As a result, the settlement has as mix of unelectrified households and illegally electrified households. Residents collected firewood for free from a site far from the settlement (about an hour's walk) and purchased it from local wood sale outlets (petrol garage and local people who collect and sell).

d) Zenzele Informal Settlement, Randfontein Local Municipality, West Rand District Municipality

Zenzele Informal Settlement in Randfontein is an unelectrified settlement and had 2 156 informal households in 2011 (Stats SA 2011). The community had street lights installed several years ago, however the transformers were vandalized for the lucrative copper contained in the electrical wiring. Since then, there has not been any promise of electrification. No illegal electricity connections were observed in this settlement.

Most of the surveyed households reported that they had moved to Gauteng in search of employment. Residents were mostly men who worked in factories/industries or as contractors, and had brought their families who were mainly unemployed women to tend the homes. These residents came to settle in these informal settlements, so that they could inhabit a space without incurring any rental expenses. Across most of the surveyed settlements, formal and informal small business enterprises have penetrated the low income household market. These businesses/spazas supply several energy sources, including paraffin and candles, as well as groceries. These businesses are predominantly run by immigrants (Somalians, Pakistanis and Ethiopians).

1.3. Survey Findings

The findings of this survey are presented under the following sections:

- Household demographic profile
- Household energy use patterns – for the essential energy services of lighting, cooking and water heating and space heating
- Household energy expenditure
- Appliance use and social acceptance
- Health and safety

1.3.1 Household demographic profile

This section provides a brief overview of the socio-economic status of the surveyed households as background to the household energy use patterns analysed in the study. It describes the households in terms of their size and composition and economic conditions.

Household Composition

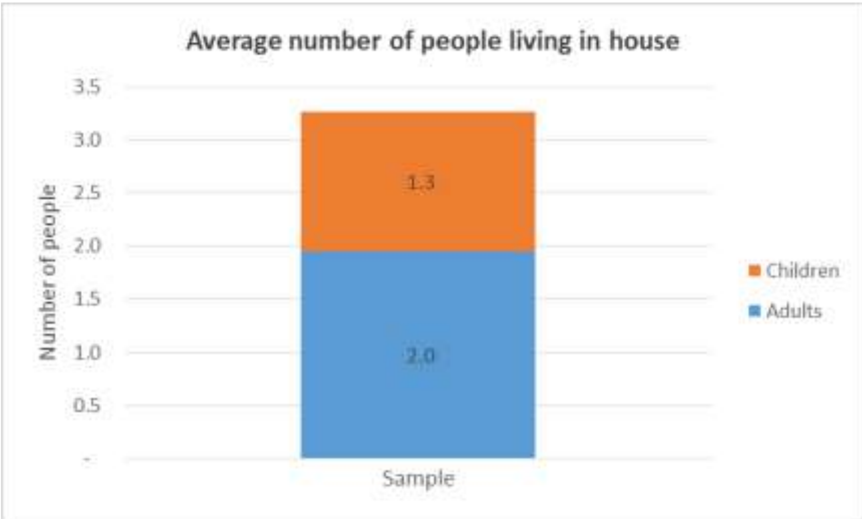

Figure 3: Average household size

The average household size for all the sampled households is 3.1, made up of two adults and one child on average.

Employment

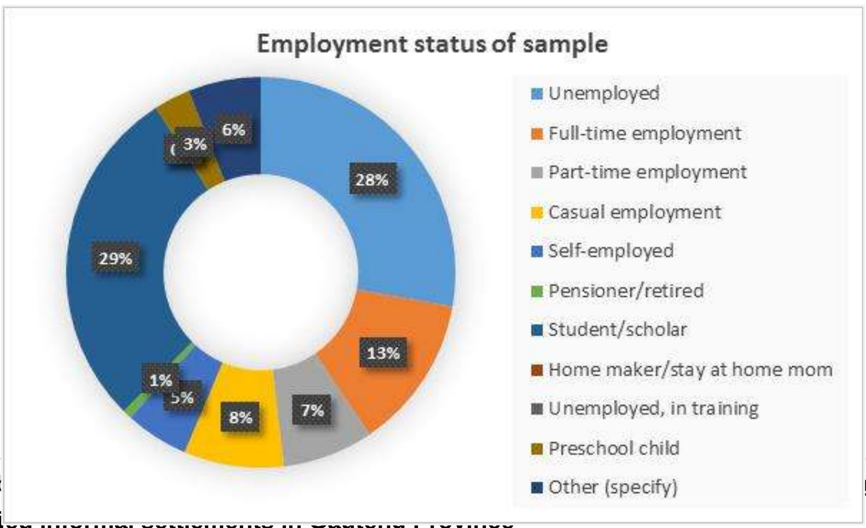

Figure 4: Employment status of informal households

Nearly a third (28%) of sampled households was unemployed (Figure 4). Another third (33%) were engaged in some form of employment. Close to a third of sampled households (32%) were scholars/students and children of pre-school age (Figure 4).

Household Income

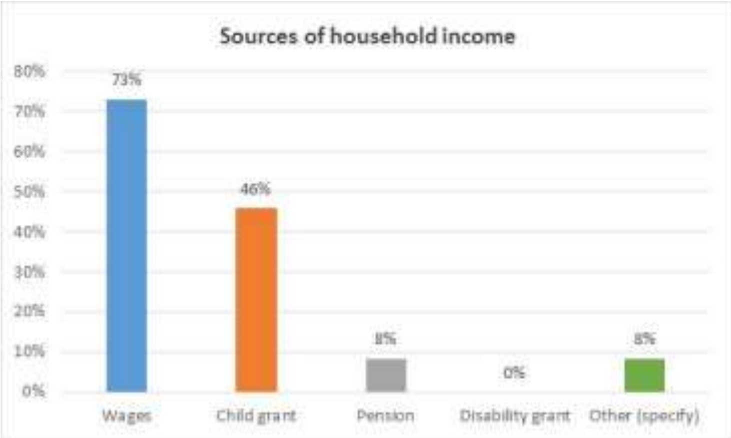

Figure 5: Sources of household income[7]

The survey sought to determine all the sources of income contributing to a household's monthly income, such as wages earned by the various members, child grants, disability grants and/or pensions. The majority of households sampled receive income from wages (73%). Close to half (46%) of all households receive income from child grants and only a very small percentage (8%) of all households receive income from old-age pensions. (Figure 5)

Most households (68%) disclosed monthly incomes within the range of R0.00 – R1 600.00 (Figure 6). According to poverty line benchmarks[8], majority of the surveyed households in this study would be classified as indigent.

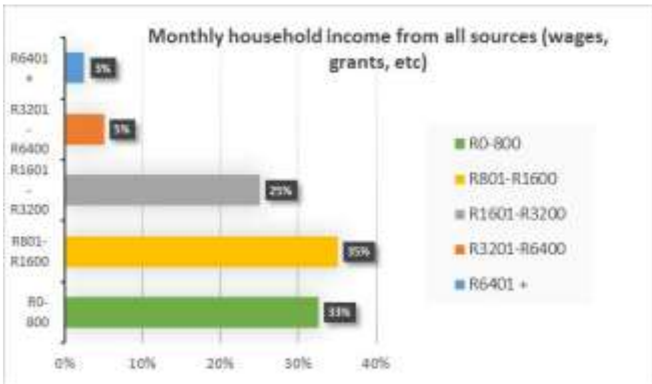

Figure 6: Monthly household income[9]

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[7] Source: Sample survey, SEA and Safe Energy 2015; Census 2011

[8] The poverty line marks the point in income or consumption below which an individual or household is defined as poor. In South Africa, numerous poverty lines have been calculated. The two lines used of households earning less than R1600 per month and less than R3200 are widely accepted poverty thresholds used in South Africa and defined by Leibbrandt et al (leading poverty and development economists of South Africa) in line with internationally recognised poverty line measures. Poor households are defined according to an upper bound poverty line of a monthly R3200 (amounting to R949 per capita in 2008 Rand values) and a lower bound poverty line of R1600 (amounting to R515 per capita in 2008 Rand values).

1.3.2 Household energy-use patterns

This section examines the prevalence and perceptions of different fuels used by the surveyed households to meet their energy service needs. The prevalence of an energy source, conveyed as proportion of households that use it, is a widely used statistic to describe energy use within a household. The information provided includes a comparison of the energy use patterns of surveyed households with Census 2011 household data for the studied informal settlements and with household energy use patterns of the informal settlements across the Province as a whole. The purpose of this comparison is to establish whether the findings are representative of the settlements surveyed and the Province.

Lighting

Candles and paraffin were reported to be the main lighting fuels used by surveyed households in all 4 settlements.

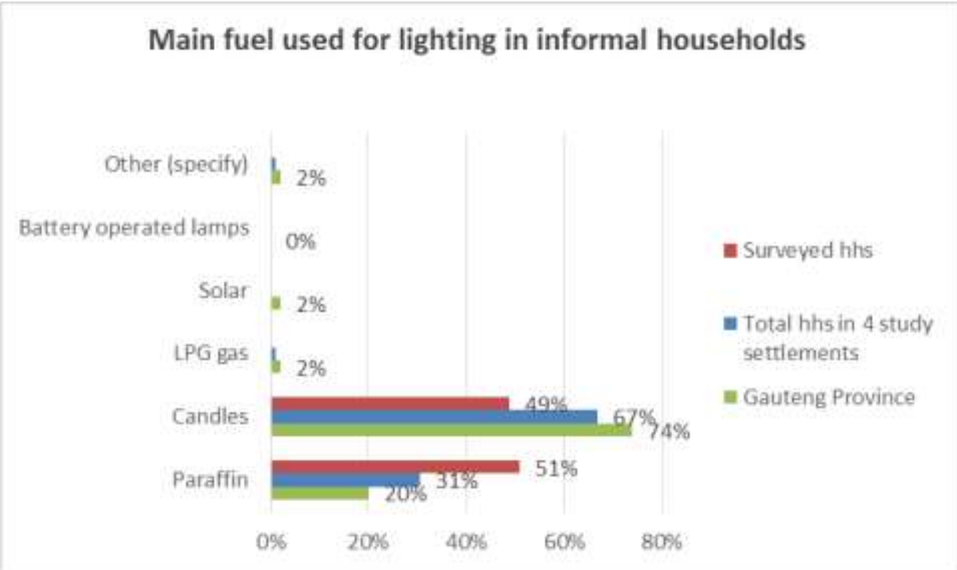

Figure 7: Main fuel used for lighting[10]

While candles and paraffin are the main lighting fuels used by both sampled households and all households across the entire 4 settlements, the proportion of households using candles compared to paraffin differs for these two datasets (Figure 7). There is a higher percentage of households (67%) using candles relative to paraffin (31%) for lighting across all households in the study settlements, whereas the surveyed households show a more even split (48% and 52% respectively). Both the informal households across Gauteng Province as a whole and the survey sample demonstrate a similar trend for candle and paraffin use for lighting - 74% of unelectrified informal hosueholds across the Province while 20% use paraffin (Stats SA 2011). Clean and alternative energy sources such as solar energy are used by a

[9] Source: Sample survey, SEA and Safe Energy 2015; Census 2011

[10] Source: Sample survey, SEA and Safe Energy 2015; Census 2011;8

mere a 2% of these households for lighting across the Province (Stats SA 2011). Similarly, survey results (Figure 7) indicated a zero percent penetration of solar and battery operated lamps as clean energy and safe alternatives to the more polluting traditional fuels.

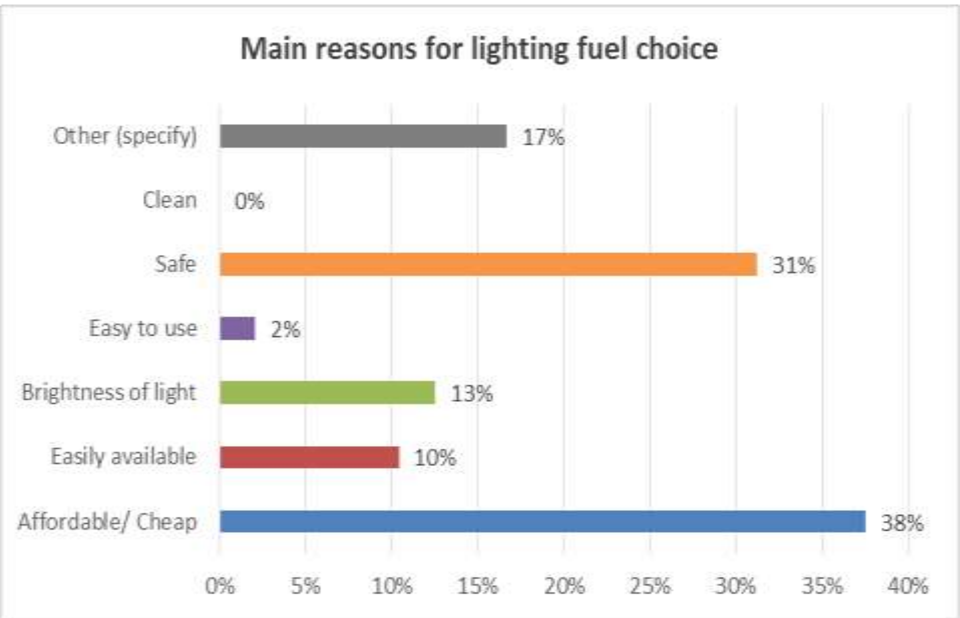

Figure 8: Main reasons for lighting fuel choice[11]

None of the sampled households attributed 'clean fuels' or 'clean technology' as influencing their lighting fuel choice. Over a third of the surveyed households reported 'affordability' or the 'cheapness' of a fuel as key factor driving lighting fuel choices (Figure 8), followed closely by safety (31% of households). Both candles and paraffin lamps pose an enormous fire risk and health hazard for households, and although paraffin lamps are relatively safer, candles are cheaper. With affordability and safety having been identified as the main drivers of fuel choice within the sample, this may explain the equal split between paraffin - as the safer fuel, and candles - as the cheaper option (Figure 7).

[11] Source: Sample survey, SEA and Safe Energy 2015

Cooking and Water Heating

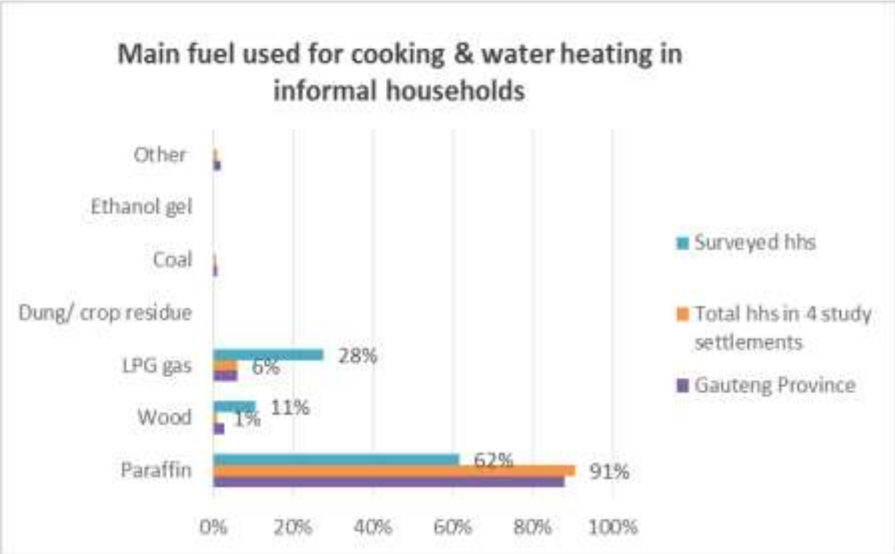

Figure 9: Main fuel used for cooking and water heating in informal households[12]

The survey identified paraffin as the major source of energy for cooking and water heating among the households (61%) (Figure 9). Census data (2011) for all households across the 4 study settlements shows an even greater share (91%) of households using paraffin as a main cooking and water heating fuel. Similar trends emerged for unelectrified informal households across the Province – paraffin is by far the most prominent main fuel used for cooking and water heating by the majority (88%) of unelectrifed households in Gauteng.

Close to a third (28%) of surveyed households use LPG, in stark contrast to 6% of the total settlement population (Figure 9). Similarly across the Province very few households (6%) use LPG as an alternative fuel for cooking or water heating. Surprisingly the use of coal for cooking and water heating was minimal - only 1% or less of surveyed households. Wood was also not widely used. This trend was also evident in the four settlements surveyed. Similarly across the Province, wood and coal are also not very prominent for cooking and water heating with 1% of households using coal for cooking, and 3% using wood for cooking (Stats SA 2011). It is evident from Figure 9 that ethanol gel, a cleaner burning fuel alternative to paraffin, was not used by surveyed households.

[12] Source: Sample survey, SEA and Safe Energy 2015

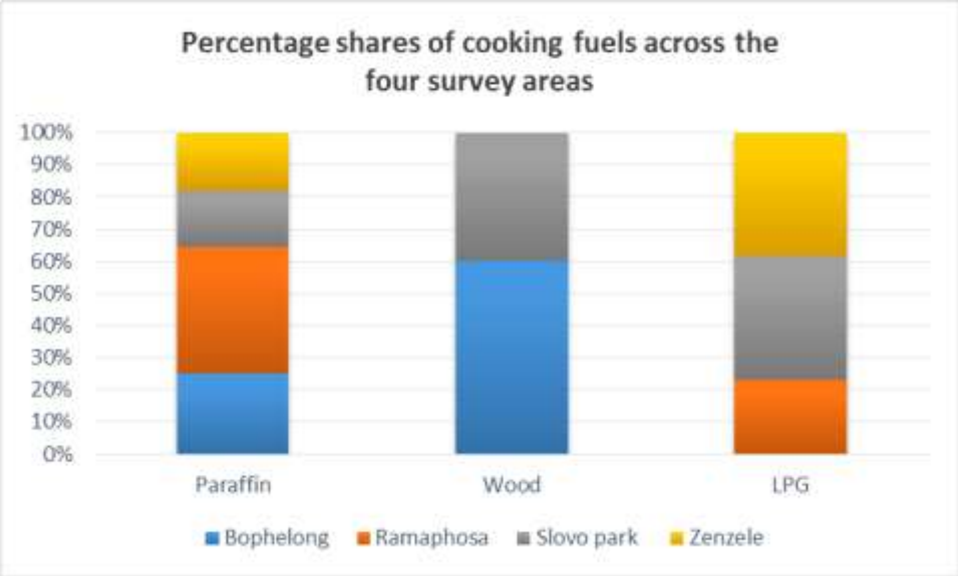

Figure 10: Cooking fuels across the four survey areas[13]

Examining the main cooking fuel used in each settlement (Figure 10), localised trends for the different settlements prevail. For the households surveyed, although paraffin is used in all four settlements, the use of wood is limited to Bophelong and Slovo Park whilst LPG is used in all settlements with the exception of Bophelong. These trends are likely linked to availability and accessibility of the different fuels in each settlement. Although a woodland may be accessible, seasonal and harvesting trends determine the availability of suitable fire wood suitable. A supplier of LPG may be accessible by foot, yet the fuel may not be available when households need it. The interaction between fuel use, availability and accessibility could be explored further in the future.

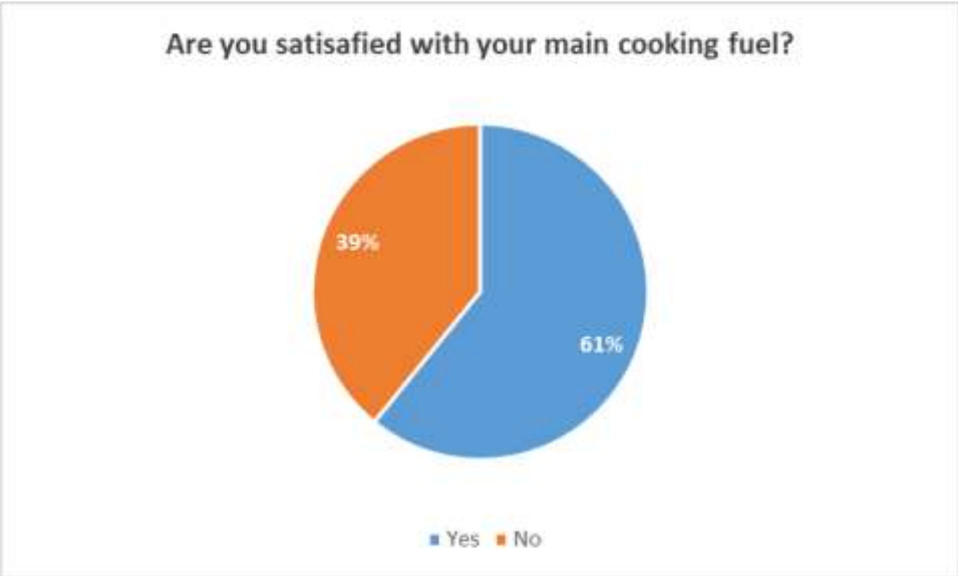

Figure 11: Household satisfaction with cooking fuel[14]

[13] Source: Sample survey, SEA and Safe Energy 2015

61% of respondents reported satisfaction with their choice of cooking fuel, while two-fifths (39%) expressed dissatisfaction (Figure 11). Acquiring insights into household user perception of cooking fuels is essential to the development of appropriate and effective marketing and awareness programmes when rolling out alternative energy technology options to informal households in the future.

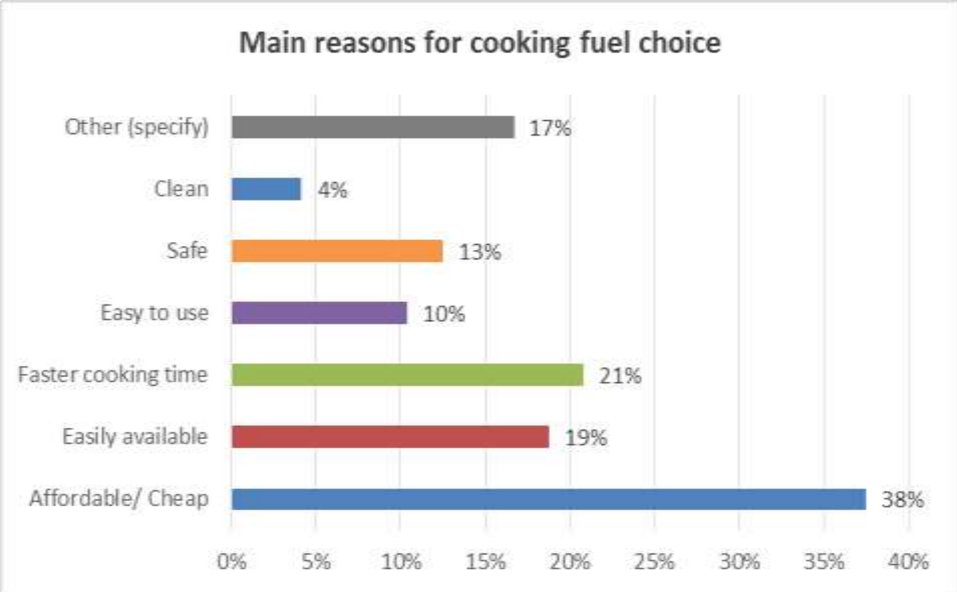

Figure 12: Main reasons for cooking fuel choice[15]

Importantly, 'cleanness' of a technology did not emerge as a key factor influencing household cooking fuel choice in the survey (Figure 12). Most household respondents (38%) reported 'affordability of fuel', 'fuels and technologies that allow for a faster cooking time' (21% of respondents) and 'fuels that are easily available' (19% of households), as key factors influencing their energy choices for cooking. This creates an interesting gap between the objectives of this study, and the potential needs and preferences of users of technologies. With regard to this, it is crucial to note that household satisfaction and acceptability of alternative fuels and technologies are based on a range of factors, including safety, affordability, availability, cooking time and functionality according to user preferences. Although some of these factors are addressed in in this study (affordability, availability, and safety), others are beyond the scope of this feasibility study, and require user engagement and further insight into the local context. This is set out in more detail in the air pollution reduction implementation strategy proposed in Part 4 of this report.

17% of respondents were of the perception that in the absence of electricity access, they lacked better cooking fuel options and were compelled to use dirty fuels to meet their household energy requirements. These households expressed a strong preference for electricity for cooking, if they were electrified.

[14] Source: Sample survey, SEA and Safe Energy 2015
[15] Source: Sample survey, SEA and Safe Energy 2015

Space Heating

The major source of energy used for space heating in surveyed households is wood (44%), followed by paraffin (20%) and coal (16%) (Figure 13). Only 2% of the sample and population use LPG for space heating. Census data for the surveyed settlements, however, show a smaller proportion of wood users (25%) compared to the sample (44%) but usage is still prominent. In contrast, both for the Province and all households in the study settlements, paraffin is the dominant fuel for space heating, used by 41% and 44% of households respectively despite the significant health and safety risk to households. Across the Province, 11% of informal unelectrified households used coal for space heating (relative to 1% who used it for cooking) and 19% used wood for this end-use (relative to the 3% who used it for cooking). This suggests that wood and coal-usage are likely seasonal, and more common in the colder months of the year for winter space heating. The survey confirms that coal is not as prominent as wood and paraffin for space heating.

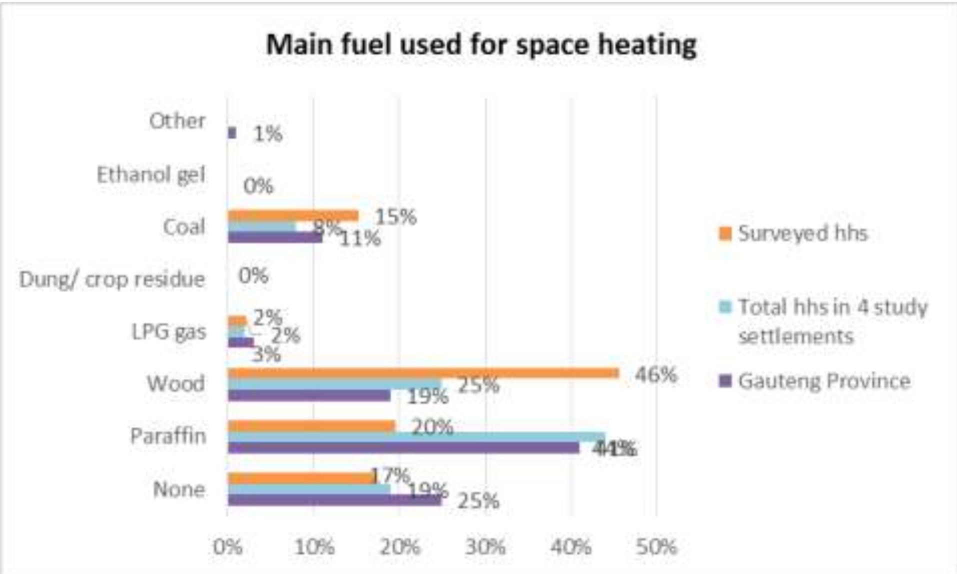

Figure 13: Main fuel used for space heating[16]

A breakdown of the space heating fuel types used by each settlement provides a localised picture (Figure 14). In the survey, paraffin and wood are used in all four settlements for space heating. Coal is used in all except Slovo Park settlement. Slovo Park respondents reported LPG as the only fuel used to meet their space heating requirements.

[16] Source: Sample survey, SEA and Safe Energy 2015

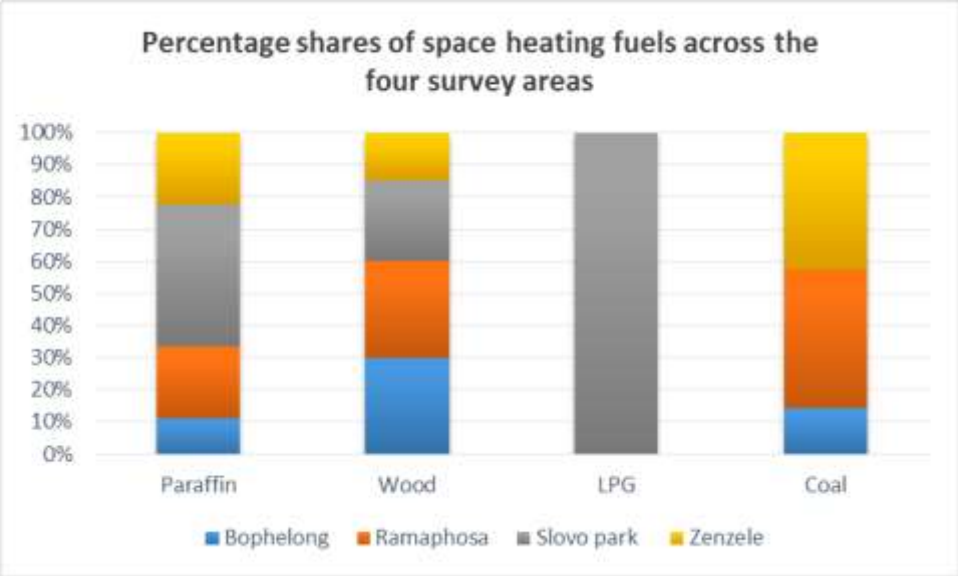

Figure 14: Space heating fuels across the four survey areas[17]

With regard to utility (benefit), 73% of household respondents were satisfied with the use of their space heating fuel. For majority of surveyed households, availability of fuel (40%) and 'affordability of fuel' (33%) were reported to be the key reasons influencing choice of fuel type for space heating (Figure 15). The importance for a fuel to be clean-burning was held by a mere 3% of households as the main reason influencing their fuel choice. Safety issues relating to fuel use was a key driving factor in determining fuel choice for 17% of surveyed households.

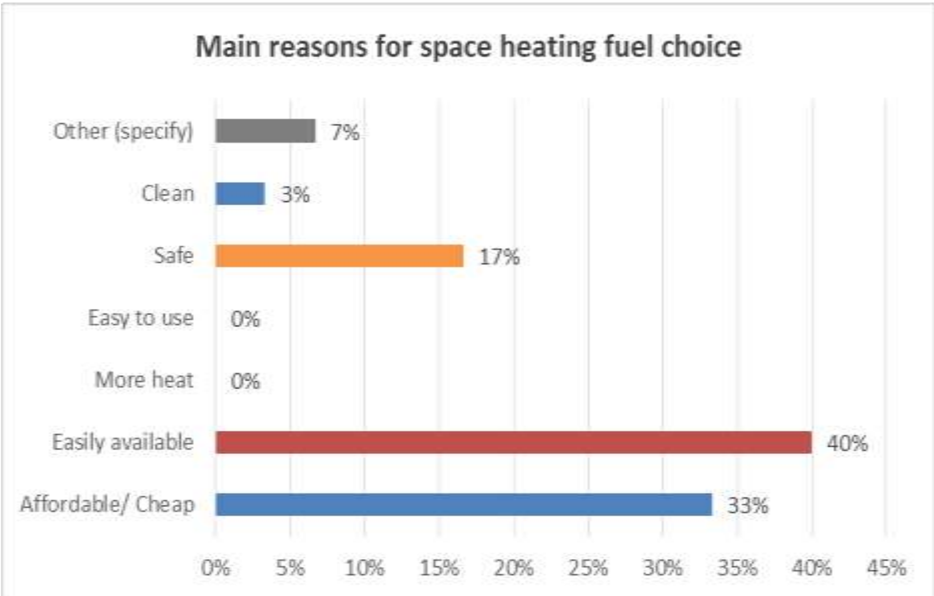

Figure 15: Main reasons for space heating fuel choice[18]

9[17] Source: Sample survey, SEA and Safe Energy 2015
[18] Source: Sample survey, SEA and Safe Energy 2015

1.3.4 Household energy expenditure

This section explores household reliance on different fuels used by examining household expenditure on the different fuel types used and the total energy expenditure, expressed as both a monetary value and as a share of household expenditure.

Energy expenditure features prominently in the economy of low-income households, and generally constitutes a significant proportion of monthly household expenditure (SEA 2015, SEA 2014, Cowan 2003, Eberhard & Van Horen 1995). It has been widely documented that low-income households spend a larger share of their income on energy than wealthier households, often in excess of 10% of their income compared to wealthier households, who typically spend 2-3% (SEA 2015, SEA 2014).

In line with these findings, the sampled households spend a substantial portion of their monthly income on energy. The average household energy expenditure for the sample is roughly R255 per month. For households living on an average monthly income of R800, this would approximate to 30% of their income being utilised for energy expenses. A significant number of households, 17%, spend between R400 to R600 per month on energy (Table 1).

Table 1: Monthly household energy expenditure

Average Monthly Energy Expenditure	Total number of households per category	% share of total sample
R1 - R100	6	13%
R101 - R200	14	29%
R201 - R300	8	17%
R301 - R400	4	8%
R401 - R600	8	17%
R601 - R800	4	8%
R801 - R1000	2	4%
R1001 - R1500	2	4%
Total	48	100%

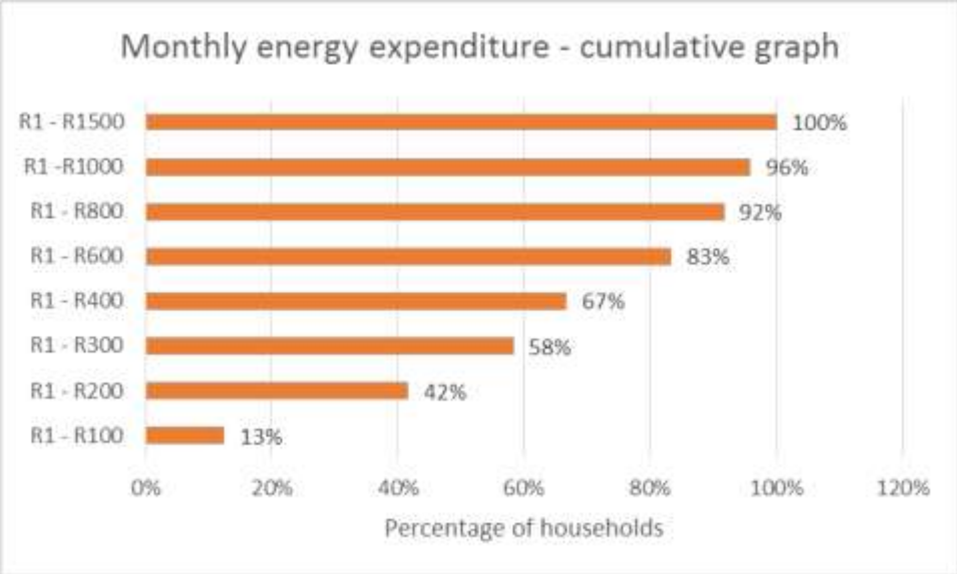

Figure 16: Monthly energy expenditure cumulative graph[19]

Households using candles, make weekly purchases of candles at R2.50 to R3.00 each, and use up to 12 to 15 candles per month (one candle can be used for two days) which costs approximately R45 per month for lighting alone.

Paraffin is purchased either every second day by the litre or in larger quantities of 5 litres (which could last a week) or 20 litres which lasts over a month. Paraffin costs R10/L, so households who use paraffin in large quantities for lighting and cooking, could spend up to R200 per month.

In addition, during the winter months, households purchase wood for space heating whereas in summer they are more likely to collect dry wood for free from surroundings. In winter, there is an additional expenditure on wood at roughly R200.00 for a 'bakkie load'.

The majority of households perceive coal, ethanol gel, solar and LPG as too expensive to be used a main fuel for their domestic energy needs. Affordability emerges as a key factor influencing household energy choices in these densely populated low income communities that were surveyed.

1.3.4 Appliance use

Energy use cannot be considered in isolation of appliances, which transform energy into a useful form to fulfil energy service needs such as cooking. In this process, significant efficiency losses occur and often only a fraction of useful energy is utilised to provide an energy service. The quantity of 'useful' energy harnessed depends on the efficiency of the appliance. Further a dynamic relationship exists between appliance use, the affordability and availability of energy sources and socio-economic conditions of the household (PDC & SCE 2003, Mehlwana & Qase 1999).

[19] Source: Sample survey, SEA and Safe Energy 2015

The majority of surveyed households use a range of appliances appropriate to the different fuels used to meet their cooking needs (Table 2), reflecting the trend in multiple fuel use to fulfil cooking needs. From the survey, majority of households (63%) reported their use of paraffin appliances as the main ***cooking*** appliance, while close to a quarter of households use gas stoves as a main cooking technology (Table 2). 22% of households used a wood stove as an additional cooking appliance, whereas 21% of households preferred to not use the wood mbawulas for cooking.

It is important to note that the high prevalence of paraffin and wood use for cooking evident among surveyed households has serious implications for indoor air pollution and human health and well-being.

Table 2: Survey responses about cooking appliances[20]

Cooking Appliance	Main appliance used for cooking	Other appliance used for cooking	Appliances that households do not prefer to use for cooking
Gas ring & cylinder	4%	4%	8%
Gas stove	24%	4%	16%
Paraffin wick stove	63%	43%	5%
Wood stove	7%	22%	4%
Wood mbawula	0%	9%	21%
Coal stove	0%	9%	5%
Coal mbawula	0%	4%	23%
Other (specify)	2%	4%	0%
Total households	100%	100%	100%

Concerning ***space heating***, most survey respondents (57%) indicated that they use wood/coal stoves to keep warm in cold weather, while 22% of households use paraffin heaters and 11% use wood mbawulas for this purpose (Table 3). The collection and use of the various types of biomass fuels is arduous, the associated technologies/appliances used are inefficient, and the resultant emissions have harmful environmental and health impacts. Nevertheless, over half of the surveyed households expressed a preference for a woodstove, followed by 26% of households favouring a gas heater while 10% favoured a paraffin heater to meet their space heating requirements.

[20] Source: Sample survey, SEA and Safe Energy 2015

Table 3: Survey responses about space heating appliances[21]

Heating appliance	Main appliance used for space heating	Preference
Wood/coal stove	57%	52%
LPG gas heater	3%	26%
Paraffin heater	20%	10%
Wood mbawula	11%	2%
Coal mbawula	6%	0%
Other (specify)	3%	10%
Total households	100%	100%

Awareness of clean energy and technology

Diesel or petrol generators were the most well-known alternative technologies among surveyed households. Yet, many households were not in favour of using these technologies for reasons of high running costs of the generator and its loud noise during operation.

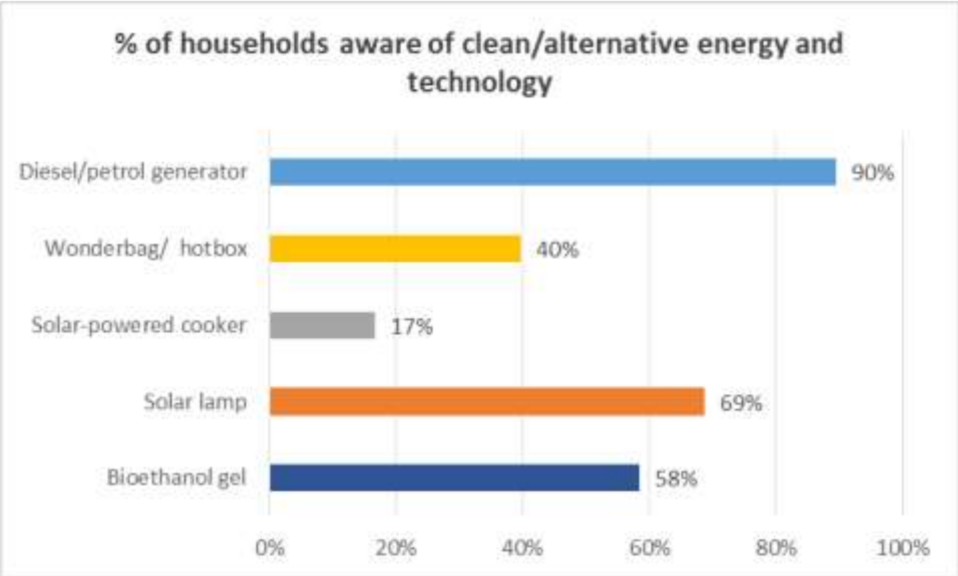

Figure 17: Household awareness of clean energy and technology[22]

The majority of households (69%) were aware of solar lamps as an alternative lighting source. Households mostly had positive perceptions of solar – *"I love it"* and *'It's like electricity."* A number of households were interested in the larger solar home systems that allows for multiple end-uses – such as powering two more lights, radio and cell phones – although affordability was mentioned as a constraint. The households surveyed found these larger solar systems too expensive. The solar

[21] Source: Sample survey, SEA and Safe Energy 2015
[22] Source: Sample survey, SEA and Safe Energy 2015

lamps were considered better than candles and paraffin in terms of safety, but some complained that the light was still 'weak'.

Very few households were aware of solar-powered cookers. This technology is still in its infancy with respect to market penetration and limited to daytime use.

Over half of the households (58%) were aware of bioethanol gel stoves through word of mouth or advertisements in shops. Yet, none of the respondents used the stove and very few had first-hand experience. Negative perceptions about this technology included: "smell not good, worse than paraffin", "gel goes very fast and does not last long", "the gel is not easily available", and "gel is not expensive but the stove parts are expensive".

Although Wonderbags (or hotboxes) have been on the market as a low-cost energy-saving technology for many years, most respondents (60%) were unaware of this technology. The 40% of households who were aware or had experience with it, generally held a positive perception of its energy saving energy food warming properties.

1.3.5 Health and Safety

Affordability emerged as the primary consideration driving fuel choice (for 69% of surveyed households), followed by safety (56%) and availability of fuel (56%) (Table 3).

Table 4: Survey responses to important considerations in fuel choices[23]

F.1 State what you consider to be the three most important characteristics to you from the following list with regard to fuel use?	% share of total sample
Safety	56%
Availability	56%
Clean	31%
Reliability	42%
Affordability	69%

Residents of densely populated informal communities, while they demonstrate an awareness of the adverse impacts of coal and wood use to meet their household energy service needs (Tables 4-6), are compelled to use these "dirty" fuels, as these are the only affordable options available for them.

[23] Source: Sample survey, SEA and Safe Energy 2015

Table 5: Survey responses to biomass smoke and health[24]

E.3 Do you think that smoke from burning coal or wood is a problem for your health?	% share of total sample
Yes	64%
No	36%
Total	100%

Table 6: Survey responses about indoor air pollution[25]

E.4 Do you experience air pollution in your house?	% share of total sample
Yes	72%
No	28%
Total	100%

Table 7: Survey responses about outdoor air pollution[26]

E.6 Do you experience outdoor air pollution in your community?	% share of total sample
Yes	83%
No	17%
Total	100%

1.4. Analysis and Conclusions

This survey provided a snapshot of household energy consumption, needs and perceptions of the four sampled informal and unelectrified settlements in Gauteng province (Bophelong, Ramaphosa, Zenzele and Slovo Park). Survey findings showed a high dependence by unelectrified households on polluting fuels such as wood, candles, paraffin and coal to meet essential domestic energy, resulting in harmful levels of indoor and outdoor pollution. Notwithstanding a few exceptions, survey trends largely reflected similar energy use patterns found in the 2011 Census. Although some localised household energy use trends was observed in the surveyed settlements, which could be related to availability of the fuel source, the survey findings are largely representative for informal households in Gauteng.

As such, strategic decisions regarding the implementation of clean energy use are likely to be applicable throughout the province.

[24] Source: Sample survey, SEA and Safe Energy 2015
[25] Source: Sample survey, SEA and Safe Energy 2015
[26] Source: Sample survey, SEA and Safe Energy 2015

Paraffin was found to be the most prominent fuel used for all three end uses - cooking (61% of households), lighting (52% of households), and space heating (20% of households). Therefore the focus should be on improving/safe, efficient paraffin appliances both for lighting and cooking (including water heating), while the uptake of other safe, clean energy such as solar PV and lamps are steadily explored.

Surprisingly, **coal** did not emerge as a prominent cooking or space heating fuel. Merely 1% or less of households used coal for cooking and water heating in the sample. This could be explained by coal being more expensive and not as easily available relative to wood and paraffin.

Wood was mainly used for space heating (44% of surveyed households) requirements but not widely used for cooking on average. Wood use is prolific (as opposed to coal use), partly because many households have locally made wood stoves inside their shacks, which they use for cooking and space heating. Moreover wood use was easily available in some settlements either through collection from a nearby source for free, or purchasing it at affordable and local prices.

Localised household energy use trends with some differences emerged for the four surveyed settlements; this could possibly be related to availability of the fuel source. Wood is used for cooking only in Bophelong and Slovo Park, but is used as a space heating fuel in all four settlements. LPG is only used in Slovo Park for space heating.

In terms of the penetration of clean technologies, much scope remains for the introduction of these technologies into communities.. Survey findings showed no evidence of the use of solar lamps for lighting and ethanol gel stoves for cooking. Households have, however, expressed an interest in solar lighting, Solar Home Systems (SHS), Wonderbags and to a lesser extent ethanol gel stoves. Affordability was identified as the main constraint to uptake of these technologies. The focus therefore should be on reducing costs to poor households in accessing clean and alternative fuels and technologies. This would be a major step forward for government in improving indoor and ambient air quality.

Another important feature revealed by the survey was the **multiple fuel use** patterns displayed by households. Households rely largely on a range of unsafe and unhealthy forms of energy such as paraffin, wood and coal for different end-uses to fulfil household energy needs – a phenomenon predominant in low-income households of South Africa (but not restricted to poor households). This pattern of fuel use by low-income households better resembles a portfolio of different energy sources at any time, and the varied fuels chosen often depend on budget, need, availability and preferences (i.e. a complexity of social and economic factors determine household fuel use) (Masera, Saatkamp & Kammen, 2000; DoE 2012). Multiple fuel use is not only associated with fuels, but also appliances, which are necessary to transform energy carriers into energy service providers. Eberhard and Van Horen (1995) explain that low-income households usually make energy choices based on “combinations” of appliances and fuels that can satisfy the desired energy services required, subject to households’ availability of resources. The multi-functionality of appliances and fuels is very important for poor households, such as in the case of paraffin, wood and coal stoves, which can be utilised for both cooking and heating.

Affordability emerged as the key driver influencing fuel choice among the majority (69%) of surveyed households. Safety and availability of fuels were also important considerations to households. Households in the sample spend a substantial amount of their income on energy per month. The average for the sample is roughly R255 per month and which constituted as much as 30% of household income spent on energy. The majority of households consider coal, ethanol gel, solar and LPG is too expensive for use as a main fuel.

Survey findings importantly indicated that while affordability played a significant role in determining household energy choice, it was not the sole factor driving energy choices. In terms of energy use, it was observed that residents on the whole lacked an **awareness** of safe, clean and efficient energy options. There was a high prevalence in the use of dirty unsafe energy sources. Residents generally held a strong perception that LPG was an unsafe energy source, particularly among non-LPG users. The few residents who used LPG for household activities however appreciated the value and benefits of LPG use. It is therefore imperative that any alternative clean energy household programme targeted at informal settlements in the Province requires a robust and continuous education and awareness component to ensure sustained adoption of the technology intervention.

The majority of households in Gauteng’s informal settlements live in conditions of poverty, with limited or no ability to afford the use of clean and safe fuel options to meet the primary household energy requirements. As a consequence, households rely predominantly on generally polluting energy sources. Such dependence on these unsafe energy sources, used in combination with inefficient and unsafe appliance, poses life-threatening challenges to the inhabitants of the informal settlements with regard to air pollution and its harmful effects. Households, while they understood the consequences of such energy practices/choices, felt constrained in their choices due to the prevailing conditions of poverty that they endure. Therefore, their energy use preferences were limited. The issues relating to affordability, perception of the cheapest fuels and appliances and awareness are important factors for the Province in dealing with air pollution and poverty. Social acceptability (affordability, availability, safety and user preference) and education form key components of the implementation plan and will need to be held strongly in order to substantially improve air quality and poverty going forward.

Together, Moving Gauteng City Region Forward

A FEASIBILITY STUDY AND AN IMPLEMENTATION PLAN OF ALTERNATIVE ENERGY TECHNOLOGY OPTIONS FOR UNELECTRIFIED INFORMAL SETTLEMENTS IN GAUTENG PROVINCE

2. PART 2: REVIEW OF ALTERNATIVE HOUSEHOLD ENERGY AND TECHNOLOGY OPTIONS FOR UNELECTRIFIED INFORMAL SETTLEMENTS IN GAUTENG

2.1. INTRODUCTION

Part 2 of this feasibility study examines alternative energy technologies and associated energy sources available in the market that are cleaner, appropriate, applicable and sustainable relative to those that are currently available and used by informal households in Gauteng for their domestic energy requirements. This review provides a range of technologies and domestic fuels available in the market, as well as highlights a host of potential suppliers/distributors. Key issues, including technical specification, impacts and risks, pro's, con's, and available social acceptability factors for each of the alternative technology and fuel options are highlighted, serving as a cost benefit and emissions analysis by which options can be compared easily against each other. This information will provide the basis of the assessment of the technologies in Part 3 of this report. Due to the exploratory nature of this study, Part 4 provides a more rigorous decision-making framework to screen the list of technologies identified in this report; to determine the best technologies suited to dense low-income settlements in Gauteng.

2.2. ALTERNATIVE ENERGY TECHNOLOGIES

2.2.1 Overview of Alternative Energy

This review defines 'alternative energy technologies' as those that are not currently mainstream in the informal settlements in Gauteng, and options that present a cleaner or more sustainable energy option for household cooking, lighting and space heating.

Alternative energy refers to energy carriers that are environmentally sound (with little or no undesired environmental consequences) and/or have lower carbon emissions, as compared to the conventional/traditional energy sources. Generally, existing energy sources are based on fossil fuels (i.e. coal, oil), whereas alternative technologies are mainly renewable or waste-derived fuel resources, or better fossil fuel options or practices.

In light of the high levels of residential air pollution caused by domestic fuel-burning of traditional energy sources and an increased consciousness of climate change, alternative energy is becoming an increasingly viable option. Among the key interventions in addressing indoor air pollution is the replacement or retrofitting of current technologies with alternatives that have comparable or better performance, and have improved and complete combustion of fuels, reducing the emission of toxic pollutants.

2.2.2 List of Technology and Energy Options

This section outlines a range of available technology and energy options and is accompanied by detailed considerations of the technical specification, impacts and risks, pro’s, con’s and available social acceptability factors for each technology and energy option.

Table 8 below presents a ‘long-list’ of available traditional and alternative technology and energy options for consideration, including its key characteristics. This includes: (1) the type of household energy service provided by each technology; (2) the capital and operating costs for each technology; and (3) where the technologies can be sourced. This is followed by more detailed information on each technology and in turn informs a more rigorous decision-making assessment (Part 3 and 4) to shortlist the most suited technologies. This is not an exhaustive list, but does include the key technologies that are available in the South African market.

It is important to note that the technologies listed in the table below were selected on the basis of a very general screening related to the appropriateness of the technologies for informal households in the Province. To this end the following were not included:

- Technology options with capital costs in excess of R 1,300.00, which was considered to be too expensive for low-income households.

- Solar water heaters (SWHs), for practical reasons, were not considered notably: 1) flimsy shack structures typical of an informal household are not robust enough to withstand the installation of SWHs on the ‘roofs’ of shacks, and 2) shacks are not likely to be fitted with a reticulated water supply to automatically fill the tank of the SWH. However, SWHs as a longer-term solution should be considered, noting that in the future it is important to support the construction of more robust informal dwellings.

- Bioethanol fuel gel, a paraffin replacement fuel and technology, was introduced into the South African market targeted at low-income households. Experience over time has shown that gel fuel does not adequately meet the energy intensive cooking and heating energy service needs of households due to its low heat content properties. In addition, the fuel proved to be inefficient and expensive for a low-income household. A lack of quality assurance/standardisation certification and accreditation in terms of stove design and fuel manufacturing deemed it not favourable for consideration for this project.

- The safe and cleaner coal burning top-down method, known as the Basa njengo Magogo (BnM) fire-lighting method was a transition method promoted by the Department of Energy ten years ago as part of broader national programme promoting the supply of cleaner, safer and efficient fuels for improved health and well-being of low-income households. The impact of BnM was not adequately monitored for its benefit to be fully proven, despite government’s major funding support to promote this method nationwide for a decade. Given that the impact of this intervention is not known, it was not included for consideration in this report.

Table 8: List of alternative and traditional technology and energy options for domestic energy use

ENERGY SOURCE/TECHNOLOGY	END USES	CAPITAL COST PER UNIT	FUEL COST PER UNIT	AVERAGE MONTHLY OPERATING COST PER UNIT	SUPPLIERS
COOKING					
1. CleanCook Methanol/Ethanol cookstove	• Cooking • Water heating • Partial space heating[27]	R1 100	Variable[28] R5.88 per litre at Rolf Chemicals	R90 per plate (based on consumption rate of 0.171 litres per hour and an average of 3 hours of cooking and water heating per day)	**Appliance Supplier(s):** Veri-Green Solutions (Pty) Ltd. **Fuel Supplier(s):** Methanol distribution is wide and is mainly characterised by bulk distributors that distribute the chemical under the license of Sasol. In Gauteng - Triangle Solvents, TAG Solvents, Rolf Chemicals and Protea Chemicals are large suppliers.
2. Protostar Bhubezi Methanol cookstove	• Cooking • Water heating • Partial space heating	R400	R5.88 per litre from Rolf Chemicals **Or** R7.20 per 500ml (R14.40 per litre) from Proto-Energy	R135 **(**based on consumption rate of 0.5 litres per hour and R5.88 per litre from Rolf Chemicals) or R315 (based on R14.40 per litre sealed container from Proto Energy)	**Appliance Supplier(s):** Proto-Energy **Fuel Supplier:** Proto Energy supplies fuel in 500ml bottles. In Gauteng, Triangle Solvents, TAG Solvents, Rolf Chemicals and Protea Chemicals are larger suppliers.
3. Mbaula Green Wood or Coal stove	• Cooking • Water heating • Partial space heating	R450	No cost if wood is collected from surroundings. If purchased, then R3 per kg for wood, **or** R7 per kg for charcoal.	No cost if wood is collected from surroundings. If purchased, R90 for wood, or R210 for coal. (based on an estimate of 1kg of fuel per day – clay liner of this technology reduces quantity of fuel required)	**Appliance Supplier(s):** Mbaula Concepts (Pty) Ltd. **Fuel Supplier:** Coal available from local coal yards and wood available for free from surroundings and can be purchased from wood vendors.

[27] Although not exclusively a space heating appliance, it does warm up small spaces typical of informal dwellings.

[28] The price of methanol varies with the crude oil price. Sasol is the major supplier of methanol in South Africa, and supplies a number of smaller localised distributors. These distributors have different pricing structures and different exit prices

ENERGY SOURCE/TECHNOLOGY	END USES	CAPITAL COST PER UNIT	FUEL COST PER UNIT	AVERAGE MONTHLY OPERATING COST PER UNIT	SUPPLIERS
4. Eco Zoom Versa Wood/Charcoal stove	• Cooking • Water heating • Partial space heating	R505	No cost if wood is collected from surroundings. If purchased, R3 per kg for wood, **or** R7 per kg for charcoal.	No cost if wood is collected from surroundings If purchased, R90 for wood, or R210 for coal. (based an estimate of 1kg of fuel per day – clay liner of technology reduces quantity of fuel required)	**Appliance Supplier:** Eco Zoom Stove **Fuel Supplier:** Coal available from local coal yards and wood available for free from surroundings and can be purchased from wood vendors.
5. Liquefied Petroleum Gas (LPG) two-plate cooker and cylinder	• Cooking • Water heating • Partial space heating	R1 100	R22.00-R25.00 per kg	R125 per plate (based on 5kg per month)	**Appliance Supplier(s):** Available from major chain stores (e.g. Game) and online stores such as Loot and TakeAlot. **Fuel Supplier(s):** Available at major petroleum/gas outlets such as BP Gas, TotalGas, Easigas, Afrox, Sasol , Reatile Gaz, Solgas, Cadac and local retailers/suppliers within localities.
6. Liquefied Petroleum Gas (LPG) one-plate cooker top and cylinder	• Cooking • Water heating • Partial space heating	R700	R22.00- R25.00 per kg	R125 per plate (based on 5kg per month)	**Appliance Supplier(s):** Available from major chain stores (e.g. Game) and online stores such as Loots and TakeAlot. **Fuel Supplier(s):** Available at major petroleum/gas outlets such as BP Gas, TotalGas, Easigas, Afrox, Sasol , Reatile Gaz, Solgas, Cadac and local retailers/suppliers within localities.
7. Sunstove solar cooker	• Cooking • Water heating	R635	None	None	**Appliance Supplier(s):** Sunstove

ENERGY SOURCE/TECHNOLOGY	END USES	CAPITAL COST PER UNIT	FUEL COST PER UNIT	AVERAGE MONTHLY OPERATING COST PER UNIT	SUPPLIERS
8. The Wonderbag/ Hotbox	• Cooking (par-cooks food through its thermal insulation properties)	Can be self-made with cardboard and newspaper or bought for R100 to R310 per bag	None	None	**Appliance Supplier(s):** Wonderbag, Restio Energy
9. Coal/Wood Mbawula	• Cooking • Water heating • Space heating	None (self-made)	Wood: None if collected from surroundings or R30 per 10kg bag if purchased. Coal: None if collected or R35 per 5 kg bag if purchased.	Wood: None if wood collected from surroundings or at least R180 if purchased (based on at least 60kg of wood per month[29]) Coal: None if collected or at least R280 if purchased (based on at least 40kg of coal per month[30])	**Appliance Supplier:** (Self-made) **Fuel Supplier:** Coal available from local coal yards and wood available for free from surroundings and can be purchased from wood vendors.
10. Coal/Wood cookstove	• Cooking • Water heating • Space heating	R450	Wood: None if collected from surroundings or R30 per 10kg bag if purchased. Coal: None if collected or R35 per 5 kg bag if purchased.	Wood: None if collected from surroundings or at least R180 if purchased (based on at least 60kg of wood per month[31]) Coal: None or if purchased at least R280 (based on at least 40kg of coal per month[32])	**Appliance Supplier:** Small steelwork companies operating in the townships. **Fuel Supplier:** Coal available from local coal yards and wood available for free from surroundings and can be purchased from wood vendors.

[29] Own calculations based on Gauteng Household Survey results. The quantities given in survey were variable, but it can be deduced with high confidence that households who cook daily are likely to use at least 6x10kg bags per month.

[30] Own calculations based on Gauteng Household Survey results. The quantities given in survey were variable, but it can be deduced with high confidence that households who cook daily are likely to use at least 8x5kg bags per month.

[31] Own calculations based on Gauteng Household Survey results. The quantities given in survey were variable, but it can be deduced with high confidence that households who cook daily are likely to use at least 6x10kg bags per month.

[32] Own calculations based on Gauteng Household Survey results. The quantities given in survey were variable, but it can be deduced with high confidence that households who cook daily are likely to use at least 8x5kg bags per month.

ENERGY SOURCE/TECHNOLOGY	END USES	CAPITAL COST PER UNIT	FUEL COST PER UNIT	AVERAGE MONTHLY OPERATING COST PER UNIT	SUPPLIERS
LIGHTING					
11. Portable Nightlight Solar Powered Candle	Lighting	R400	None	None	**Appliance Supplier(s):** Proto-Energy
12. WakaWaka light	Lighting	R400	None	None	**Appliance Supplier(s):** Online stores such as WakaWaka, TakeAlot, Solar-Panel.co.za
13. Solar G3 Lantern light and charger	Lighting	R665	None	None	**Appliance Supplier(s):** Restio Energy
14. Portable solar kit	Lighting	R1 300	None	None	**Appliance Supplier(s):** Solarway, Restio Energy
15. Litre of light	Lighting	R100 for materials and is self-made.	None	R1	**Appliance Supplier(s):** (self-made)
16. Easilite LPG lamp	Lighting	R195	R22.00 - R25.00 per kg	R225 (based on a fuel consumption estimate of 0.060kg per hour[33], for 5 hours of lighting per day)	**Appliance Supplier(s):** Cadac Gas, online stores such as Loots and TakeAlot **Fuel Supplier:** Available at major petroleum/gas outlets such as BP Gas, TotalGas, Easigas, Afrox, Sasol , Reatile Gaz, Solgas, Cadac and local retailers/suppliers within localities.
17. Candle	Lighting	None	R2.50	R37.50 (based on an estimate of 15 candles per month at a rate of a half a candle per day[34], for 5 hours of burning per day)	**Fuel Supplier:** Available from major chain stores (Shoprite) and most local spaza shops.

[33] Cadac provided estimates.

[34] Field research and experiment with candle to determine the combustion rate per hour.

ENERGY SOURCE/TECHNOLOGY	END USES	CAPITAL COST PER UNIT	FUEL COST PER UNIT	AVERAGE MONTHLY OPERATING COST PER UNIT	SUPPLIERS
18. Paraffin lamp	Lighting	R25	R13 per litre	R91 (based on an estimate of 7 litres per month for 5 hours of burning per day[35])	**Appliance Supplier(s):** Available from major chain stores (e.g. Shoprite) and most local spaza shops **Fuel Supplier:** Available from major chain stores (e.g. Shoprite) and most local spaza shops.
SPACE HEATING					
19. LPG heater	Space heating	R1 200	R22.00 - R25.00 per kg	R225 (based on 9kg per month)	**Appliance Supplier(s):** Available from major chain stores (e.g. Game) and online stores such as Loot and TakeAlot. **Fuel Supplier:** Available at major petroleum/gas outlets such as BP Gas, TotalGas, Easigas, Afrox, Sasol , Reatile Gaz, Solgas, Cadac and local retailers/suppliers within localities.
20. Paraffin Heater	• Space heating • Cooking • Water heating	R350	R13 per litre	R260 (based on an estimate of at least 20 litres per month for heating)	**Appliance Supplier:** Available from Shoprite and some Chinese retailers operating in informal settlements **Fuel Supplier:** Available from major chain stores (e.g. Shoprite) and most local spaza shops.

[35] Experiment with paraffin lamp to determine the combustion rate per hour.

2.2.3 Detailed Description of Alternative Technologies and Energy Options

This section expands on Table 8, by providing detailed technical descriptions of energy technologies and energy sources. In addition, it highlights the costs and benefits of each option in relation to the needs of households living in dense informal communities, including: (1) reduced air pollution levels; (2) improved health and safety; (3) affordability; and (4) sustainable energy supply. Although every effort is made to include social acceptability factors such as cooking time and ease of use, despite their overall importance, the limited studies available did not offer sufficient data to include these factors.

COOKING AND HEATING TECHNOLOGIES

#1 Cooking Technology	TWO PLATE METHANOL/ETHANOL STOVE

#1 Cooking Technology	TWO PLATE METHANOL/ETHANOL STOVE

Brand: Veri-Green CleanCook

End-use: Cooking, Water Heating and Space heating

Technical Description:

- Composition: The stove is made up of a stainless steel body, two fuel chambers (canister) with a capacity of 1.2 litres each, and two plates.
- Weight: When the canister is full, it weighs 1.6 kg. When it is empty, the canister weights 0.59 kg.
- Fuel: Ethanol or Methanol
- Calorific value[36]: 22.7 MJ/kg for Methanol
- Cooking hours: 4.5 hours per full canister and at maximum level
- Fuel consumption rate: 0.171 litres per hour, per canister
- Lifespan: 6 – 10 years

Figure 1: Two plate stove *(Above);*
Fuel chamber canister without lid *(Below left);*
Fuel chamber canister with lid *(Below right)*

Costs:

- Capital Cost: R1 100
- Monthly Operating Cost: R180 (R90 per plate based on 3 hours of cooking on each)

Safety for users:

The canisters hold an absorbent mineral fibre covered by a protective mesh metal, preventing fuel from spilling or leaking from it even when the stove is inverted. The flame can be extinguished easily with the regulator.
The refuelling is on the exchange of canisters for safety purposes (to avoid any potential risk of ingestion of the fuel by children or any other hazards).

Emission factor:

CO (carbon monoxide)/CO_2 (carbon dioxide) ratio of 1:0.003, which meets the South African Bureau of Standards specification (less than 2%) for open flame devices permissible for indoor cooking and heating.

Acceptance/Adoption:

There are currently approximately 30,000 CleanCook stoves in circulation in Mozambique, under the local brand NDZiLO. In Ethiopia, there are now nearly 3,000 stoves in circulation in Addis Ababa.

Pros	Cons	Risks	Energy Impacts	Remarks

[36] Calorific value of a fuel is the measure of the amount of heat released during the combustion of a specific amount of the fuel (https://en.wikipedia.org/wiki/Heat_of_combustion).

#1 Cooking Technology	**TWO PLATE METHANOL/ETHANOL STOVE**			
• Safe, clean and more efficient than paraffin • No odours • High calorific value compared to more traditional fuels like paraffin and wood • Sustainable supply of the technology and the fuel • Potential for Small Medium and Micro-sized Enterprises (SMME) development for fuel distribution in canister, since refuelling is on the basis of exchange of canisters that are in easily-manageable sizes • Stove is easy to use • Operating costs are comparable to the going rate of paraffin that is currently in use	• Due to the recent introduction of this fuel on the market, there is a great need to raise awareness of this fuel for household cooking.	• Government financing mechanisms to spearhead SMME development and fuel supply	• High impact on heating/ cooking provision, assuming development and carbon finance	

#2 Cooking Technology	PROTOSTAR ONE PLATE METHANOL STOVE

Brand: Protostar Bhubezi

Technical Description:

- Composition: The stove is made up of stainless steel body, one fuel chamber (tank) with a capacity of 500ml and a single plate.
- Operation: Power is adjusted by moving a small lever to open or restrict these air inlets.
- Fuel: Methanol
- Calorific value: 22.7 MJ/kg
- Fuel consumption rate: 0.250 litres per hour SeTAR test result showed good combustion efficiency.
- Lifespan: 5 years

Figure 2: Protostar Bhubezi Methanol stove and the pre-packaged 500ml bottles of

Costs:

- Capital Cost: R400
- Monthly Operating Cost: R135 **(**Based on consumption rate of 0.5 litres per hour, 3 hours of cooking per day and R5.88 per litre) or R315 (using ProtoStar methanol fuel in sealed bottle of R14.40 per litre)

Safety for users:

The temperature of the stove operation is low, posing no risk of contact burns on the touchable surfaces of the stove, since the temperature remains under 40°C even after continuous operation.

The stove is not easily tipped over, thereby reducing the risk of injuries from fires and spilt liquids and foods. Once refuelled, the stove can be turned over without fuel spillage, further minimising the risk of fires in case of accidents.

Methanol fuel for the Protostar stove is delivered in pre-packaged, sealed 500 ml plastic capsules, minimising the chances of accidental ingestion by toddlers or children.

Emission factor:

CO/CO_2 ratio of 1:0.001, which meets the South African Bureau of Standards specification (less than 2%) for open flame devices permissible for indoor cooking and heating.

Acceptance/Adoption:

Proto Energy started selling their clean cookstoves in February 2012 and opened Proto Energy Malawi in December 2012.

The stove is SeTAR (Sustainable Energy and Research Centre) approved. The SETAR centre, based at the University of Johannesburg, is part of the Global Alliance for Clean Cookstoves.[37] The SeTAR centre specialises in clean cookstove testing.

[37]The Global Alliance for Clean Cookstoves is a public-private partnership hosted by the UN Foundation and aims to save lives, improve livelihoods, empower women, and safeguard the environment by creating a thriving global market for clean and efficient household cooking solutions. The Alliance's 100 by '20 goal calls for 100 million households to adopt clean and efficient cookstoves and fuels by 2020. The Alliance works with a strong network of public, private and non-profit partners to accelerate the production, deployment, and use of clean cookstoves in developing countries. (http://cleancookstoves.org/)

#2 Cooking Technology	PROTOSTAR ONE PLATE METHANOL STOVE			
Pros	**Cons**	**Risks**	**Energy Impacts**	**Remarks**
• Safe, clean and more efficient than paraffin • No odours • High calorific value compared to more traditional fuels like paraffin and wood • Methanol fuel for the Protostar™ is sold exclusively in pre-packaged 500 ml sealed capsules, without any cap or opening, minimising the chances of any child mistakenly opening the container and drinking the contents.[38] • Good existing fuel distribution	• Distribution network is not regulated • The stove is a single plate and this would impact on cooking time	• Ingestion of the fuel by children • There is a risk that impure forms of the methanol fuel maybe sold on the black market at a lower cost, as it is sold in 500ml bottles. This could potentially outcompete SMMEs that would be involved in the rollout of these stoves, as users are likely inclined to purchase fuel through cheaper channels.	• High impact on heating/cooking provision	

[38] SeTAR [Sustainable Energy Technology and Research Centre] University of Johannesburg, 2015. A report of the laboratory test results of the Protostar TM stove. University of Johannesburg. Johannesburg, South Africa. Available at: http://www.proto-energy.co.za/Portals/0/Documents/Protostar-Bhubezi%20Stove%20-%20Final%20Report.pdf

#3 Cooking Technology	MBAULA GREEN COOKSTOVE

Brand: Mbaula

Technical Description:

Figure 3: Mbaula Green Stove

- Composition: The stove is made up of a galvanised or stainless steel base with a ceramic, heat-absorbing liner. It comes with a stainless steel grill and a stainless steel pot spacer.
- Weight: 4.5 kg
- Operation: The unique liner is heated by either wood or charcoal. Once hot, it optimises the heat. The clay liner significantly reduces burning fuel required, which in turn reduces smoke emissions; decreasing costs, carbon footprint and health risks. It is much safer than paraffin or gas stoves and uses only 7-15 pieces of charcoal to cook a meal for a family.
- Fuel: Charcoal, wood or other biomass
- Calorific value: Depends on fuel. Charcoal 29.6 MJ/kg. Wood 14.4 MJ/kg.
- Fuel consumption rate: Depends on fuel – temperature and fuel consumption rate controlled by ventilation lever.
- Lifespan: 10+ years

Cost:

- Capital Cost: R450
- Monthly Operating Cost: None if wood or coal is collected from surroundings.
- If purchased, R90 for wood or R210 for coal (based an estimate of 1kg of fuel per day – clay liner reduces fuel quantity required).

Safety for users: Must be used in ventilated area. Uses burning fuel and is therefore a fire risk.

Emission factor: Charcoal 3.3 kg CO_2e/kg. Wood 1.18 kg CO_2e/kg (Note: these fuels are from renewable sources)

Acceptance/Adoption:

Mbaula Concepts (Pty) Ltd has been selected as a flagship company by the 110% green initiative of the Western Cape Government to replace unhealthy cooking methods with the Mbaula Green. It is also a World Design Capital Project.

The stove is SeTAR (Sustainable Energy and Research Centre) approved. The SeTAR centre (based at the University of Johannesburg) is part of the Global Alliance for Clean Cookstove and specialises in clean cookstove testing.

Pros	Cons	Risks	Energy Impacts	Remarks
• Efficient • Uses familiar and available fuels • Compact and mobile	• Cannot be used indoors • Uses “dirty” fuels that negatively affect air quality	• Is a fire risk if not used safely • Can have significant health impacts if used indoors	• More efficient use of fuels therefore reduces costs and air pollution.	• Efficient stove for fuels that are already widely used and available.

#4 Cooking Technology	ECOZOOM VERSA ROCKET COOKSTOVE

Brand: EcoZoom Versa

Technical Description:

- Composition: The stove is made up of a sheet metal casing with a ceramic, heat-absorbing liner and a cast-iron stove-top. It also has a steel wood support rack.
- Weight: 9 kg
- Fuel: Charcoal, wood or other solid biomass
- Calorific value: Depends on fuel. Charcoal 29.6 MJ/kg. Wood 14.4 MJ/kg.
- Fuel consumption rate: Depends on fuel. 3 small pieces of wood are enough to prepare either 1 kg of rice, 1.5kg of pap or boil 5 litres of water in 20 minutes.
- Lifespan: 10+ years

Figure 4: EcoZoom Versa stove

Costs:

- Capital Cost: R505
- Monthly Operating Cost: None if wood or coal collected form surroundings.
- If purchased, R90 for wood or R210 for coal (based on an estimate of 1kg of fuel per day - clay liner reduces fuel)

Safety for users: Must be used in ventilated area. Uses burning fuel and is therefore a fire risk.

Emission factor: Charcoal 3.3 kg CO_2e/kg. Wood 1.18 kg CO_2e/kg (Note: these fuels are from renewable sources)

Acceptance/Adoption: Mainly rural, off-grid areas where wood is in abundance.

Pros	Cons	Risks	Energy Impacts	Remarks
• Efficient • Uses familiar and available fuels • Compact and mobile	• Cannot be used indoors • Uses “dirty” fuels that negatively affect air quality	• Is a fire risk if not used safely • Can have significant health impacts if used indoors	• More efficient use of fuels, therefore reduces costs and air pollution	• Efficient stove for fuels that are already widely used and available

#5 Cooking Technology	LPG TWO PLATE COOKSTOVE AND CYLINDER

Brand: various brands

Technical Description:

- <u>Composition:</u> The stove is made up of a stainless steel body with two plates. It connects to a separate gas cylinder via a hose and flow regulator.
- <u>Weight:</u> Gas cylinders of 3kg, 5kg or 9kg when full.
- <u>Fuel:</u> LPG
- <u>Calorific value:</u> 61.4 MJ/kg,
- <u>Fuel consumption rate:</u> 5kg (9.52 litres) per household per month for cooking and water heating, roughly 0.108 litres per hour (based on 3 hours of cooking and water heating per day)
- <u>Lifespan:</u> 5 years

Figure 5: Example of Cadac two plate

Costs:

- <u>Capital Cost:</u> R1 100
- <u>Monthly Operating Cost:</u> R125 per plate

Safety for users:
LPGSASA Safe Appliance Approval. Safety is ensured through adhering to safety precautions for careful handling and storage, especially with children around. Gas leaks are possible if regulator lever not closed properly, which poses a risk of explosions.

Emission factor: 1.622 kg CO_2e/litre

Acceptance/Adoption: Mature technology, widely used, particularly in middle - to high-income households.

Pros	Cons	Risks	Energy Impacts	Remarks
• Convenient, clean and relatively safe • High calorific value reduces cooking time significantly. • LPG is a clean burning fuel and reduces indoor air pollution by as much as 90%[39] in comparison to burning traditional fuels • LPG stoves quickly supply heat and work more efficiently than wood and paraffin stoves. The simple and precise regulation simplifies the cooking process and can save time. • Good existing distribution.	• Reliance on distributor and distribution network – does not promote enterprise development through SMMEs/cooperative • LPG tank management is difficult (storage, transportation) due to their sizes. • LPG operating costs are high and are more suitable for the middle- to high-income earning households. • May not be user-friendly.	• Risk of gas tank explosions in the informal settlements that may lead to fatal shack fires IF not properly used. • Distributer cost recovery • Assurance of LPG supply	• Good impact on heating/cooking provision, as well as space heating.	• There is a great need for widespread household education and awareness on the safe and efficient use of this technology.

[39] World Health Organisation (WHO). Health in the Green Economy. http://www.who.int/hia/hgebrief_henergy.pdf

#6 Cooking Technology	LPG ONE PLATE COOKER TOP AND CYLINDER

Brand: various brands

Figure 6: Example of Cadac cooker

Technical Description:

- Composition: The cooker is made up of one plate. It connects directly to a gas cylinder via a flow regulator.
- Weight: Gas cylinders of 3kg, 5kg or 9kg when full.
- Fuel: LPG
- Calorific value: 61.4 MJ/kg
- Fuel consumption rate: 5kg (9.52 litres) per household per month for cooking and water heating, roughly 0.108 litres per hour (based on 3 hours of cooking and water heating per day)
- Lifespan: 5 years

Costs:

- Capital Cost: R700
- Monthly Operating Cost: R125 per plate

Safety for users: LPGSASA Safe Appliance Approval. Safety is ensured through adhering to safety precautions for careful handling and storage, especially with children around. Gas leaks are possible if regulator lever not closed properly, which poses a risk of explosions.

Emission factor: 1.622 kg CO_2e/litre

Acceptance/Adoption: Mature technology, widely used, particularly in middle - to high-income households.

Pros	Cons	Risks	Energy Impacts	Remarks
• Convenient, clean and relatively safe • High calorific value reduces cooking time. • LPG is a clean burning fuel and reduces indoor air pollution (health damaging air pollutants like particulate matter) by as much as 90% compared to burning traditional fuels[40] • LPG stoves quickly supply heat and work more efficiently than wood and paraffin stoves. Simple and precise regulation simplifies the cooking process and can save time. • Good existing distribution.	• Reliance on distributor and distribution network – does not promote enterprise development through SMMEs/cooperative • South Africa sometimes experiences interruptions in the supply of LPG • LPG tank management is difficult (storage, transportation) due to their sizes • LPG operating cost are high and are more suitable for the middle- to high-income earning households • May not be user-friendly	• Risk of gas tank explosions in the informal settlements that may lead to fatal shack fires IF not properly used. • Distributer cost recovery • Assurance of LPG supply	• High impact on heating/cooking provision, as well as space heating	• There is a great need for widespread education of users on how to use the technology safely

[40] World Health Organisation (WHO). Health in the Green Economy. http://www.who.int/hia/hgebrief_henergy.pdf

#7 Cooking Technology	SUNSTOVE

Brand: Sunstove

Technical Description:

- Composition: The stove is made up of a rugged plastic body, with space inside for several cooking pots. The Perspex lid allows light in, but traps heat within the cooker. The cooker works best with black pots.
- Weight: 4.3 kg
- Fuel: Sunlight
- Calorific value: Not applicable
- Fuel consumption rate: Not applicable
- Lifespan: 10+ years

Figure 7: Example of Sunstove

Costs:

- Capital Cost: R635
- Monthly Operating Cost: None

Safety for users: Very safe, needs little supervision

Emission factor: Zero emissions

Acceptance/Adoption: Mature technology, used in many low-income communities globally.

Pros	Cons	Risks	Energy Impacts	Remarks
• Free to operate • Safe • Needs little supervision • Can cook entire meal at once • Provides better air quality indoors, reduces carbon monoxide emissions and cooler temperatures indoors can be enjoyed.	• Relies on the sunlight for cooking (not predictable, can only cook during the day), and also makes it difficult to use during winter months or rainy days • Cooking takes significantly longer than conventional methods • Bulky appliance • Cannot be used indoors	• Food cannot be cooked using this appliance on days that are not sunny – therefore does not allow flexibility as to what part of day household can cook. • There is the risk of food being stolen while it cooks outdoors	• Free to operate, therefore saves significantly on energy costs	• Unlikely to provide all the cooking services needed by households. A backup appliance that operates on another fuel source will be needed when weather is unfavourable or whenever the sun is hidden. • Perceived as slow and unreliable.

#8 Cooking Technology	EFFICIENT COOKING – WONDERBAG/HOT BOX

Figure 8: Example of Stovetec

Brand: Various

Technical Description:

- <u>Composition:</u> The Wonderbag is an insulated cooker made up of two poly-cotton bags filled with expanded polystyrene (EPS) balls, into which a pot of food brought to the boil can be placed. The Wonderbag uses the principle of thermal insulation to continue the cooking process without needing additional heat. EPS is ecologically harmless, contains no chlorofluorocarbons (CFCs) and is fully recyclable.
- <u>Weight:</u> 250g
- <u>Fuel:</u> None
- <u>Calorific value:</u> Not applicable
- <u>Fuel consumption rate:</u> Saves at least 6.5 litres of paraffin per week. Monthly savings: R50 – R75, if used 2-3 times per week
- <u>Lifespan:</u> 3 years

Costs:

- <u>Capital Cost:</u> Can be self-made with cardboard and newspaper, or straw, or bought for R100 to R310 per bag
- <u>Monthly Operating Cost:</u> None

Safety for users: Very safe, needs little supervision

Emission factor: Zero emissions

Acceptance/Adoption: Mature technology, used in many low-income communities globally.

Pros	Cons	Risks	Energy Impacts	Remarks
• Free to operate • Safe and convenient • In the many households where paraffin or coal is used for cooking, a direct improvement in indoor air quality can be expected as does not emit any health damaging pollutants. • Needs little supervision • Low capital cost • Reduces the amount of fuel needed for cooking (estimated to save up to 30% of total fuel costs associated with cooking with paraffin alone) • Good for food that takes long time to cook, such as beans, samp, tripe, rice, stews. • Safe to use • Easy to use • Meals can be safely prepared ahead of time	• Cannot cook all food types, such as steamed bread, pap, and food that requires stirring	• No known risks	• Free to operate, therefore saves on energy costs • Medium impact on cooking provision • High impact on energy efficiency • Saves on cooking time and energy but can be only be used to complement another form of energy	• Unlikely to provide all the cooking services needed by household. Perceived as slow.

• Hotboxes are relatively easy to make, and thus lend themselves to decentralised small business production in low-income areas, and can be made using low-cost, recycled materials.				

#9 Cooking Technology	WOOD/COAL MBAWULA

Figure 9: Typical mbawula stove

Brand: None

Technical Description:

- Composition: The stove is usually made from an old metal drum. Holes are made on the sides enable air circulation and aid burning of material. Some sort of grid or metal sheet is placed on top to provide a cooking surface.
- Weight: Varies
- Fuel: Charcoal, wood or other biomass
- Calorific value: Depends on fuel. Charcoal 29.6 MJ/kg. Wood 14.4 MJ/kg.
- Fuel consumption rate: Temperature and fuel consumption depends on fuel type, moisture content of fuel and air exchange through stove.
- Lifespan: Varies

Costs:

- Capital Cost: None
- Monthly Operating Cost: *Wood*: None or at least R180 if purchased (based on at least 60kg of wood per month). *Coal*: None or if purchased at least R280 (based on at least 40kg of coal per month).

Safety for users: Must be used in ventilated area. Uses burning fuel and is therefore a fire risk

Emission factor: Charcoal 3.3 kg CO_2e/kg. Wood 1.18 kg CO_2e/kg (Note: these fuels are from renewable sources)

Acceptance/Adoption of the Stove: Mature technology, historically widely used in informal non-electrified settlements

Pros	Cons	Risks	Energy Impacts	Remarks
• Uses familiar and available fuels • Very cheap to manufacture • Easy to use	• Not suitable for indoor cooking • Uses “dirty” fuels that negatively affect air quality due to emitting high levels of smoke (harmful pollutants) • Inefficient • Cooking time is much longer compared to electricity or LPG	• Is a fire hazard if not used safely • Smoke inhalation can result in severe respiratory health impacts	• Medium impact on cooking provision • Saves on energy costs (if wood is available for free from surroundings)	• Unlikely to provide all the cooking services needed by household. • Perceived as slow technology for cooking

#10 Cooking Technology	WOOD/COAL COOKSTOVE

Brand: None

Technical Description:

- Composition: The stoves are built in various configurations, but generally consist of a burning chamber with a door to allow more fuel to be loaded. Above the burning chamber is a cooking surface. At the rear of the cooking chamber is a flue where the smoke can escape.
- Weight: Varies. Usually not mobile.
- Fuel: Charcoal, wood or other biomass
- Calorific value: Depends on fuel. Charcoal 29.6 MJ/kg. Wood 14.4 MJ/kg.
- Fuel consumption rate: Temperature and fuel consumption depends on fuel type, moisture content of fuel and air exchange through stove.
- Lifespan: Varies

Figure 10: Typical wood/coal cookstove

Costs:

- Capital Cost: R450
- Monthly Operating Cost: Wood: None or at least R180 if bought (based on at least 60kg of wood per month). Coal: None or if bought at least R280 (based on at least 40kg of coal per month).

Safety for users: Can be used indoors if flue is installed correctly. Uses burning fuel and is therefore a fire risk.

Emission factor: Charcoal 3.3 kg CO_2e/kg. Wood 1.18 kg CO_2e/kg
(Note: these fuels are from renewable sources)

Acceptance/Adoption: Mature technology, historically widely used in informal non-electrified settlements

Pros	Cons	Risks	Energy Impacts	Remarks
• Uses familiar and available fuels • Heats living space during colder seasons • Can be used indoors if installed correctly	• Uses “dirty” fuels that emit health damaging air pollutants and negatively affects indoor air quality • Heats living spaces during warmer seasons	• Is a fire risk if not used safely • Can have significant health impacts if used indoors without an adequate flue and ventilation in the dwelling	• High impact on cooking provision • Saves on energy costs (if wood is available for free from surroundings)	• Often used in low-income settlements, mainly due to low cost of fuel, no need for electricity and familiarity with technology

LIGHTING TECHNOLOGIES

Lighting Technology	SOLAR LANTERNS

#11 **Brand:** Nightlight Solar Powered Candle

Figure 11: Proto Energy's Nightlight Solar Powered

Technical Description:

- Charging hours per day: 5-6 hours in bright sunlight; 8-9 hours if overcast
- Lighting provision: 6 – 7 hours of light
- Light output: 65 lumen (5 candle power[41] or 0.14 lightbulb power)
- Lifespan: 3 – 4 years

Capital Cost: R400

#12 Brand: WakaWaka light

Figure 12: WakaWaka light

Technical Description:

- Charging hours per day: 5 – 10 hours in bright sunlight
- Lighting provision: 80 hours of light
- Light output: 25 lumen (2 candle power or 0.05 lightbulb power)
- Lifespan: 3 – 4 years

Capital Cost: R400

Aceptance/Adoption: Widely rolled out to informal hosueholds by City of Cape Town's Distaster Risk Management Department during times of widespread shack fire disasters.

#13 Brand: Solarway G3 Lantern

Figure 13: Solarway G3

Technical Description:

- Charging hours per day: 8 hours in bright sunlight or from socket in less than 7 hours
- Lighting provision: 20 hours of light on low setting
- Communication: Cell phone charging via one USB port
- Light output: 65 lumen (5 candle power or 0.14 lightbulb power)
- Lifespan: no information available

Capital Cost: R635

[41] As a comparison, 1 candle power produces about 13 Lumens. A 40 W incandescent electric lightbulb produces 450 lumens, therefore 25 lumens of solar is 5% of the light power of an electric bulb or 0.05 lightbulb power.

#14 Brand: Solarway

Technical Description:

- Charging hours per day: 8 hours in bright sunlight
- Lighting provision: 20 hours of light on low setting
- Entertainment and Communication: Dual Cell phone charging via two USB ports, FM radio
- with speaker, headphone socket and volume control
- Light output: Main lantern 165 Lumen (13 Candle Power or 0.4 Lightbulb Power), Detachable lantern
- 42 lumens (3 Candle Power or 0.1 Lightbulb power)
- Lifespan: no information available

Capital Cost: R1 300

Figure 14: Solarway Lantern

Generic details for solar lighting technology

Technical Description:

- Composition: Solar PV module for charging and an LED light
- Weight: Light-weight
- Fuel: None
- Calorific value: Not applicable
- Fuel consumption rate: Not applicable

Monthly Operating Cost: None

Safety for users: Very safe, needs no supervision

Emission factor: Zero emissions

Acceptance/Adoption: Mature technology, used in many low-income communities globally.

Pros	Cons	Risks	Energy Impacts	Remarks
• Free to operate • Safe to use • Needs no supervision • Safer, cleaner and brighter than candles and paraffin lamps • Simple to use • Children can do homework and study at night • Zero emissions • Low maintenance costs (after lifespan, only battery needs to be replaced)	• Much higher capital cost compared to candles and paraffin lamps • Needs sunlight, therefore charging time limited during winter • Operation/management required – to move apparatus indoors at night for lighting and outdoors during the day for charging	• Risk of theft if left unattended or solar panel installed on the roof	• Free to operate, therefore saves significantly on energy costs • Medium impact on lighting provision • High impact on indoor air pollution	• Unlikely to provide all the lighting services needed by household. • Perceived as expensive.

#15 Lighting Technology	A LITRE OF LIGHT

Brand: (Self-made)

Figure 15: A litre of light embedded in shack roof

Technical Description:

- Composition: A plastic bottle (e.g. 1.5 or 2 litre Coke bottles) filled with water and some bleach (to prevent algal growth), is embedded into the corrugated iron shack roof, with the top part of it protruding outside to capture sunlight. The bottom half serves as a light source (commonly referred to as a solar bulb) inside the dwelling. The hole is covered with sealant for weatherproofing.
- Charging hours per day: None, only needs contact with bright sunlight to emit light instantly
- Lighting provision: Only works during the day for as many hours as there is daylight
- Light output: 450 Lumen (35 candle power or 1 lightbulb power)
- Weight: 1.5 to 2 kg
- Fuel: None
- Calorific value: Not applicable
- Fuel consumption rate: Not applicable
- Lifespan: 5 years (if properly installed)

Costs:

- Capital Cost: R100
- Monthly Operating/Maintenance Cost: R1 (R12 bottle of bleach averaged over 12 months)

Safety for users: Very safe, no supervision

Emission factor: Zero emissions

Acceptance/Adoption: Mature technology, used in many low-income communities globally.

Pros	Cons	Risks	Energy Impacts	Remarks
• Free to operate • Safe to use • Needs no supervision • Safer, cleaner and brighter than candles and paraffin lamps • Low maintenance costs • Can be used in shacks that are not well lit, during the day, given that shacks usually do not have windows to allow natural light to stream in.	• Use is limited to daytime only and cannot be used at night.	• There is the risk of falling from the roof and possibly injuring occupants, if not well installed.	• Free to operate, therefore saves on energy costs where daylighting is required • No impact on night lighting but high impact on day lighting • Positive impact on indoor air pollution if daylighting is required	• Does not provide all the lighting services needed by household.

#16 Lighting Technology	EASILITE LPG LAMP

Brand: Cadac

Technical Description:

- Composition: The lamp connects directly to a gas cylinder via a flow regulator.
- Weight: Gas cylinders of 3kg, 5kg or 9kg when full.
- Fuel: LPG
- Calorific value: 61.4 MJ/kg
- Fuel consumption rate: 0.060 kg/hour
- Light output: 1300 lumen (100 candle power or 3 lightbulb power)
- Lifespan: 5 years

Figure 16: Easilite LPG lamp

Costs:

- Capital Cost: R195
- Monthly Operating Cost: R225 (based on a fuel consumption estimate of 0.060kg per hour,
- for 5 hours of lighting per day)

Safety for users:

LPGSASA Safe Appliance Approval. Safety is ensured through adhering to safety precautions for careful handling and storage, especially with children around. Gas leaks are possible if regulator lever not closed properly, which poses a risk of explosions. The lamp has a stay-cool carry handle.

Emission factor: 1.622 kg CO_2e/litre

Acceptance/Adoption: Mature technology, widely used particularly in middle- to high-income households for outdoor or camping activities.

Pros	Cons	Risks	Energy Impacts	Remarks
• High light output, better than candles and paraffin, roughly equivalent to a 100W incandescent lightbulb • Good calorific value • Convenient and relatively safe • LPG is a clean burning fuel and reduces indoor air pollution (health damaging air pollutants like particulate matter) • Good existing supply distribution network	• Reliance on distributor and distribution network – does not promote enterprise development through SMMEs/cooperative • LPG tank management is difficult (storage, transportation) due to their sizes • LPG operating cost are high and are more suitable for the middle- to high-income earning households • May not be user-friendly	• Risk of gas tank explosions in the informal settlements that may lead to fatal shack fires IF not properly used. • Distributor cost recovery • Assurance of LPG supply	• High impact on lighting provision for one-roomed dwellings and households without access to electricity • Fossil fuel, therefore contributes to Greenhouse Gas Emissions (GHG) emissions	• Awareness required for how to use the technology properly to ensure safety

#17 Lighting Technology	CANDLES

Brand: Various
Technical Description:

- Composition: A candle is made up of a central cotton wick, embedded in paraffin wax. Once the wick is lit, it melts the wax and further absorbs and transports the liquid wax to its tip, where it continues to burn as a bright flame together with oxygen.
- Weight: 71g per 25cm long candle (2.84g/cm)
- Fuel: Candle made of paraffin wax (25cm long)
- Calorific value: 42MJ/kg
- Fuel consumption rate: 2.5cm per hour or half a candle a day
- Light output: 13 lumens (0.03 lightbulb power)
- Lifespan: Not applicable

Figure 17: Typical Candle

Costs:

- Capital Cost: R2.50 each
- Monthly Operating Cost: R37.50 each (based on an estimate of 15 candles per month at a rate of a half a candle per day, for 5 hours of burning per day)

Safety for users: Requires high supervision. Poses fire risk.

Emission factor: Around 2.3 kg CO_2e/per kg candle.

Acceptance/Adoption: Mature technology, widely used particularly in middle to high income households for outdoor or camping activities.

Pros	Cons	Risks	Energy Impacts	Remarks
• Low fuel cost compared to solar • Good distribution, high availability and easily accessible • Easy to use	• Low light output • Polluting • Restricts evening activity such as children doing homework • Leaves soot deposits inside dwelling	• Fire hazard • Risk of burns	• Provides households without access to electricity, access to light at a relatively low cost.	• There is need for energy awareness on how to properly use the technology to ensure safety • Does not provide all the lighting services needed by household.

#18 Lighting Technology	PARAFFIN LAMP

Brand: Various

Technical Description:

- Composition: Made up of a glass fuel canister, a wick and glass shield
- Weight: Unknown
- Fuel: Paraffin
- Calorific value: 46.2MJ/kg
- Fuel consumption rate: 2.5cm per hour or half a candle a day
- Light output: 13 lumens (1 candle power or 0.03 lightbulb power)
- Lifespan: 1 year

Figure 18: Typical paraffin lamp

Costs:

- Capital Cost: R25 each
- Monthly Operating Cost: R91 (estimated 7 litres per month for 5 hours of burning per day)

Safety for users: Needs high supervision. Poses fire risk.

Emission factor: 2.58 kg CO_2e/litre

Acceptance/Adoption: Mature technology, widely used particularly in middle- to high-income households for outdoor or camping activities.

Pros	Cons	Risks	Energy Impacts	Remarks
• Low fuel cost compared to LPG • Good distribution, high availability and easily accessible • Easy to use	• Low light output • Polluting • Limits evening activities such as children doing homework • Glass shield breaks easily and needs regular replacing • Leaves soot deposits inside dwelling	• Fire hazard • Risk of burns • Can cause poisoning if ingested (paraffin needs to be carefully stored away in sealed, marked containers) • Noxious fumes can be hazardous • Creates large amounts of moisture if burned indoors	• Provides households without access to electricity, access to light at a relatively low cost	• Awareness strongly required for users on how to use the technology safely

#19 Space Heating Technology	LPG HEATER

Brand: various brands

Technical Description:

- Composition: The heater is made up of a metal housing with the heating elements at the front. The housing holds the LPG cylinder, which connects via a hose and flow regulator.
- Weight: Gas cylinders of 3kg, 5kg or 9kg when full.
- Fuel: LPG
- Calorific value: 94 MJ/m³, k
- Fuel consumption rate: 100g per panel per hour. Roughly 600g of gas per day (two panels on for three hours per day).
- Lifespan: 10+ years

Figure 19: Example of a LPG

Costs:

- Capital: R1 200
- Operating: R225 (based on 9kg per month and using 1 panel per day for 30 days)

Safety for users: LPGSASA Safe Appliance Approval. Safety mechanisms built in. Safety is ensured through adhering to safety precautions for careful handling and storage, especially with children around. Gas leaks are possible if regulator lever not closed properly, which poses a risk of explosions

Emission factor: 1.622 kg CO_2e/litre

Acceptance/Adoption: Mature technology, widely used particularly in middle- to high-income households.

Pros	Cons	Risks	Energy Impacts	Remarks
• High calorific value which heats efficiently • LPG is a clean burning fuel and reduces indoor air pollution (health damaging air pollutants like particulate matter) • Good existing distribution	• Reliance on distributor and distribution network – does not promote enterprise development through SMMEs/Cooperatives • LPG tank management is difficult (storage, transportation) due to their sizes • LPG operating cost are high and are more suitable for the middle- to high-income earning households • May not be user-friendly	• Risk of gas tank explosions in the informal settlements that may lead to fatal shack fires **IF** not properly used. • Distributer cost recovery • Assurance of LPG supply	• Very efficient for space heating provision	• Strong awareness required for the users on how to properly use the technology to ensure safety

#20 Space Heating Technology	PARAFFIN HEATER

Brand: None

Technical Description:

- Composition: The stove is made from mild steel with a paraffin reservoir at the bottom and a heating element with a protective cage above. There is often a cooking plate above the heating element to allow one to heat food or water. Needs to be SABS approved (there are many illegal heaters sold in the market).
- Weight: 3-5 kg
- Fuel: Paraffin
- Calorific value: 46 MJ/kg
- Fuel consumption rate: Depends on stove but approximately 200 ml – 400 ml per hour.
- Lifespan: Varies

Figure 20: Typical paraffin heater

Safety for users: Should be used in ventilated area. Uses burning fuel and is therefore a fire risk. Poison risk if ingested. Creates moisture in confined space when burned. The legal SABS approved appliances usually have a self-extinguishing mechanism in the event of the appliance being knocked over accidently.

Emission factor: 2.58 kg CO_2e/litre

Acceptance/Adoption: Paraffin stoves and heaters are widely used in low-income settlements. They are accessible, familiar and relatively inexpensive to operate.

Pros	Cons	Risks	Energy Impacts	Remarks
• Uses familiar and available fuel • Relatively cheap to purchase and operate • Versatile - also provides for cooking needs	• Requires adequate ventilation • Can be dangerous • Paraffin emits health damaging air pollutants and negatively affects indoor air quality	• Fire hazard • Risk of burns • Can cause poisoning if ingested (paraffin needs to be carefully stored away in sealed, marked containers) • Noxious fumes can be hazardous to human health • Creates large amounts of moisture if burned indoors	• High impact on space heating provision	• Often used in low-income settlements, mainly due to low cost of heater and fuel and household user familiarity with technology

2.3. Net Supplier Map for Alternative Technology and Energy Options

The table below presents a range of operating suppliers/distributors of various household clean energy technologies and energy options highlighted in this report. The list, while not exhaustive and compiled within the short time constraints of this project, provides insight into the actors in the supply and distribution chains of domestic clean energy technologies. Many suppliers listed in the map below are relevant to this GDARD Clean Energy Project, as they have experience in projects and partnerships delivering alternative energy solutions and services to the low-income non-electrified households.

Many of these suppliers/distributors operate as SMME's (Small Medium and Micro Enterprises) and could potentially be suitable partners during the project's implementation. This list was correct as of December 2015, but SMME's are sometimes short-lived. Therefore, it would be in the interest of Province, and for the sustained and successful rollout of clean energy technologies to informal households, to provide support to these businesses to ensure long-term viability, local market leadership, and strengthen local entrepreneurship.

<table>
<tr><th colspan="4">2.3.1 Energy One</th></tr>
<tr><td>Email address:</td><td>grant@energy-one.co.za</td><td>Website:</td><td>www.energy-one.co.za</td></tr>
<tr><td>Contact person:</td><td>Grant Mashile</td><td>Telephone:</td><td>011 482 1069
082 381 3939</td></tr>
<tr><td colspan="2">Physical Address:</td><td colspan="2">11 Frere Road, Parktown, Johannesburg</td></tr>
<tr><td colspan="4">BRIEF COMPANY PROFILE

Energy One is a South African company that develops and supplies alternative energy products for households without access to electricity. The Company's products are based on 30 years' experience in the developmental engineering and manufacturing of consumer electrical products. By providing homes and small businesses that are off the electrical grid with an inexpensive source of power, they offer an opportunity for men, women and children living at the bottom of the income pyramid to improve their lives. Energy-One also offers product specification, quality assurance, safety compliance, and logistics management programs and services.

Energy One has worked in collaboration with Ikhayalami, a non-profit organisation aimed at developing and implementing affordable technical solutions for Informal Settlement Upgrading in South Africa.

Energy-One has been endorsed by the Global Off-Grid Association.</td></tr>
</table>

2.3.2 Three Diamonds Trading 454 - a NAMEC[42] empowered company

Email address:	info@khanyaled.co.za	**Website:**	www.khanyaled.co.za
Contact person:	-	**Telephone:**	087 151 0537
Physical Address		249 Basden Ave, Centurion, Gauteng	

BRIEF COMPANY PROFILE

Three Diamonds Trading 454 is a design engineering, procurement and project development company working in the field of renewable energy, water and waste management. The company is affiliated to the NAMEC association, and has partnerships and projects involved in the solar energy sector. Three Diamonds Trading 454 is a registered supplier of Insele solar lighting solutions.

2.3.3 Insele Solar

Email address:	erni@jcgroup.co.za louwrens@segametsi.co.za	**Website:**	www.insele-solar.co.za
Contact person:	-	**Telephone:**	011 792 5322
Physical Address		Unit 8, 78 Pony Street, Tijger Vallei Office Park, Silver Lakes, Pretoria, Gauteng, 0054	

BRIEF COMPANY PROFILE

Insele Solar provides solar PV charger units, designed for those living in rural and low-income areas without access to electricity. The solar charger unit is a complete solar intelligent battery management system. The unit powers up to 4 bright, low-energy LED lights, which can be fitted to the walls or ceilings of any dwelling. The unit also provides two USB power outputs and one car charger (cigarette lighter) socket. The units are designed and manufactured locally.

2.3.4 LED IQ (Pty) Ltd trading as Khanya LED

Email address:	info@khanyaled.co.za	**Website:**	www.khanyaled.co.za
Contact person:	-	**Telephone:**	087 151 0537
Physical Address		249 Basden Ave, Centurion, Gauteng	

BRIEF COMPANY PROFILE

Khanya LED is a company that provides LED lighting, street lighting, lights retrofitting and re-designing of new and renewable energy solutions. The company is also a registered distributor of Insele lighting solutions.

[42] National Association of Manufacturers in Electronic Components

2.3.5 Litre of Light

Email address:	literoflight.org/contact-us (requires filling in of online form)	**Website:**	www.literoflight.org
Contact person:	-	**Telephone:**	-
Physical Address		-	

BRIEF COMPANY PROFILE

Litre of Light is an international non-profit organization, based in the Philippines, with branches in Switzerland, India and Indonesia. The focus is to provide lighting made of cheap, easily-accessible materials. Their website contains a video on how to make a light out of old plastic bottle filled with water and chlorine. This provides the light equivalent of a 100W bulb during the day within households that are not well-lit. Communities can be trained on how to make their own lights.

2.3.6 Mbaula Green

Email address:	sales@mbaula.co.za	**Website:**	www.mbaula.co.za
Contact person:	-	**Telephone:**	021 438 6003 086 620 0001
Physical Address		9 Petrel Close, Camps Bay, Cape Town	

BRIEF COMPANY PROFILE

Mbaula Green is a supplier of clean cookstoves through various distributors (Outdoor Warehouse, Yuppiechef, TakeAlot, Loot, etc.)

Mbaula Concepts (Pty) Ltd has been selected as a flagship company by the 110% green initiative of the Western Cape Government to replace unhealthy cooking methods with the Mbaula Green. It is also a World Design Capital Project.

2.3.7 Restio Energy

Email address:	-	**Website:**	www.restio.co.za
Contact person:	-	**Telephone:**	021 987 0687
Physical Address		Sales agents located across South Africa	

BRIEF COMPANY PROFILE

Restio Energy has been in operation since 2001. It focuses on the provision of modern energy access to low-income households, through developing innovative delivery models for sustainable energy access and commercialising clean energy products. It is a distributor of products including efficient cookstoves, Wonderbags, solar lights, solar phone and light chargers, and solar lighting systems and power supplies. Sales agent details for various areas can be found on their website.

The company's management has over 15 years of experience in sustainable energy service business models and has worked with various development institutions organisations including the World Bank, United Nations, Millennium Challenge Account, GVEP-I and GIZ, as well as government institutions, the private sector and NGOs in Southern and East Africa.

2.3.8 Proto Energy

Email address:	info@proto-energy.co.za	**Website**:	www.proto-energy.co.za
Contact person:	-	**Telephone:**	011 707 4900
Physical Address		Block C, Ground Floor, Little Fourways Office Park, 1 Leslie Avenue East, Fourways, Johannesburg	

BRIEF COMPANY PROFILE

In 2009, Rudolph de Bruin, an industrialist, Chairman of AMED Private Equity Fund and co-founder of Sephaku Holdings, approached the experienced industrial designer Ken Hall with a request to design a low-cost clean cookstove, the Protostar. Proto Energy since February 2012 has retailed the Protostar clean cookstoves.

2.3.9 Solardome SA

Email address:	-	**Website:**	www.solardome.co.za
Contact person:	-	**Telephone:**	021 886 6321
Physical Address		18 Stoffel Smit Road, Plankenbrug Industria, Stellenbosch, 7599	

BRIEF COMPANY PROFILEs

Solardome SA cc is a long-running (more than 30-year track record) solar hot water system manufacturer, with the majority of manufacturing taking place in Stellenbosch. The company branched out to also supply residential-scale PV and wind turbines, and efficient lighting and fridges.

Solardome SA's focus areas include the establishment of standards for solar water heater (SWH) units and solar water heater training under the National Skills Development programme. It has undertaken market research into installed SWH capacity in the Western Cape (in conjunction with One World Investments and the German government) and has been involved in many commercial and residential projects both nationally and internationally (Namibia, Botswana, Mozambique, St Helena Island, etc.). Installations have taken place in low income settlements and care centres, e.g. Lwandle Hostel SWH Implementation in Khayelitsha Cape Town.

2.3.10 Sol Gas

Email address:	sastri@solgas.co.za	**Website:**	www.solgas.co.za
Contact person:	Sastri Naidu	**Telephone:**	082 324 7942
Physical Address		Sol Gas, No. 7 Stanley Road, Clivale, Bapsfontein	

BRIEF COMPANY PROFILE

Sol Gas primarily retails liquefied petroleum gas (LPG) to the household market. The company is among the largest BEE suppliers within the LPG industry and is the sixth largest member of the Liquefied Petroleum Gas Association of Southern Africa (LPGASA) alongside Totalgas, Easigas, BP Gas, Afrox, and Reatile. Sol Gas was an implementer of Department of Energy's low-income LPG project (initiated in 2006); offering two 6kg cylinders, an LPG heater and a two plate LP Gas stove.

2.3.11 Sunfire Solutions			
Email address:	info@sunfire.co.za	**Website:**	www.sunfire.co.za
Contact person:	-	**Telephone:**	011 646 1939 074 346 9810
Physical Address		Greenside, Johannesburg	

BRIEF COMPANY PROFILE

Sunfire was formed in 2004 by Crosby Menzies after considerable years of experience in the UK. The company deals with solar energy for cooking in South Africa. It also supplies efficient wood stoves and heat-retaining bags.

2.3.12 Veri-Green Solutions (Pty) Ltd			
Email address:	abramphaahla@yahoo.com	**Website:**	-
Contact person:	Abram Phaahla	**Telephone:**	074 411 0423
Physical Address		9 Simon Rd, Witfield, Boksburg, 1459	

BRIEF COMPANY PROFILE

Veri-Green Solutions (Pty) Ltd is a South African-based, BEE level 4 company, specializing in cleaner energy solutions for residential cooking, space and water heating. The company is a distributor of the SABS-approved Methanol/Ethanol CleanCook stoves produced locally in Durban by CleanCook (Pty) Ltd, an off-shoot of Dometic (Pty) Ltd. The CleanCook stove has been adopted by authoritative organizations including the United Nations. This technology has been rolled out in Haiti, Ethiopia, Mozambique, Kenya, Nigeria, Madagascar and Djibouti.

2.3.13 WakaWaka			
Email address:	info@sungridgroup.com talana@sungridgroup.com	**Website:**	za.waka-waka.com
Contact person:		**Telephone:**	021 447 6849
Physical Address		Retail partners can be found here: za.waka-waka.com/retail-partners (they include Outdoor Warehouse, Makro and Kalahari.com amongst others)	

BRIEF COMPANY PROFILE

WakaWaka, founded in 2010, manufactures solar-powered lamps for the low-income and the developing world market. Their distributors are based in various countries (African and other). Proceeds made from selling products at competitive prices are used to make them available to off-grid communities around the world at an affordable rate. Production of both the solar lights and a later product that combines a solar lamp with the ability to charge phones were crowd-funded. Independent research showed that the WakaWaka Light was twice as efficient as any other solar lamp on the market and that the cross-subsidy sustainable business model was successful. This lamp is distributed by the City of Cape Disaster Risk Management, to informal households in times of widespread shack fire disasters.

2.3.14 Wonderbag Company			
Email address:	enquiries@nb-wonderbag.com	**Website:**	www.wonderbag.co.za/Default
Contact person:	-	**Telephone**:	031 536 8220
Physical Address		9 Walter Reid Road, Tongaat Industrial Park, Tongaat	
BRIEF COMPANY PROFILE The Wonderbag Company is a supplier of Wonderbag; a non-electric portable slow cooker. It continues to cook food that has been brought to the boil by conventional methods for up to 8 hours without the use of additional electricity or fuel. For each bag purchased in a developed country, a bag is donated to a family in Africa by the Wonderbag Foundation. The product can be found at various distributors across the country (including Spar, Outdoor Warehouse and others). A list of distributors can be found here: http://www.wonderbag.co.za/Stockists			

2.4. Conclusion

This part of the report presents a range of energy forms and technologies that are available and applicable for low income households in South Africa. The technologies and energy options include:

- traditional solid fuels such as coal and wood;
- liquid petroleum fuels such as paraffin and LP Gas;
- renewable energy such as solar energy technologies in its various forms and derivatives;
- new technologies that are being expanded within the household energy market such as methanol/ethanol stoves and improved wood/coal stoves; as well as supplementary cooking technologies such as the Wonderbag/Hotbox

There is a host of cleaner energy options, with varying costs, potentially appropriate for informal households, as highlighted in the tables in this report. It must be noted that the capital costs of the cleaner energy options will prove to be a hurdle in the uptake by poor households, although in many instances the monthly operating costs are lower, particularly for solar options (see Annexure 5). Technologies using a renewable energy source, such as solar lamps, have the lowest monthly operating costs, which could add to their attractiveness of uptake, but may fail relative to paraffin lamps that have higher operating costs but much lower capital costs (see Annexure 5). Similarly, fuels like wood and coal that can be collected for free from surroundings, where available, also become an attractive option to poor households and stand as a competitor to the more efficient but more expensive cleaner fuels such as LPG cookstoves.

The technologies presented and described in some detail in this report along the lines of technical specifications, costs, pro’s and con’s, impacts and risks have been used to inform the screening of the long-list of technologies to determine the best shortlist for implementation.

A FEASIBILITY STUDY AND AN IMPLEMENTATION PLAN OF ALTERNATIVE ENERGY TECHNOLOGY OPTIONS FOR UNELECTRIFIED INFORMAL SETTLEMENTS IN GAUTENG PROVINCE

3. PART 3: DECISION-MAKING FRAMEWORK FOR THE SELECTION OF TECHNOLOGY OPTIONS FOR UNELECTRIFIED HOUSEHOLDS IN INFORMAL SETTLEMENTS IN GAUTENG

3.1. Introduction

This part of the study develops a decision-making framework to determine the most appropriate household energy technologies for use in dense informal settlements in Gauteng Province in an effort to substantially reduce harmful levels of air pollution. As part of this feasibility study six technology options on alternative energy mix will be identified for: (1) Cooking and heating applications; and four for (2) Lighting and Charging applications. As identified in the earlier sections of this report, there are a host of cleaner household energy options that may be appropriate to implement to reduce air pollution in informal settlements in Gauteng. In order to assess which technology options are the most suitable to achieve the objectives of the study a multi-criteria analysis (MCA) was undertaken. The intention of this assessment is not to provide a restrictive list of 'ideal' technologies, but instead provide a range of technologies that can be employed as a stand-alone technology or paired with other technologies to address indoor air pollution in Gauteng. The technologies are evaluated based on a set of criteria developed with experts from Gauteng Provincial Government.

3.2. A Multi-Criteria Assessment of Technology Options

MCA is a structured approach used to determine overall preferences among alternative energy options where options accomplish several objectives (UNFCCC 2015). This approach has been widely used in technology selection for climate change adaptation and mitigation measures, for example, in the UNDP's Technology Needs Assessment, and by the UK government to develop its air quality policy (DEFRA 2003). The MCA is a decision analysis tool that is also very useful when a single-criterion approach (e.g. a conventional cost-benefit analysis) falls short. This is the case in this feasibility study, as social, health and environmental impacts cannot be assigned meaningful monetary values at this point in time. MCA allows for the inclusion of a full range of criteria including social, environmental, technical, economic and financial criteria (UNFCCC 2015). In the MCA, desirable objectives are specified and corresponding attributes or indicators are identified. The measurement of indicators does not usually consist of monetary valuation, but instead is often used in the quantitative analysis of a wide range of qualitative impact categories and criteria (UNFCCC 2015). Crucially, a range of environmental and social indicators may be developed alongside economic costs and benefits, as it recognises that both monetary and non-monetary objectives may influence policy decisions. MCA provides techniques that allows for comparing different outcomes based on quantitative analysis which takes place through scoring, ranking and weighting.

Concerning this study, the MCA approach assesses each energy technology on a range of weighted criteria. The criteria, weighting and scoring relies to a large degree on 'expert judgement' of the technology in practice, but also on the implementation context. Therefore, the researchers liaised with relevant expert stakeholders in the Gauteng Department of Agriculture and Rural Development to develop the criteria and assign weightings. This is a very important aspect of the process as local expertise enables linking of the features of a technology to their implementation on the ground and the various issues at stake. For example, the air pollution reduction potential of a technology is a key criterion when it comes to fulfilling the objectives of this study. Within this objective, however, the capital cost and running costs of a cleaner energy option are very important criteria for the community as adopters of the technology. At the same time, maturity of technology and rollout costs for government must also be considered when determining the most appropriate options. These are all incorporated in this MCA.

The technologies that will be assessed are:

Thermal energy technologies:

- CleanCook Methanol/Ethanol cookstove
- Protostar Bhubezi Methanol cookstove
- Mbaula Green Wood or Coal stove
- Eco Zoom Versa Wood/Charcoal stove
- Liquefied Petroleum Gas (LPG) two-plate cooker and cylinder
- Liquefied Petroleum Gas (LPG) one-plate cooker top and cylinder
- Sunstove solar cooker
- The Wonderbag/ Hotbox
- Wood Mbawula
- Coal cookstove
- Coal Mbawula
- LPG heater
- Paraffin heater

Lighting and charging technologies

- Portable Nightlight Solar Powered Candle
- WakaWaka light
- Solar G3 Lantern light and charger
- Portable Solar kit
- Litre of light
- LPG lamp
- Candle
- Paraffin lamp

Some technologies that are not considered clean technologies were incorporated in the overall analysis to increase validity of scoring and MCA assessment.

The MCA consisted of four consecutive steps:

- Selection of the criteria against which the technologies will be assessed
- Evaluation of technology options
- Weighting of criteria
- Technology ranking and short-listing cleaner energy technologies

The remainder of this section will discuss each step in the analysis and their results.

3.2.1 Step 1: Selection of criteria

The first step towards the screening for the most appropriate technologies entailed identifying criteria against which each technology was to be assessed. Based on the Scope of Work for this project, an initial set of criteria was developed, which was shared with the project partners and GDARD, the research commissioner. This is an important step in the process, as it ensures that selection criteria:

- Take into account the objectives of the study. It is important that the criteria reflect the project objective which is to undertake a feasibility study and develop an implementation plan for the use of *safe*, *reliable* and *affordable* clean energy and technologies targeted at households in informal settlements in the Gauteng Province to reduce air pollution.
- Are *relevant* to the study areas;
- Are *mutually agreed upon* by project partners. This is important to ensure that the criteria are relevant to the study areas, but also to take a participatory approach to the MCA design based on local expertise.

The joint input in this process led to the identification of twelve criteria, which consist of:

- The **criterion** and a brief description of the criterion;
- The **unit of measurement and type of scale** used to measure the criterion (to ensure comparability of options using the criteria). With regard to this, it is more important to be able to compare options than to have measurement precision; To ensure comparable units, generally a Likert Scale was adopted ranging from low-medium-high;
- The numerical **range** that constitutes the scoring of the technology option against the criteria. In this study this generally ranged from 0-3, to reflect the categories of low-medium-high described above. Including '0' in the range allowed for the absence of an effect or a negative effect to be measured.
- The **preferred value** of the score on a given scale. For example, for some criteria a lower value is better for the outcome (e.g. running costs for users) and in other cases a higher value is preferred (e.g. air pollution reduction potential).

The full list of criteria is shown below (Table 9).

Table 9: List of assessment criteria including unit of measurement, range and preferred value

Number	Criterion	Unit of measurement: Type of Scale	Range	Preferred value
1	**Air pollution reduction potential**	Low-Medium-High	0-3	High
	The potential of a technology to reduce air pollution. Due to the availability of detailed emissions data for some technology options and not for others, a Likert scale was used, such that possible air pollution from a renewable energy source (excluding wood) received a score of 3; air pollution from cleaner modern energy sources a score of 2; pollution from traditional biomass fuels a score of 1, and air pollution from coal a score of 0.			
2	**Running cost for users**	Low-Medium-High	0-3	Low
	The expense for the end-user to run the technology with the appropriate fuel. The Likert scale used consisted of a score of 0 if there are no costs to run the technology; a score of 1 if the costs are less than R100.00 per month; a score of 2 for running cost between R100.00-R200.00, and a score of 3 for R200.00+ per month. For the sake of technology comparison with regard to running costs, it is assumed that energy sources are bought.			
3	**Implementation/rollout cost**	Low-Medium-High	0-3	Low
	The cost for government to implement and rollout the technologies in low-income households in Gauteng. These are assessed based on a scale range from 1-3, due to the absence of detailed implementation costings. A score of 1 signifies limited roll-out costs for government, e.g. largely covering awareness and marketing campaigns, a score of 2 that some government intervention needed with regard to market development and facilitation, and a score of 3 concerns a largely government-driven approach needed for rollout.			
4	**Security of energy supply used by the technology**	Low-Medium-High	0-3	High
	The security of energy supply used by the technology in Gauteng (e.g. LPG, Electricity, wood, solar). A score of 3 represents an unlimited abundance of supply (solar), a score of 2 an energy supply that is widely available, yet not in an unlimited manner, and a score of 1 represents an energy source that is not easily available (e.g. biomass briquettes) or undesirable (e.g. coal).			
5	**Potential to expand supply in Gauteng**	Low-Medium-High	0-3	High
	The potential to expand the supply in Gauteng based on availability of the energy source in combination with marketing the technology. A score of 1 signifies a supply that is not easy or desirable to expand (e.g. technologies using wood); a score of 2 that some issues may emerge if demand increases substantially (e.g. LPG which has been experiencing availability issues in South Africa); and a score of 3 that there is ample potential to expand the energy supply of this particular energy source.			
6	**Versatility of application**	Number of applications	0-3	High
	The potential uses of the technology. The criterion is measured by the number of applications a technology has with a maximum of three. The options consisted of cooking, heating, lighting and charging.			
7	**Initial capital outlay required by users**	Low-Medium-High	0-4	Low
	Capital outlay required by users to start using the technology. The Likert scale for this criterion ranges from a score of 0 for a freely available or self-made technology with no costs for the materials, a score of 1 for up to 300 rand capital costs; a score of 2 for 301-600, and a score of 3 for 601-900, and a score of 4 for 900+.			
8	**Safety for users**	Low-Medium-High	0-3	High
	The safety of the technology for users. Most technologies come with a range of safety features and issues. This criterion is assessed based on a general estimation of the safety risk associated with the technology relative to other technologies and is considered accumulative. A score of 0 was given if the technology posed a significant air pollution health risk[43]; a score of 1			

[43] The score of 0 was added because technologies that aggravate air pollution and the health problems go directly against the objectives of this study

Number	Criterion	Unit of measurement: Type of Scale	Range	Preferred value
	was given for technologies with a high risk of shack fires and explosion; a score of 2 for limited fire and explosion potential but posed a risk for poisoning if handled incorrectly; and a score of 3 for technologies with negligible safety concerns, e.g. solar lanterns.			
9	**Technology maturity and accessibility**	Experimental-Emerging-Well established	0-3	High
	The immediate accessibility for users to the technology based on the maturity of technology and ease of gaining access to the technology. The scores range from 1 for a relatively new technology that is not easily available over the counter (and, for example needs to be bought online or in a speciality shop) , a score of 2 for a more matured technology and a score of 3 for a widely available over the counter product available at most supermarkets and spaza shops or self-made.			
10	**Energy efficiency of the technology**	Low-Medium-High	0-3	High
	This refers to the overall energy efficiency of the technology. The range adopted for this criterion includes high fuel consumption of the technology, to energy saving technologies and those fuelled by an unlimited supply of energy. Considered most efficient is energy derived from renewable sources. Although wood is a renewable source, it is not considered as energy efficient, because it causes significant deforestation. A score of 3 signifies a highly efficient energy technology such as one fuelled by a renewable, unlimited energy source; a score of 2 an energy source that compared to traditional and non-improved efficiency technologies uses less energy; and a score of 1 for inefficient technologies.[44]			
11	**Lifespan of the technology**	Low-Medium-High	0-3	High
	The overall lifespan of the technology. The scoring was based on a short life span of less than a year, scored as 1; a lifespan between 1-5 years was scored as 2; and a life span of more than 5 years was scored as 3.			
12	**Technology complexity**	Low-Medium-High	0-3	Low
	In light of the technologies assessed having different levels of complexity, this was considered in the analysis. This scale was assessed on a general estimation of the technology's complexity level as a move away from the most traditional ways of achieving the technology's function (e.g. cooking, heating, lighting), towards more complex technologies that generally use modern energy services. A score of 1 was awarded if the technology was largely based on a traditional technology, e.g. a cookstove that has an adapted design to be more efficient. A score of 2 represents a technology that moves away from the traditional shape of the technology and incorporates other energy sources to function and provide the energy service required (e.g. an LPG stove). A score of 3 represents a more sophisticated technology design that involves (generally) electronics and a total move away from the traditional source (e.g. solar lantern).[45]			

In the next steps, each clean energy technology option was assessed against these criteria.

3.2.2 Step 2: Evaluation of technology options

The purpose of this step is to evaluate each option based on the criteria set in the previous step. The technology information sheets (in Part 2 of this report) formed the primary input for this step, and based on the data revealed in these sheets, more

[44] Technologies that are energy efficiency based (e.g. wonder bag) and that only operate when there is daylight (e.g. litre of light) are scored as 2 because they reduce consumption of other sources of energy.
[45] Note that this criterion regards the complexity of the technology itself, not the ease for people to use the technology

detailed parameters of the criteria were set. Depending on the units and scales selected in the previous step (Table 9), a score was assigned to each option. This score reflects how it performs in relation to the particular criterion. Given that most of the scores are based on Likert scales, the relative differences in consequences for each option were carefully considered.

Based on the above, each technology option was scored against each criterion (Table 10&13)

Table 10: Option evaluation for cooking and heating technologies

Colour key	
Green	Performs well
Yellow	Performs relatively well
Orange	Performs less well
Red	Performs poorly

Option/Criterion	Air pollution reduction potential	Running cost for users	Implementation/ roll-out cost	Security of energy supply used by the technology	Potential to expand supply in Gauteng	Versatility of application	Initial capital outlay required by users	Safety for users	Technology maturity and accessibility	Energy efficiency of the technology	Technology lifespan	Technology complexity
Units Preferred value	0-3 High	0-3 Low	0-3 Low	0-3 High	0-3 High	0-3 High	0-4 Low	0-3 High	0-3 High	0-3 High	0-3 High	0-3 Low
CleanCook Methanol/Ethanol Cookstove	2	1	2	2	3	3	4	2	1	2	3	2
Protostar Bhubezi Methanol Cookstove	2	2	2	1	3	3	2	2	1	2	2	2
Mbaula Green Wood or Coal Stove	1	1	2	1	1	3	2	0	2	2	3	1
Eco Zoom Versa Wood/Charcoal Stove	1	1	2	1	1	3	2	0	1	2	3	1
Liquefied Petroleum Gas (LPG) two-plate cooker and cylinder	2	2	1	2	2	3	4	1	3	2	2	2
Liquefied Petroleum Gas (LPG) one-plate cooker top and cylinder	2	2	1	2	2	3	3	1	3	2	2	2
Sunstove Solar cooker	3	0	2	3	3	2	3	3	1	2	3	2
The Wonderbag/ Hotbox	2	0	2	2	2	1	2	3	2	2	2	1

Option/Criterion	Air pollution reduction potential	Running cost for users	Implementation/ roll-out cost	Security of energy supply used by the technology	Potential to expand supply in Gauteng	Versatility of application	Initial capital outlay required by users	Safety for users	Technology maturity and accessibility	Energy efficiency of the technology	Technology lifespan	Technology complexity
Coal or Wood Mbawula	0	2	1	1	1	3	1	0	3	1	1	1
Coal or Wood Cookstove	0	2	1	1	1	3	2	0	3	1	1	1
LPG heater	2	3	1	2	2	1	4	2	3	2	3	2
Paraffin Heater	0	3	1	3	3	1	4	0	3	1	3	2

Table 11: Option evaluation for lighting and charging

Option/Criterion	Air pollution reduction potential	Running cost for users	Implementation/roll-out cost	Security of energy supply used by the technology	Potential to expand supply in Gauteng	Versatility of application	Initial capital outlay required by users	Safety for users	Technology maturity and accessibility	Energy efficiency of the technology	Lifespan of the technology	Technology complexity
Units Preferred value	0-3 High	0-3 Low	0-3 Low	0-3 High	0-3 High	0-3 High	0-4 Low	0-3 High	0-3 High	0-3 High	0-3 High	0-3 Low
Portable Nightlight Solar Powered Candle	3	0	2	3	3	1	2	3	1	3	2	3
WakaWaka light	3	0	2	3	3	1	2	3	2	3	2	3
Solar G3 Lantern light and charger	3	0	2	3	3	2	3	3	1	3	2	3
Portable Solar kit	3	0	2	3	3	3	4	3	1	3	2	3
Litre of light	2	0	1	3	3	1	1	3	3	2	1	1
LPG lamp	2	3	0	2	2	1	1	2	2	2	2	2
Candle	0	1	0	3	3	1	1	0	3	2	1	0
Paraffin lamp	0	1	0	3	3	1	1	0	3	2	3	1

3.2.3 Step 3: Weighting of criteria

This is a crucial step in the MCA and its purpose is to assess weights of each criterion to reflect its relative importance to the decision. To achieve this, input was sought from Gauteng Province to ensure that the complete set of weights represented the relative importance of each criterion to the decision based on the GDARD's priorities. The GDARD team established in a participatory manner the weightings for the set of criteria, based on an intra-team discussion. They were asked to allocate a budget of 100 points (a full 'pie' with 100 'slices') to divide between the twelve criteria. The complete set of weightings is shown in Table 12.

Table 12: Allocation of budget and criterion weights

	Criterion	Allocation of budget (total = 100)	Weight (%)
1	Air pollution reduction potential	15	15%
2	Running cost for users	10	10%
3	Implementation/roll-out cost	10	10%
4	Security of energy supply used by the technology in Gauteng (e.g. LPG, Electricity, solar)	10	10%
5	Potential to expand the energy supply in Gauteng	5	5%
6	Versatility of application/amount of potential uses (e.g. lighting, heating, cooking, etc)	5	5%
7	Initial capital outlay required by users	5	5%
8	Safety for users	10	10%
9	Immediate accessibility for users/maturity of technology	12	12%
10	Energy efficiency of the technology	5	5%
11	Lifespan of the technology	3	3%
12	Technology complexity	10	10%
	Total allocated	**100**	
	Budget usage	**OK**	

The table shows that some criteria are considered more important than others, and three rough weighting categories can be distinguished:

<u>Key criteria</u>

In line with the objectives of the study, the air pollution potential criterion was weighted most heavily at 15%. Yet, the immediate accessibility and maturity of technology ranked also highly with 12%. These criteria will be more than average contributors to the technology ranking.

<u>Mid-range criteria</u>

Majority of criteria fell in the middle and were considered quite important at 10%. These included:

- Running cost for users;
- Implementation/roll-out cost;
- Security of energy supply used by the technology in Gauteng;
- Safety for users; and
- Technology complexity.

These criteria will still have relatively high influence on the final ranking.

Peripheral criteria

The final five criteria, although considered important enough to be part of the assessment, will have a small influence on the final outcome of the process. They include:

- Potential to expand the energy supply in Gauteng
- Versatility of application/amount of potential uses (e.g. lighting, heating, cooking, etc)
- Initial capital outlay required by users
- Energy efficiency of the technology
- Lifespan of the technology

The weighting was then applied to the table in "ANNEXURE 2: MCA results for cooking and heating applications" and "ANNEXURE 3: MCA results for lighting and charging."

3.2.4 Step 4: Technology ranking and shortlist of cleaner energy technologies

The final step in the MCA processes consisted of a comparison of the weighted scores, and identification of the six highest scoring technology options. Before discussing the shortlist of cleaner energy technologies it should be noted that this analysis is based on a criteria list largely from the perspective of the Gauteng Provincial Government, which balances multiple objectives in decision-making. It is important to engage in a similar exercise with end-users as part of the implementation framework that accompanies this assessment, as they are an important stakeholder that must be consulted on the criteria they consider important and the weight they assign to these. For example, it is highly likely that low income households will prioritise affordability of the energy source and quality of the energy service provided, when making energy choices or add a criterion on cooking time and convenience of use. This, however, is an additional process that must take place that is beyond the scope of this study. Some of these shortcomings will be briefly addressed at the end of this section.

Cooking and Heating Technologies

Table 13 shows that to reduce air pollution in informal households in Gauteng, low cost technologies using energy from renewable sources is preferred, as well as energy reducing technologies. These are followed by technologies using cleaner burning fuels such as LPG, Methanol and Ethanol. The least beneficial technologies consist of the traditional and dirty fuels such as coal, wood and paraffin. The Protostar Methanol cookstove uses a cleaner burning fuel, but the technology scored particularly poor because of the lack of maturity of both the technology and the fuel canisters used in the stove. Such issues would have to be addressed in rollout processes.

Table 13: Option scores and shortlist of highest scoring technologies for cooking and heating

Option scores	Weighted Score
CleanCook Methanol/Ethanol Cookstove	34,7
Protostar Bhubezi Methanol Cookstove	26,7
Mbaula Green Wood or Coal Stove	31,5
Eco Zoom Versa Wood/Charcoal Stove	25,5
LPG two plate cooker and cylinder	42,8
LPG one plate cooker top and cylinder	45,3
Sunstove Solar cooker	55,5
The Wonderbag/ Hotbox	53,5
Coal or Wood Mbawula	31,5
Coal or Wood Cookstove	29,0
LPG heater	39,2
Paraffin Heater	25,0

	Ranking of options	Weighted Score
1	**Sunstove Solar cooker**	**55,5**
2	**The Wonderbag/ Hotbox**	**53,5**
3	**LPG one plate cooker top and cylinder**	**45,3**
4	**LPG two plate cooker and cylinder**	**42,8**
5	**LPG heater**	**39,2**
6	**CleanCook Methanol/Ethanol Cookstove**	**34,7**
7	Mbaula Green Wood or Coal Stove	31,5
8	Coal or Wood Mbawula	31,5
9	Coal or Wood Cookstove	29,0
10	Protostar Bhubezi Methanol Cookstove	26,7
11	Eco Zoom Versa Wood/Charcoal Stove	25,5
12	Paraffin Heater	25,0

Based on the agreed set of criteria of this study, the six highest ranking options for cooking and heating applications are:

No. 1: Sunstove solar cooker[46]. This cooker scored high largely because it is a renewable energy cooking application, and cooking is an energy intensive activity. In addition, because solar energy is an unlimited source of energy, this added to its success in the analysis. However, it should be noted that this technology has other drawbacks that were not possible to include in the analysis, e.g. the social acceptability of the technology and the quality of the energy service it provides. For example, although the solar cooker runs on a free energy source, cooking takes a long time and only operates during the day. For people in employment that do not have the opportunity of time to oversee their cooking for the lengthy cooking period, this poses a constraint. Issues of social acceptability and level of energy service supply are briefly discussed later.

No. 2: Wonderbag/Hotbox. The Hotbox or Wonderbag, despite the fact that it is not directly a cooking or heating device, scored very high in this analysis because it is a low cost energy saver that is safe and widely available. People are even able to construct their own device. With relatively limited implementation or roll-out costs, this technology would be well-suited as an 'intermediary' solution to air pollution reduction. If people, for example, cannot afford to invest in another cooking technology immediately, the hotbox could significantly reduce the amount of dirty fuels required to prepare a meal. However, it should be noted that this technology cannot function on its own to achieve the household's complete cooking needs, as it cannot heat food independently and relies on other heating sources to initiate the cooking process. Nevertheless, if paired with another technology such as LPG cookers, ethanol and methanol stoves, this technology could make a significant contribution to reducing air pollution.

No. 3-5: LPG using technologies including: a) one plate cooker top and cylinder; b) LPG two plate cooker and c) LPG heater. The third and fourth highest scoring options are LPG cookers because the energy source, although not free, is widely available, has a long lifespan, and is relatively affordable and efficient. Although the one plate cooker performed better than the two-plate cooker in the MCA, due its lower purchase cost, it is highly likely that users prefer a stove that allows for multiple dishes to be cooked

[46] In 1996 a comprehensive 6 year-long Solar Cooker Field Test Programme was undertaken jointly by the Department the Energy (formerly known as the Department of Minerals and Energy) and GIZ (formerly known as GTZ) which explored the development impact of solar cookers (Wentzel & Pouris, 2007). If solar cookers are to be considered for rollout in Gauteng Province, it is important to read the conclusions and lessons learnt documented in the report on the Solar Cooker Programme.

simultaneously (e.g. pap and stew). The LPG heater also falls in this category as it uses the same fuel as the cooking devices, and in some cases, food can be kept warm or even prepared on this technology. The LPG using technologies are therefore solid performers that do not require extensive rollout and implementation costs. A key issue with this technology, however, is that to expand the energy supply in informal settlements in Gauteng safety measures will need to be implemented to maintain secure storage and distribution of the fuel.

No. 6: CleanCook Methanol/Ethanol Cookstove. This technology, although requiring high initial capital from users, is also a technology that has significant potential to reduce indoor air pollution. As with the LPG two plate cooker, this technology is end-user friendly and its social acceptability is likely to be high.

No 7: Mbaula Green Wood or Coal Stove. This technology was added to the highest scoring cooking applications that were assessed in this MCA because the Wonderbag/Hotbox technology, technically speaking, is not a cooking technology as it needs to be applied alongside another technology that heats the food. The Green Wood or Coal Mbaula, because of its low complexity, maturity and lifespan of technology scored high. Although this technology performs poorly on the key objective of this study, that of identifying technologies that reduce indoor air pollution, its potential significance should not be understimated compared to 'traditional' Mbaula's and in combination with Wonderbag or Hotbox technology.

Compared to the lighting and charging technologies, the range of scores for cooking and heating applications is quite narrow, which means that small changes in criteria weightings could result in a different top six. For example, if one takes away the 'renewable energy' benefits of the Solar Cooker and the advantages of the Hotbox, both LPG and Methanol/Ethanol applications would become high performers. As stressed earlier, the shortlist of technologies is not intended to be restrictive in the approach taken by Gauteng Provincial Government in the implementation of an air pollution reduction strategy. Instead, the range of technologies together allows for several technologies to be considered dependent on the available human, environmental and financial resources available at a particular point in time.

It is therefore highly advisable that before rollout and implementation of cleaner technologies the end-users are involved to allow for social acceptability of the technology options and ensure that the technologies chosen reflect user preferences with regard to quality and of the energy service provided and user friendliness of the technology. Social or public acceptance is generally defined, as a positive attitude towards a technology or measure, which leads to supporting behaviour if needed or requested, and the counteracting of resistance by others. Elements of social acceptance include: awareness of the problem and knowledge of the technology; fairness of the decision-making process; an overall evaluation of costs, risks and benefits of a technology; the local context in which a technology will be used; and trust in decision-makers and other relevant stakeholders (Climate Policy Info Hub 2015). In-depth study of these factors was beyond of the scope of this research (and is very much specific to the local context).

Lighting and Charging Technologies

Table 14 shows the four highest-ranking options against the agreed set of criteria.

Table 14: Option scores and shortlist of highest scoring technologies for lighting and charging

Option scores	Weighted Score
Portable Nightlight Solar Powered Candle	59,8
WakaWaka light	65,8
Solar G3 Lantern light and charger	60,7
Portable Solar kit	61,5
Litre of light	73,7
LPG lamp	42,5
Candle	58,7
Paraffin lamp	58,3

	Ranking of options	Weighted Score
1	**Litre of light**	**73,7**
2	**WakaWaka light**	**65,8**
3	**Portable Solar kit**	**61,5**
4	**Solar G3 Lantern light and charger**	**60,7**
5	Portable Nightlight Solar Powered Candle	59,8
6	Candle	58,7
7	Paraffin lamp	58,3
8	LPG lamp	42,5

No. 1: A Litre of Light is a simple no-fuss, low cost technology that allows natural sunlight to penetrate a shack's rooftop and illuminate the interior of a shack during the day. Although this technology may at first not seem to contribute much to reducing indoor air pollution, because it can only operate during the day, the technology has a very low cost and will be easy to rollout in informal settlements. For example, an information and awareness campaign would go a long way, in which the quick energy savings are demonstrated and people are taught how to install the technology (or even be assisted in this process). This technology would suit deployment alongside a technology that can be used at night.

No. 2: WakaWaka Light, because of its use of solar energy, has a high potential in informal settlements to reduce indoor air pollution. This technology has already seen an implementation and rollout in the City of Cape Town. A large benefit over the Litre of Light is that this technology operates at night-time. It is also important to note that this technology whilst it offers the lowest light output (as measured in Lumens) compared to the other solar lanterns options, it exceeds that of the candles by a factor of 2.

No. 3: Portable Solar Kit. This technology will be a valuable contribution to energy technologies used in informal settlements because of its multiple functions, including a USB charger for cell phones and other small appliances. The reliance of the technology on a renewable energy source increases its potential contribution to reducing indoor air pollution significantly. However, due to the high costs of this technology, it is possible that the provincial or local government would need to play a larger role in the implementation and rollout process, e.g. through subsidies, loans or other financial instruments to support the poor in informal settlements to afford the technology. As a consequence of this, it is more likely that people would buy the fourth ranked technology, the Solar G3 Lantern Light and Charger, which also allows for multiple applications.

No. 4. Solar G3 Lantern light and charger. The lantern is the technology that has by far the most light output, and has multiple applications, including charging. Its detachable additional 'light' enhances usability. Although the technology is less mature than some of the others and requires more initial capital outlay by users, the technology may be favoured by end-users. However, end-user engagement will have to establish this as this is context dependent, e.g. based on available capital.

Similarly to the thermal energy applications, it is of critical importance to engage end-users to ensure social acceptability of the technologies prior to implementation, as they might prefer technologies with higher initial capital cost but that have high lumen characteristics. This engagement process will ensure that the technology options reflect user preferences with regard to quality/level of the energy service provided and user friendliness. To illustrate the importance of this: The WakaWaka light is an affordable solar powered technology which, based on the set of criteria applied in this study, can contribute significantly to reducing air pollution in low income settlements in Gauteng.

3.3. Conclusions from Multi-Criteria Analysis

The MCA conducted as part of this study identified the highest scoring technologies to inform the decision-making framework for the selection of technology options for households in informal settlements in Gauteng.

Based on the criteria and weightings identified by the researchers and experts from Gauteng Provincial Government, key 'promising' technologies were identified for each group of technologies:

Cooking and Heating:

1. Sunstove solar cooker
2. Hotbox/Wonderbag energy saving technology
3. LPG one plate cooker top and cylinder
4. LPG two plate cooker top and cylinder
5. LPG heater
6. CleanCook Methanol/Ethanol Cookstove
7. Mbaula Green wood or Coal stove

Lighting and Charging:

1. Litre of Light
2. WakaWaka Light
3. Portable Solar Kit
4. G3 Solar Lantern

These technologies can be implemented as a stand-alone strategy, but also in combination, e.g. an LPG cooker with the Wonderbag technology, and the Litre of Light with a solar application.

Although it would have been desirable to engage in this same process with end-users of the technology, to explore in-depth the social acceptability and end-user preferences due to time and budget restraints this was not possible. To ensure that these issues are considered in the MCA, several of the key social acceptability issues that emerged from the survey were incorporated in this analysis, including: affordability, safety and accessibility, alongside lifespan of the technology and versatility of application. For many technologies highlighted in this study, little is known about people's preferences for a particular technology over the other and the trade-offs members of the public make, e.g. with regard to the light output (lumen) of a technology or cooking time. Scant data was available for the suite of technologies considered to provide a comprehensive and reliable assessment of a) cooking time; and b) convenience of use. Therefore, notwithstanding this shortlist of technologies, it is recommended that an MCA based on criteria and weightings developed by end-users accompany this study. This is important, as end-users may have additional criteria that need to be considered to ensure successful and widespread air pollution reduction in informal settlements in Gauteng. Such a study will complement the expert and government driven set of criteria and will ensure a strategy that is highly tailored to local circumstances.

Together, Moving Gauteng City Region Forward

A FEASIBILITY STUDY AND AN IMPLEMENTATION PLAN OF ALTERNATIVE ENERGY TECHNOLOGY OPTIONS FOR UNELECTRIFIED INFORMAL SETTLEMENTS IN GAUTENG PROVINCE

4. PART 4: IMPLEMENTATION PLAN

unelectrified informal settlements in Gauteng Province

GAUTENG PROVINCE
AGRICULTURE AND RURAL DEVELOPMENT

4.1. INTRODUCTION

It is clear from the feasibility study that the energy needs of informal settlements, particularly households without access to electricity requires Province's attention and prioritisation. It is unlikely that universal access to electricity will be achieved within the Province before 2025 which is the date set by the National Department of Energy for the country. In view of this and in light of the adverse effects of the continued use of unsafe fuels, and the poor air quality of the province, Gauteng Province has commissioned this study to determine the least costly and safest alternative energy forms for non- electrified informal settlements. An analysis of alternative and safer fuels was considered and this was followed by a multi-criteria analysis which indicated the most advantageous technologies for the Province based on accessibility, cost, safety and improved air quality levels. This section provides a high level implementation plan for the rolling out of those appliances and fuels. Whilst the multi-criteria analysis is a scientific tool which identified the top six technologies, these are not cast in stone nor are they necessarily applicable to all municipalities over time. The intention of the implementation plan is to provide for local contextual factors to be incorporated in the roll out of technologies, allowing for changes in technologies, in costs and in the context of the province as well as the country.

This implementation plan is in line with Gauteng Province's intention to transform to a sustainable energy future.

> *"As modern cities are defined by their energy mix, so are they increasingly defining the energy mix of nations. As the frontline of the developmental state in South Africa, cities must forge the next generation of energy security solutions in real-time, building innovative approaches to meeting present energy needs which begin to future-proof our energy systems" (Parks Tau, Executive Mayor City of Johannesburg, 2015).*

The purpose of the project is to meet the energy needs of poor households in Gauteng province without access to electricity and safe energy sources and in doing so to positively impact on the health of those households and the overall air quality of the Province. To this end the intention is to develop an implementation plan for the roll out of the alternative energy interventions identified through the feasibility study that incorporates sustainability, local economic development and the involvement of SMMEs.

This implementation plan has established a set of high level targets and draws on the core principles of the Gauteng Integrated Energy Strategy that was developed for the Province in 2010. The detailed action plan does not include dates as these will be established by the Steering Committee as the Implementation Plan rolls out.

This implementation plan has not been developed through key stakeholder engagement processes nor the communities themselves and it is recognised that this would be the next step in finalising such a plan to ensure that all stakeholders buy into creating a sustainable energy province. It is only then that the plan will succeed.

4.2. A Clean Alternative Energy Vision for Informal Households in Gauteng Province

The proposed alternative energy vision for informal households in Gauteng Province is:

> *A Gauteng province that facilitates the use of alternative energy technologies for informal settlements that are safe, clean and affordable and reduces the negative impacts of air pollution on human health and the general environment.*

4.2.1 The Future of Energy in Gauteng

Gauteng province undertook to develop an integrated energy strategy and implementation plan in 2010. If the objectives of the strategy are fully implemented by 2055, Gauteng would show a markedly different development path that would ensure energy for all in an equitable and environmentally sound way.

To this end by 2055, Gauteng will have a modern energy system that is highly efficient and where fossil fuel use and energy poverty are markedly reduced. Gauteng will be powered by a low carbon economy with a significant share of national "green jobs", where citizens have accessible, affordable, safe and efficient energy services that do not impact on the health of people or the environment.

The Department of Agriculture and Rural Development have built on this strategy by undertaking a feasibility study on alternative energy and technologies and an implementation plan. The intention being to assist poor households that do not have access to electricity to meet their energy needs and at the same time impacting on their health through changing the air quality. Collaboration and cooperation between the Province and the local authorities will be required in implementing the Plan.

4.2.2 Proposed Alternative Energy Targets

Action	2016	2020	2025
Stakeholder engagement process:			

Action	2016	2020	2025
• Provincial government • Local government • Communities • Civil society • SMMEs, suppliers and business			
Finalise implementation plan with selected suppliers			
Awareness raising, educational plan developed and rolled out			
Roll out of efficient technologies		50%	100%
Electrification			100%
Free Basic Alternative Energy subsidy rolled out to informal households		60%	100%

4.2.3 Current National Targets

Action	Target	Year	Source
A national target for energy efficiency improvement	12%	2015	Energy Efficiency Strategy of the Republic of South Africa, Department of Minerals and Energy, March 2005
Residential Sector Final Energy Demand Reduction	10%	2015	
Renewable energy target: 10 000 GWh (0,8 Mtoe)	4%	2013	White Paper on Renewable Energy Policy, November 2003
Electrification targets (universal access)	100%	2025	Department of Energy, INEP 2013
GHG emissions reduction	PPD	2030	National GHG inventory, DEA 2013, INDC, DEA 2015, NCCRWP, DEA 2011

4.2.4 Direction, Principles and Approach

The Gauteng Department of Agriculture and Rural Development has undertaken a feasibility study and developed an implementation plan for the use of safe, reliable and affordable clean energy and technologies targeted at households in informal settlements in the Gauteng Province. This study arises out of the serious need to address dangerously high levels of indoor and ambient air pollution prevalent in dense low-income settlements in Gauteng. The use of safe, affordable, 'clean burning energy technologies and energy sources would not only substantially reduce the risk of fires and indoor air pollution, but will also contribute vastly to improved ambient air quality.

The role of province is to facilitate the co-ordination of energy supply and protect environmental and human health use through managing air quality and ensure the implementation of national policy at the local level. According to current legislation, province has particular roles and responsibilities which will enable it to play a facilitating role in terms of the implementation plan. But to give real effect to the implementation plan, areas must be identified where the province can use its competency and where local government can assist in the roll out of the technologies.

Gauteng province through GDARD will provide leadership and be the driver, promoter and co-ordinator of the plan.

4.3. Implementation Plan

4.3.1 Vision to Action

The implementation plan consists of four pillars or enablers which are fundamental to transforming the vision into action. Stakeholder engagement is crucial for transforming vision into action, and therefore, relevant stakeholders must be engaged in each pillar. Each one is important in its own right, but implementation of all elements is key to successfully transforming the vision into action which ultimately puts Gauteng in line with national goals of providing for its citizens, reducing poverty and moving towards a cleaner and low-carbon economy whereby poor air quality is no longer a threat to citizens.

The four pillars include firstly an institutional, governance and leadership pillar which underpins and enables the plan to function. The second pillar will relate to financing and funding the project. The third pillar involves working with the local municipalities in rolling out the appliances and fuels through the suppliers and SMMEs.

Determining roles of the different key players will form part of this pillar. A final pillar will involve the awareness and education of the community in terms of cost and safety and will involve key NGOs and CBOs.

The plan is premised on the following key goals:

- GDARD to provide the leadership and institutional framework required to drive the implementation plan forward.
- Support the move towards a clean and low carbon economy.
- Air quality is improved in informal settlements in line with ambient air quality standards
- Prioritise access to safe, clean and affordable energy.
- Develop and grow the alternative and energy efficiency industry as a critical aspect of Gauteng's economy.
- Build a robust community awareness and engagement

4.3.2 Institutional and Strategic Leadership

Intention Statement

To demonstrate institutional holding and sound leadership that promotes decisions and actions in line with a cleaner environment that supports the poor informal sector.

Objective

- Provide co-ordination, alignment and leadership on low income non electrified energy matters.
- Drive the plan through firmly institutionalising energy poverty within provincial government and building effective partnerships with all spheres of government and other key stakeholders

The adoption and implementation of this plan should be integrated and encourage alignment, co-ordination and co-operation by government and all stakeholders. In this respect four initial workshops will be held. The first will involve the various Gauteng provincial departments to ensure alignment and coordination of the project. The second meeting will be with representatives from the municipalities to determine their role in the implementation process. The third workshop will be with civil society and the affected community groups to further explore needs and preferences in the local context. In addition this workshop will be critical in assessing the MCA's top technologies. The fourth workshop will be with the SMMEs, suppliers and other stakeholders from the private and business sector.

These workshops may result in changes to the suggested action plans listed below and should provide more detailed actions and timeframes.

A **Provincial Steering committee should be established** to drive and lead the implementation of this project. Without leadership and given the number of different stakeholders many elements are likely to fall through the gaps. It will take into consideration the socio-economic aspects of the technologies. Such a committee will help promote a common and shared vision in the province. It will help eliminate duplication – across the private and public sectors - and will help to drive goals, source funding, provide direction and above all enable change to happen. This committee will offer institutional support by providing formal structures and co-ordination of its implementation. It would be pivotal in providing leadership through **effective partnerships** with all spheres of government, various departments, the communities themselves, civil society, key industry players and other significant stakeholders.

The province will develop an **annual update report** commencing in 2017 to assess and evaluate the success of the project as well as progress on electrification and its impact on the need for alternative energy technologies. This report should include information on the status of the technologies being employed, what is new on the market and housing developments within each municipal boundary.

Institutional and Strategic Leadership			
Intention: To demonstrate institutional holding and sound leadership that promotes decisions and actions in line with a cleaner environment that supports the poor.			
Objective: Provide co-ordination, alignment and leadership on low income non electrified energy matters.			
Output	**Action**	**Who**	**Date**

Adoption of the Implementation Plan by Provincial government	Set up a workshop to determine: • Report on findings of feasibility study • Determine levels of responsibility lie in relation to roll out • Outline relevant provincial policies and consider alignment with other provincial policies • Finalise and adopt implementation plan once other stakeholder workshops have taken place • Appoint steering committee and consider stakeholders from outside government • Identify key SMMEs and other businesses • Identify informal settlements across the province	GDARD and other Provincial Departments	
Institutional and Strategic Leadership			
Intention: To demonstrate institutional holding and sound leadership that promotes decisions and actions in line with a cleaner environment that supports the poor.			
Objective: Provide co-ordination, alignment and leadership on low income non electrified energy matters.			
Adoption of the Plan by Local Government	Set up a workshop to determine: • Report on findings of feasibility study • Where local levels of responsibility lie in relation to roll out • Finalise and adopt implementation plan • FBAE rollout implications • Identify challenges relating to the informal settlements • Report on electrification progress	GDARD and local government departments	
Adoption of the Plan by civil society and communities	Set up a workshop to determine: • Response to findings of feasibility study • Identify need and gaps with a focus on social acceptability • Finalise and adopt implementation plan	civil society, community	
Adoption of the Plan by SMMEs and business	Set up a workshop to determine: • Response to findings of feasibility study • Discuss potential technologies and how to roll out • Finalise and adopt implementation plan	SMMEs, business	
Government leadership on alternative energy in the province	▪ Ensure coordination, alignment, support and participation of all key departments and spheres of government ▪ Energy champions to be appointed if deemed necessary across province ▪ Alternative energy to become a standing	GDARD, Steering Com GDARD,	

	agenda item on the premier's coordinating council and of all relevant municipal council meetings ▪ Development of an annual update and evaluation report. This report will provide an overview and assessment of the success of the project and to what extent it is being implemented and where opportunities and challenges lie. ▪ Monitor air pollution in the province and determine if levels are affected by roll out of project	Steering com Municipalities GDARD, Steering com Municipalities Communities GDARD, Steering com Municipalities	

4.3.3 Financial and Funding Mechanisms

Intention Statement

To have the financial support to implement the Plan

Objectives

- Develop a funding plan and framework to support the rollout of the alternative energy and technologies.
- Develop a supportive environment for new business development
- Implement a framework for the rollout of FBAE
- Grow job potential

The financing of the strategy is critical in terms of enabling implementation and the achievement of targets. It is also important that such an investment is not seen as contrary to the economic growth and development of the province. Many provincial documents have focused on or included economic growth and the alleviation of poverty as a priority for the province.

The mechanisms developed should focus on various sources of funding namely; FBAE rollout including developing operating procedures and criteria, the extent to which the recipients contribute financially and producing a developmental business opportunity.

Financial and Funding Mechanisms			
Intention: To have the financial support to implement the Plan			
Objective: Develop a funding plan and framework to support the roll-out of alternative energies and technology			
Output	**Action**	**Who**	**Date**

Short- to medium-term funding plan	• Develop a business plan for the roll out of the project • Identify sources of funding to support the business plan and secure funding • Determine recipient contributions • Develop a database of potential donors, funders and partners and their interest areas • Consider reduced levies on clean alternative fuels as a mechanism of promoting these fuels and instituting regulations which generally can't be monitored in the poor residential sector	GDARD Steering Committee	
Develop a bidding system for SMMEs	• Finalise SMMEs selection • Guidelines to include costing to recipient, socio economic component • Criteria for accepting SMMEs	GDARD Steering Committee	
Develop municipal FBAE roll out	• To develop criteria for roll out of FBAE • Framework for roll out	Steering Committee Municipal finance departments	

4.3.4 Promoting Clean Energy Technologies and Fuel

Intention Statement

To promote technologies and fuel use that is clean, safe, affordable and accessible to the informal settlements

Objectives

- Identify technologies and fuel
- Training of SMMEs
- Develop costing and safety and sustainability of supply
- Build relationships and networks with research institutes, academia and the business sector

The feasibility study identified 20 technologies and from the multi criteria analysis was able to rate the top technologies according to 12 criteria based broadly on cost, safety, applicability and accessibility. Whilst this is a recommendation, the finalising of the technologies to be rolled out must be workshopped as stated above with key stakeholders. This pillar of the implementation plan focuses on maintaining the lists and their relevance for the province. It also involves the training of and support to the SMMEs, intermediaries and government officials.

Promoting Clean Energy Technologies and Fuel			
Intention Statement: To promote technologies and fuel use that is clean, safe, affordable and accessible to the informal settlements			
Objective: Identify technologies and fuels, train the trainers and build relationships and networks with research institutes, academia and business sector			
Output	**Action**	**Who**	**Date**
Updated list of technologies	• Ensure that technology and fuel list is relevant and updated - facilitate ongoing research and assessment of fuels and appliances • Assessment of technologies and fuels must include; impact on air pollution, cost, time and accessibility and other criteria as determined • Update the feasibility of energy options through a detailed energy resource assessment conducted in conjunction with industry and other sectors as appropriate • Clarify recommended combination technologies	GDARD Research institutes, civil society, communities	Annually
Multi criteria analysis updated	• Update the MCA based on new criteria if required.	GDARD	
Update supplier list	• Update the supplier list	Municipalities GDARD	
Supportive mechanisms to promote clean alternative technology business	• Support the establishment of clear standards for products working with SABS and other standards authorities • Municipalities develop an approved supplier list for appliances and fuels • Consumer and business education and awareness on clean energy alternatives • Train and support SMMEs • Information on combined technology use • Develop easily understood material for customers • Focus programmes for selected government employees • Develop training course for provincial and municipal workers	GDARD Steering Committee Municipalities SMMEs	

4.3.5 Empowering Citizens to Reach the Vision

Intention statement

Empowering citizens to reach the vision through knowledge

Objectives

To develop citizens that empowered to make energy decisions based on health, safety and air quality

A key element of the strategy is supporting consumers to move towards the vision, which will be done through building awareness and education. It is clear that the nature of change being advocated through the strategy will not happen overnight, it is a process of transition and critical to this transition is the building of awareness. People create change and thus what is needed is a change in behaviour, a paradigm shift. The awareness programme must be designed to target ordinary citizens living in informal settlements so that they understand the options available and why recommendations of particular appliances and fuels are being made. Issues relating to cost are crucial for the poor and they must understand the benefits to health and affordability.

Knowledge of the impact of one's actions on the environment, on energy consumption, on personal budgets and on one's health, will empower people to make choices that will ultimately uphold the vision and objectives of the implementation plan.

Empowering Citizens to Reach the Vision			
Intention: That citizens are supported to reach the vision through knowledge			
Objective: To develop citizens that become agents of change in all aspects of energy efficiency			
Output	**Action**	**Who**	**Date**
Ongoing awareness campaign	• Identify potential energy champions within communities who can be trained to take forward relevant messages and campaign amongst communities • Champions are to be supported by Province/municipalities or other suitable organisations in a systematic way • Clinics and shops should be targeted as places to meet with residents. • Publish flyers • Arrange community meetings	All key stakeholders including: CBOs, Ward committees,	Annually
Communities empowered to make choices	• Building on the above actions develop a programme to assist the citizens in making choices that are based on information relating to cost, time, convenience and impact on health	All key stakeholders including: CBOs, Ward committees,	Annually
Informed	• Design and implement awareness	Steering	

government departments	programme for local government employees • A select group of ward councillors to be trained • The voice of the community to be assimilated into the MCA and other decision making processes	committee Community representatives	

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ANNEXURES

ANNEXURE 1: Energy Data for Non-Electrified Households in Gauteng

Lighting

Table 15: Fuels used for lighting in the four surveyed areas (total population)[47]

Municipality	(Sedibeng) Emfuleni	Randfontein	Ekurhuleni	City of Johannesburg	Total
Ward	Ward 23	Ward 12	Ward 42	Ward 68	
Informal settlement	Bophelong	Zenzele	Ramaphosa	Slovo Park	
Gas	3	10	40	8	**61**
Paraffin	128	708	1,326	647	**2,808**
Candles (not a valid option)	719	1,426	1,640	2,410	**6,195**
Solar	9	2	16	17	**43**
None	10	10	21	30	**71**
Total	**869**	**2,156**	**3,043**	**3,112**	**9,178**

Table 16: Percentage shares of fuels used for lighting in the four surveyed areas (total population)[48]

Municipality	(Sedibeng) Emfuleni	Randfontein	Ekurhuleni	City of Johannesburg	Total
Ward	Ward 23	Ward 12	Ward 42	Ward 68	
Informal settlement	Bophelong	Zenzele	Ramaphosa	Slovo Park	
Gas	0.3%	0.5%	1.3%	0.3%	**0.7%**
Paraffin	14.7%	32.8%	43.6%	20.8%	**30.6%**
Candles	82.7%	66.1%	53.9%	77.4%	**67.5%**
Solar	1.0%	0.1%	0.5%	0.5%	**0.5%**
None	1.2%	0.5%	0.7%	1.0%	**0.8%**
Total	**100%**	**100%**	**100%**	**100%**	**100%**

Table 17: Fuels used for lighting in all non-electrified households in Gauteng Province[49]

Municipality	Sedibeng	West Rand	Ekurhuleni	City of Johannesburg	City of Tshwane	Total
Gas	595	543	2,636	2,710	1,767	8,252
Paraffin	4,352	11,831	46,835	23,775	13,880	100,672
Candles	20,287	35,322	126,937	98,945	84,372	365,864
Solar	603	570	2,076	3,217	2,019	8,485

[47] Source: Stats SA Census 2011
[48] Source: Stats SA Census 2011, own calculations
[49] Source: Stats SA Census 2011

None	579	792	2,537	3,162	2,319	9,390
Total	**26,416**	**49,058**	**181,021**	**131,810**	**104,357**	**492,662**

Table 18: Percentage shares of fuels used for lighting in non-electrified households in Gauteng[50]

Municipality	Sedibeng	West Rand	Ekurhuleni	City of Johannesburg	City of Tshwane	Total
Gas	2%	1%	1%	2%	2%	2%
Paraffin	16%	24%	26%	18%	13%	20%
Candles	77%	72%	70%	75%	81%	74%
Solar	2%	1%	1%	2%	2%	2%
None	2%	2%	1%	2%	2%	2%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Cooking

Table 19: Fuels used for cooking in the four surveyed areas (total population)[51]

Municipality	(Sedibeng) Emfuleni	Randfontein	Ekurhuleni	City of Johannesburg	Total
Ward	Ward 23	Ward 12	Ward 42	Ward 68	
Informal settlement	Bophelong	Zenzele	Ramaphosa	Slovo Park	
Gas	26	287	64	44	421
Paraffin	802	1,810	2,906	822	6,340
Wood	20	31	8	25	83
Coal	7	22	10	7	47
Animal dung	-	-	-	-	-
Solar	2	4	4	1	11
Other	-	-	-	2	2
None	6	-	8	5	**19**
Total	**868**	**2,155**	**3,044**	**934**	**7,001**

Table 20: Percentage shares of fuels used for cooking in the four surveyed areas (total population)[52]

Municipality	(Sedibeng) Emfuleni	Randfontein	Ekurhuleni	City of Johannesburg	Total
Ward	Ward 23	Ward 12	Ward 42	Ward 68	
Informal settlement	Bophelong	Zenzele	Ramaphosa	Slovo Park	

‘50 Source: Stats SA Census 2011, own calculations
51 Source: Stats SA Census 2011
52 Source: Stats SA Census 2011, own calculations

Gas	3.0%	13.3%	2.1%	4.9%	6.1%
Paraffin	92.9%	84.0%	96.9%	90.7%	91.6%
Wood	2.3%	1.4%	0.3%	2.8%	1.2%
Coal	0.8%	1.0%	0.3%	0.8%	0.7%
Animal dung	-	-	-	-	-
Solar	0.2%	0.2%	0.1%	0.1%	0.2%
Other	-	-	-	0.2%	-
None	0.7%	-	0.3%	0.6%	0.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table 21: Fuels used for cooking in all non-electrified households in Gauteng[53]

Municipality	Sedibeng	West Rand	Ekurhuleni	City of Johannesburg	City of Tshwane	Total
Gas	3,224	2,852	8,732	9,939	4,636	29,382
Paraffin	18,676	41,945	159,616	111,772	88,164	420,174
Wood	2,202	2,533	3,068	1,949	6,142	15,895
Coal	841	277	4,199	746	809	6,871
Animal dung	69	44	144	158	87	501
Solar	68	121	407	513	281	1,390
Other	20	16	77	184	83	379
None	245	297	837	1,053	753	3,185
Total	**25,344**	**48,085**	**177,081**	**126,313**	**100,955**	**477,778**

Table 22: Percentage shares of fuels used for cooking in non-electrified households in Gauteng[54]

Municipality	Sedibeng	West Rand	Ekurhuleni	City of Johannesburg	City of Tshwane	Total
Gas	13%	6%	5%	8%	5%	6%
Paraffin	74%	87%	90%	88%	87%	88%
Wood	9%	5%	2%	2%	6%	3%
Coal	3%	1%	2%	1%	1%	1%
Animal dung	0%	0%	0%	0%	0%	0%
Solar	0%	0%	0%	0%	0%	0%
Other	0%	0%	0%	0%	0%	0%
None	1%	1%	0%	1%	1%	1%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

[53] Source: Stats SA Census 2011

[54] Source: Stats SA Census 2011, own calculations

Space Heating

Table 23: Fuels used for space heating in the four surveyed areas (total population)[55]

Municipality	(Sedibeng) Emfuleni	Randfontein	Ekurhuleni	City of Johannesburg	Total
Ward	Ward 23	Ward 12	Ward 42	Ward 68	
Informal settlement	Bophelong	Zenzele	Ramaphosa	Slovo Park	
Gas	15	67	57	31	**170**
Paraffin	140	728	1,656	553	**3,076**
Wood	467	673	377	212	**1,728**
Coal	43	277	235	22	**577**
Animal dung	-	1	18	2	**21**
Solar	4	1	3	4	**11**
None	192	407	647	89	**1,334**
Total	**861**	**2154**	**2993**	**913**	**6917**

Table 24: Percentage shares of fuels used for space heating in the four surveyed areas (total population)[56]

Municipality	(Sedibeng) Emfuleni	Randfontein	Ekurhuleni	City of Johannesburg	Total
Ward	Ward 23	Ward 12	Ward 42	Ward 68	
Informal settlement	Bophelong	Zenzele	Ramaphosa	Slovo Park	
Gas	1.7%	3.1%	1.9%	3.4%	2.5%
Paraffin	16.3%	33.8%	55.3%	60.6%	44.5%
Wood	54.2%	31.2%	12.6%	23.2%	25.0%
Coal	5.0%	12.9%	7.9%	2.4%	8.3%
Animal dung	-	0.0%	0.6%	0.2%	0.3%
Solar	0.5%	0.0%	0.1%	0.4%	0.2%
None	22.3%	18.9%	21.6%	9.7%	19.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table 25: Fuels used for space heating in all non-electrified households in Gauteng[57]

Municipality	**Sedibeng**	**West Rand**	**Ekurhuleni**	**City of Johannesburg**	**City of Tshwane**	**Total**
Gas	1,521	1,114	3,847	4,265	2,707	13,453
Paraffin	7,679	19,338	75,759	59,704	36,237	198,717
Wood	7,731	15,479	21,145	18,940	27,224	90,519

[55] Source: Stats SA Census 2011
[56] Source: Stats SA Census 2011, own calculations
[57] Source: Stats SA Census 2011

Municipality	Sedibeng	West Rand	Ekurhuleni	City of Johannesburg	City of Tshwane	Total
Coal	2,671	2,261	37,023	8,672	3,117	53,744
Animal dung	108	57	155	168	85	573
Solar	122	114	497	664	353	1,751
Other	1	1	5	18	9	34
None	5,783	9,979	39,582	34,659	31,834	121,837
Total	**25,616**	**48,344**	**178,012**	**127,090**	**101,566**	**480,628**

Table 26: Percentage shares of fuels used for space heating in non-electrified households in Gauteng[58]

Municipality	Sedibeng	West Rand	Ekurhuleni	City of Johannesburg	City of Tshwane	Total
Gas	6%	2%	2%	3%	3%	3%
Paraffin	30%	40%	43%	47%	36%	41%
Wood	30%	32%	12%	15%	27%	19%
Coal	10%	5%	21%	7%	3%	11%
Animal dung	0%	0%	0%	0%	0%	0%
Solar	0%	0%	0%	1%	0%	0%
Other	0%	0%	0%	0%	0%	0%
None	23%	21%	22%	27%	31%	25%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

[58] Source: Stats SA Census 2011, own calculations

ANNEXURE 2: MCA results for cooking and heating applications

Performance matrix with option scoring for Cooking and Heating

Option/Criterion	Air pollution reduction potential	Running cost for users	Implementation/ roll-out cost	Security of energy supply used by the technology	Potential to expand supply in Gauteng	Versatility of application	Initial capital outlay required by users	Safety for users	Technology maturity and accessibility	Energy efficiency of the technology	lifespan of the technology	technology complexity
Units	0-3	0-3	0-3	0-3	0-3	0-3	0-4	0-3	0-3	0-3	0-3	0-3
Preferred value	High	Low	Low	High	High	High	Low	High	High	High	High	Low
CleanCook Methanol/Ethanol Cookstove	2	1	2	2	3	3	4	2	1	2	3	2
Protostar Bhubezi Methanol Cookstove	2	2	2	1	3	3	2	2	1	2	2	2
Mbaula Green Wood or Coal Stove	1	1	2	1	1	3	2	0	2	2	3	1
Eco Zoom Versa Wood/Charcoal Stove	1	1	2	1	1	3	2	0	1	2	3	1
Liquefied Petroleum Gas (LPG) two-plate cooker and cylinder	2	2	1	2	2	3	4	1	3	2	2	2
Liquefied Petroleum Gas (LPG) one-plate cooker top and cylinder	2	2	1	2	2	3	3	1	3	2	2	2
Sunstove Solar cooker	3	0	2	3	3	2	3	3	1	2	3	2
The Wonderbag/ Hotbox	2	0	2	2	2	1	2	3	2	2	2	1
Coal or Wood Mbawula	0	2	1	1	1	3	1	0	3	1	1	1

Coal or Wood Cookstove	0	2	1	1	1	3	2	0	3	1	1	1
LPG heater	2	3	1	2	2	1	4	2	3	2	3	2
Paraffin Heater	0	3	1	3	3	1	4	0	3	1	3	2

Calculation of scores for cooking and heating applications

Criteria Options	Air pollution reduction potential	Running cost for users	Implementation/roll-out cost	Security of energy supply used by the technology	Potential to expand supply in Gauteng	Versatility of application	Initial capital outlay required by users	Safety for users	Technology maturity and accessibility	Energy efficiency of the technology	Lifespan of the technology	Technology complexity	Weighted scores of each option
Units	0-3	0-3	0-3	0-3	0-3	0-3	0-4	0-3	0-3	0-3	0-3	0-3	
Preferred value	High	Low	Low	High	High	High	Low	High	High	High	High	Low	
Weight	15%	10%	10%	10%	5%	5%	5%	10%	12%	5%	3%	10%	
CleanCook Methanol/Ethanol Cookstove	50,00	50,00	0,00	50,00	100,00	100,00	-50,00	66,67	0,00	0,00	100,00	0,00	34,67
Protostar Bhubezi Methanol Cookstove	50,00	0,00	0,00	0,00	100,00	100,00	50,00	66,67	0,00	0,00	0,00	0,00	26,67
Mbaula Green Wood or Coal Stove	0,00	50,00	0,00	0,00	0,00	100,00	50,00	0,00	50,00	0,00	100,00	100,00	31,50
Eco Zoom Versa Wood/Charcoal Stove	0,00	50,00	0,00	0,00	0,00	100,00	50,00	0,00	0,00	0,00	100,00	100,00	25,50
Liquefied Petroleum Gas (LPG) two-plate cooker and cylinder	50,00	0,00	100,00	50,00	50,00	100,00	-50,00	33,33	100,00	0,00	0,00	0,00	42,83
Liquefied Petroleum Gas	50,00	0,00	100,00	50,00	50,00	100,00	0,00	33,33	100,00	0,00	0,00	0,00	45,33

(LPG) one-plate cooker top and cylinder													
Sunstove Solar cooker	100,00	100,00	0,00	100,00	100,00	50,00	0,00	100,00	0,00	0,00	100,00	0,00	55,50
The Wonderbag/ Hotbox	50,00	100,00	0,00	50,00	50,00	0,00	50,00	100,00	50,00	0,00	0,00	100,00	53,50
Coal or Wood Mbawula	-50,00	0,00	100,00	0,00	0,00	100,00	100,00	0,00	100,00	0,00	-100,00	100,00	31,50
Coal or Wood Cookstove	-50,00	0,00	100,00	0,00	0,00	100,00	50,00	0,00	100,00	0,00	-100,00	100,00	29,00
LPG heater	50,00	-50,00	100,00	50,00	50,00	0,00	-50,00	66,67	100,00	0,00	100,00	0,00	39,17
Paraffin Heater	-50,00	-50,00	100,00	100,00	100,00	0,00	-50,00	0,00	100,00	0,00	100,00	0,00	25,00

ANNEXURE 3: MCA results for lighting and charging

Performance matrix with option scoring for Lighting and Charging

Option/Criterion	Air pollution reduction potential	Running cost for users	Implementation/roll-out cost	Security of energy supply used by the technology	Potential to expand supply in Gauteng	Versatility of application	Initial capital outlay required by users	Safety for users	Technology maturity and accessibility	Energy efficiency of the technology	Lifespan of the technology	Technology complexity
Units	0-3	0-3	0-3	0-3	0-3	0-3	0-4	0-3	0-3	0-3	0-3	0-3
Preferred value	High	Low	Low	High	High	High	Low	High	High	High	High	Low
Portable Nightlight Solar Powered Candle	3	0	2	3	3	1	2	3	1	3	2	3
WakaWaka light	3	0	2	3	3	1	2	3	2	3	2	3
Solar G3 Lantern light and charger	3	0	2	3	3	2	3	3	1	3	2	3
Portable Solar kit	3	0	2	3	3	3	4	3	1	3	2	3
Litre of light	2	0	1	3	3	1	1	3	3	2	1	1
LPG lamp	2	3	0	2	2	1	1	2	2	2	2	2

Candle	0	1	0	3	3	1	1	0	3	2	1	0
Paraffin lamp	0	1	0	3	3	1	1	0	3	2	3	1

Calculation of scores for lighting and charging applications

The values shown in the table below are normalized, and the final scores of each option are shown per criteria. The final column shows the weighted scores of each option.

Criteria Options	Air pollution reduction potential	Running cost for users	Implement ation/roll-out cost	Security of energy supply used by technology	Potential to expand supply in Gauteng	Versatility of application	Initial capital outlay required by users	Safety for users	technology maturity and access	Energy efficiency of the technology	Lifespan of the technolog y	technology complexity	Weighted scores of each option
Units	0-3	0-3	0-3	0-3	0-3	0-3	0-4	0-3	0-3	0-3	0-3	0-3	
Preferred value	High	Low	Low	High	High	High	Low	High	High	High	High	Low	
Weight	15%	10%	10%	10%	5%	5%	5%	10%	12%	5%	3%	10%	
Portable Nightlight Solar	100,00	100,00	0,00	100,00	100,00	0,00	66,67	100,00	0,00	100,00	50,00	0,00	59,83
WakaWaka light	100,00	100,00	0,00	100,00	100,00	0,00	66,67	100,00	50,00	100,00	50,00	0,00	65,83
Solar G3 Lantern light and charger	100,00	100,00	0,00	100,00	100,00	50,00	33,33	100,00	0,00	100,00	50,00	0,00	60,67
Portable Solar kit	100,00	100,00	0,00	100,00	100,00	100,00	0,00	100,00	0,00	100,00	50,00	0,00	61,50
Litre of light	66,67	100,00	50,00	100,00	100,00	0,00	100,00	100,00	100,00	0,00	0,00	66,67	73,67
LPG lamp	66,67	0,00	100,00	0,00	0,00	0,00	100,00	66,67	50,00	0,00	50,00	33,33	42,50
Candle	0,00	66,67	100,00	100,00	100,00	0,00	100,00	0,00	100,00	0,00	0,00	100,00	58,67
Paraffin lamp	0,00	66,67	100,00	100,00	100,00	0,00	100,00	0,00	100,00	0,00	100,00	66,67	58,33

ANNEXURE 4: Comparative Lifecycle Cost Analysis of Technologies

Lifecycle Cost Analysis (LCCA)

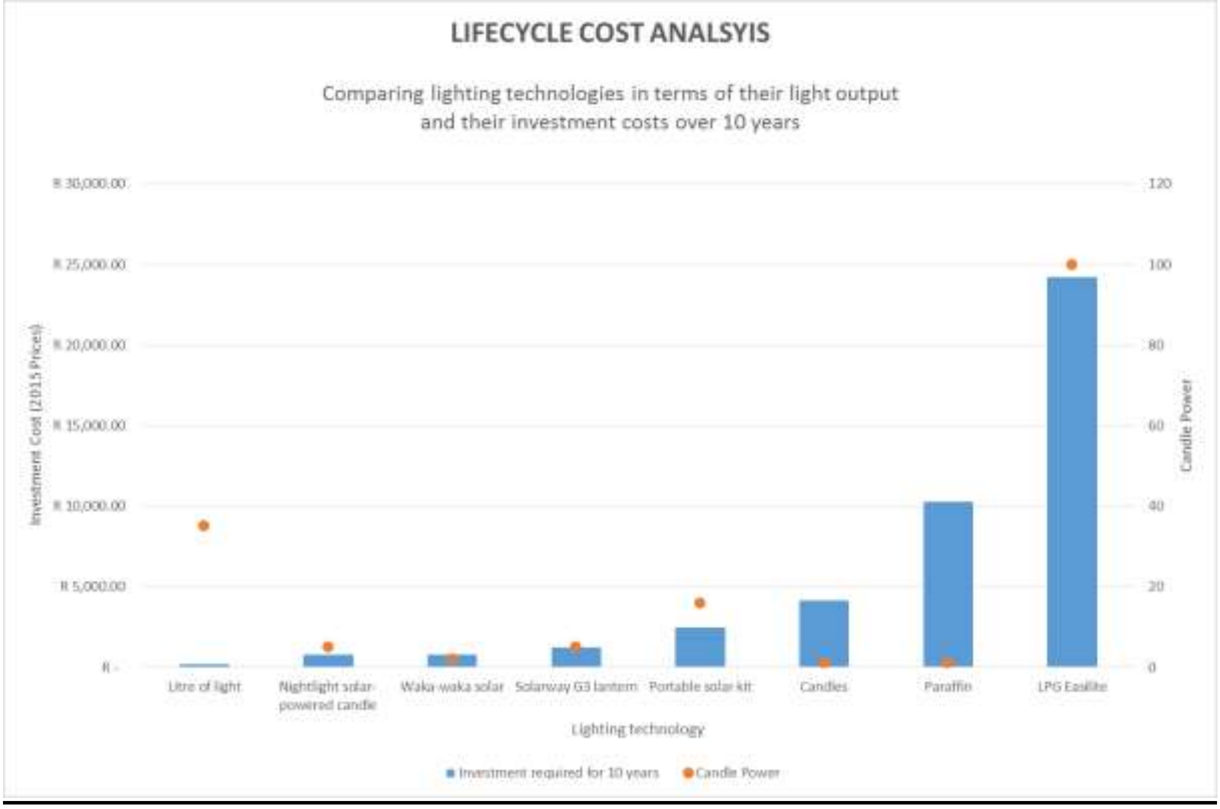
A lifecycle cost analysis is a useful way of comparing different technologies over a common period (in this case 10 years) taking into account the initial capital cost, operating costs, lifespan and replacement cost of each technology within the period. These costs are presented in terms of a present value investment cost which is interpreted as the upfront investment required for meeting the full cost of using the technology over 10 years. In order to do this, an assumed inflation and a discount rate were factored into the calculation in order to convert future values into present day values (2015 prices). In addition, fuel price increases were considered as seen below.

Global data

Inflation rate	5%
Discount factor	8%
Petroleum price increases	5%
Biomass price increases	2%

Average cooking time per day (hrs)	**3**
Average cooking time per month (hrs)	**90**
Average lighting hours per day in (hrs)	**5**
Average lighting hours per month (hrs)	**150**

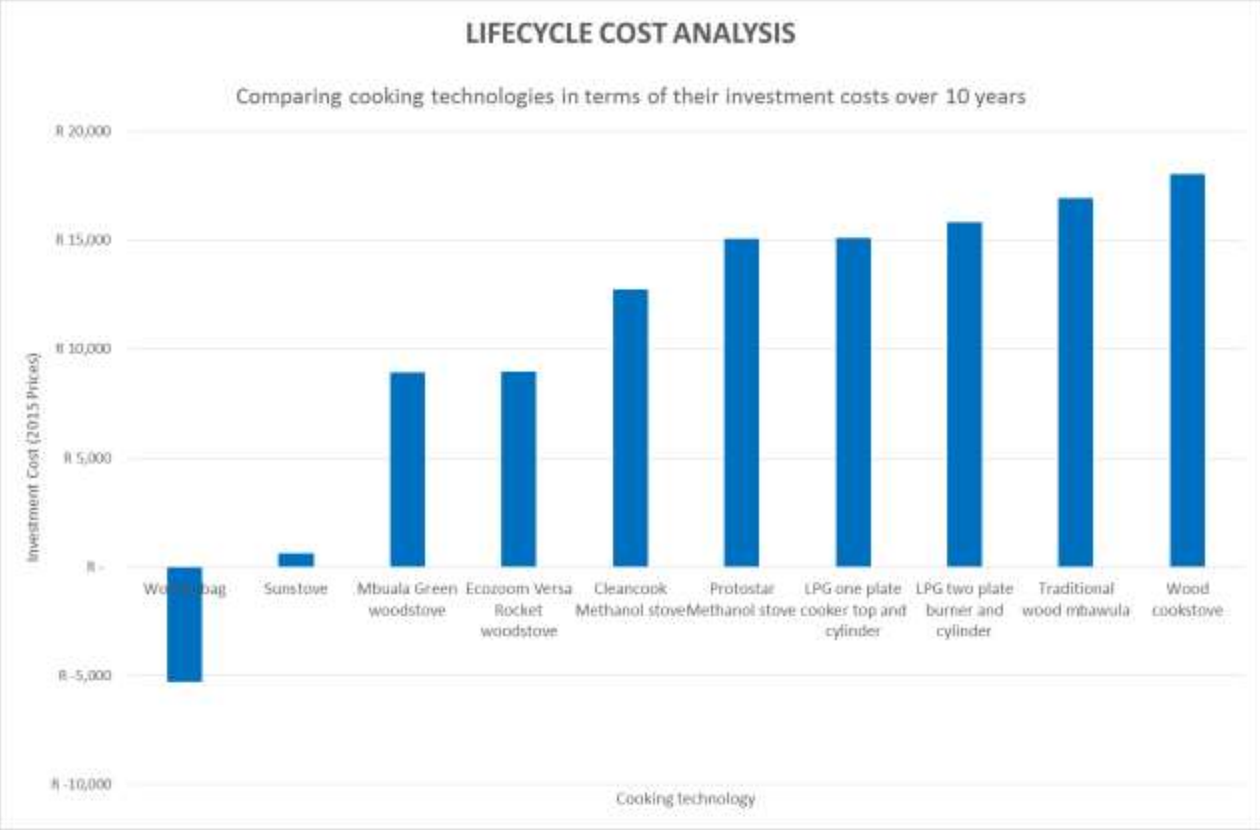
LCCA for Lighting Technology



For the lighting technology, the investment cost and the luminosity (in terms of candle power) was plotted on a graph. This allows one to see whether the increased investment cost is worthwhile when considering the gains in luminosity. For example, the LPG Easilite is the most expensive but is also the brightest (100 times brighter than a candle). Some more observations from the graph:

- On a 10-year scale, candles and paraffin are more expensive than solar technologies. They also emit less light, cause indoor air pollution and are safety hazards.
- The portable solar kit offers the brightest light among the solar technologies and it has additional features for cell phone charging and radio access. It is therefore a more costly technology.
- The litre of light (suitable only for daylighting) is much brighter than solar, candles and paraffin, and is also the least expensive. Where practical, this technology should be installed in all shacks in combination with the other cleaner lighting options.

LCCA for Cooking Technology



The graph above compares the investment cost of modern and traditional cooking technology over a 10 year period. It is assumed that all fuel is purchased and collected for free. The following is observed in the graph:

- The traditional cookstoves such as the wood mbawula and wood cookstove are more costly than the modern technologies. This is because they require relatively more fuel for the same heat output as a result of inefficient combustion. The modern technologies have been designed to improve combustion efficiencies which not only reduce fuel requirements and costs but also reduces pollution.
- The Wonderbag has a negative investment cost to illustrate that it saves energy over time. If used in combination with another technology it will reduce the cooking time and therefore reduces the cost of that technology.
- The sunstove emerges as the second least expensive technology since it has no running costs. It is limited in that it can only be used during the daytime and particularly during the warmer months. It may benefit the household to use it in combination with other modern technologies for the days that a household member is available for daytime cooking or for those who have a small catering business.

The modern woodstoves are in the lower cost range, methanol stoves in the mid cost range and the LPG technology in the higher cost range.

ANNEXURE 5: Household Energy Use Survey

Gauteng Province Air Quality Department Household Energy Use Survey October 2015 Survey conducted by: Sustainable Energy Africa & Safe Energy Tel: 021 702 3622	Interviewer Name
	Date:
	Quest. No.

Introductory note (read to respondent): Hello, my name is ____________________. I am a researcher from ________________________________ (name of organisation).

We are conducting a survey for the Gauteng Province Air Quality Department on household energy use in your community. This contributes to a study investigating clean burning fuels and appliances that can be used by households to reduce air pollution and improve the health and safety of households. We are therefore interested in learning about the types of fuels your household uses for lighting, cooking and space heating. We kindly ask that you help us by participating in a short interview, which should only take about 30 minutes. The information you share will be kept confidential.

Notes for enumerator

- Only interview households which are non-electrified.
- Only interview an adult household member, do not interview minors.
- Try to interview the most knowledgeable adult household member.
- Random sampling is preferable. Example – sample every 5th dwelling if possible.
- Question A.3 relating to income is often a sensitive subject for households and therefore engage respondent with understanding and sensitivity when enquiring as to which income category from the list provided the household roughly falls under.

Interview information

Name of respondent			Name of Municipality	
Gender of respondent *(Tick the appropriate box)*	Female	Male	Name of informal settlement	
Respondent's position in household e.g. mother, father, child etc.				
Age				

SECTION A: INFORMATION ON HOUSEHOLD

A.1 A) How many people live in this house?	

B) How many are adults?	

C) How many are children?	

A.2 What is the employment status of household members? *Indicate the number of members next to the relevant employment category listed below.*	
1. Unemployed	
2. Full-time employment	
3. Part-time employment	
4. Casual employment	

5. Self-employed	
6. Pensioner/retired	
7. Student/scholar	
8. Home maker/stay at home mom	
9. Unemployed, in training	
10. Preschool child	
11. Other (specify)	

A.3 What are all the sources of your household income, such as wages, pensions, child grants etc.? *Please tick <u>all</u> appropriate boxes.*				
1. Wages	2. Child grant	3. Pension	4. Disability grant	5. Other (specify)

A.4 What is the total monthly income of the household coming from all sources, such as wages, pensions, child grants etc.? *Please tick relevant box and note any additional information in the comments box provided.*					
Income	1. R0-800	2. R801-R1600	3. R1601-R3200	4. R3201-R6400	5. R6401 +

SECTION B: INFORMATION ABOUT DWELLING

B.1 Indicate the type of main dwelling that the household occupies? *Enumerator to make the observation and tick in appropriate box.*	
1. Informal Shack (not backyard)	
2. Backyard Shack	
3. Other (specify)	

B.2 What material was used to construct the dwelling? *Enumerator to make the observation and tick in appropriate boxes.*			
Material	**A. Inner Walls**	**B. Floor**	**C. Roof**
1. Bricks			
2. Wood			
3. Corrugated Iron/Zinc			
4. Cement Block/Concrete			
5. Plastic			
6. Cardboard			
7. Mixture of mud and cement			
8. Other (specify)			

B.3 How many rooms does the dwelling have? *Please tick the appropriate box.*	
1. One	
2. Two	
3. More than two	

B.4 Where does the cooking mainly take place? *Please tick the appropriate box.*	
1. Inside the dwelling	
2.Outside the dwelling	
3. Other (specify)	

B.5 Does the dwelling have any windows? *Please tick the appropriate box.*	
1.Yes	
2. No	

B.6 Do you have any of the following problems with your dwelling? *Please tick the appropriate box.*	
1. Overcrowding, with too little space	
2. Insufficient light	
3. Cold, not enough heating	
4. Leaking roof	
5. Damp walls, floors, foundations, etc.	
6. Damaged or broken windows or doors	
7. None of these problems	
8. Other (specify)	

Comments/Notes:

SECTION C: FUELS USED IN THIS HOUSEHOLD

Lighting:

C.1 What is the main/regular fuel used for lighting? (used for most of the month) *Please tick the appropriate box.*					
1. Paraffin	2. Candles	3. LPG gas	4. Solar	5. Battery operated lamps	6. Other (specify)

C.2 How often is this main fuel used for lighting? *Please tick the appropriate box and please note any additional information in the comments box provided*.						
1. Every day	2. A few times a week	3. Once a week	4. Three times a month	5. Once per month	6. Less often/irregularly	7. Other (specify)

C.3 What are the main reasons for using this fuel for lighting? *Please tick <u>all</u> appropriate boxes.*						
1. Affordable/ Cheap	2. Easily available	3. Brightness of light	4. Easy to use	5. Safe	6. Clean	7. Other (specify)

C.4 Can your main fuel for lighting be bought from a supplier(s) in your area (within settlement)? *Please tick the appropriate box.*			
	1. Yes		→ GOTO C.5
	2. No		→ GOTO C.7

C.5 Is this your supplier(s) you usually buy your lighting fuel? *Please tick the appropriate box.*	1. Yes		GOTO C.7
	2. No		GOTO

C.6 Why don't you use the local supplier to buy your main lighting fuel?

C.7 Are you satisfied with the brightness of the lighting fuel? *Please tick the appropriate box.*	1. Yes	
	2. No	

C.8 Do you or anyone in your household find it difficult to read, write or do any activity at night using your current lighting fuel? *Please tick the appropriate box.*	1. Yes	
	2. No	

C.9 What second (other) fuel is used for lighting?

Please tick the appropriate box.

1. None	2. Candles	3. Paraffin	4. Solar	5. LPG gas	6. Battery operated lamps	7. Other (specify)

GOTO C.15

C.10 How often is this second (other) fuel used for lighting? *Please tick <u>all</u> appropriate boxes.*				
1. Once a week	2. Last week of the month	3. Less often/irregularly	4. Special occasions, during holidays and celebrations	5. Other (specify)

C.11 Can your second (other) lighting fuel be bought from a supplier in your area (within settlement)? *Please tick the appropriate box.*	1. Yes		→ GOTO C.12
	2. No		→ GOTO C.14

C.12 Is this your supplier(s) you usually buy your second lighting fuel from? *Please tick the appropriate box.*	1. Yes		→ GOTO C.14
	2. No		→ GOTO C.13

C.13 Why don't you use the local supplier to buy your second (other) lighting fuel?

C.14 Are you satisfied with your second (other) lighting fuel? *Please tick the appropriate box.*	1. Yes	
	2. No	

Comments/Notes:

Cooking:

C.15 What is the main/regular fuel used for cooking? (used for most of the month) *Please tick the appropriate box.*						
1. Paraffin	2. Wood	3. LPG gas	4. Dung/ crop residue	5. Coal	6. Ethanol gel	7. Other (specify)

C.16 How often is this main fuel used for cooking? *Please tick appropriate box and please note any additional information in the comments box provided*.						
1. Every day	2. A few times a week	3. Once a week	4. Three times a month	5. Once per month	6. Less often/irregularly	7. Other (specify)

C.17 What are the main reasons for using this fuel for cooking? *Please tick <u>all</u> appropriate boxes.*						
1. Affordable/ Cheap	2. Easily available	3. Faster cooking time	4. Easy to use	5. Safe	6. Clean	7. Other (specify)

C.18 Do you buy your main cooking fuel or collect it for free from the surroundings (like coal from a quarry, or wood from fields)? *Please tick the appropriate box.*				
1. Buy	2. Collect for free	3. Mostly buy and sometimes collect for free	4. Mostly collect for free and sometimes buy	5. Other (specify)

<u>NOTE:</u> *If the cooking fuel is <u>different</u> to the lighting fuel then complete the supplier information in the questions below, from C.19 to C.21. If it is the <u>same</u>, then GOTO C.22, for example paraffin used for lighting and cooking.*

C.19 Can your main cooking fuel be bought from a supplier in your area (within settlement)? *Please tick the appropriate box.*			
	1. Yes		→ GOTO C.20
	2. No		→ GOTO C.22

C.20 Is this your supplier(s) you usually buy your main cooking fuel from? *Please tick the appropriate box.*			
	1. Yes		→ GOTO C.22
	2. No		→ GOTO C.21

C.21 Why don't you use the local supplier to buy your cooking fuel?

C.22 Are you satisfied with your main cooking fuel?		
	1. Yes	
	2. No	

C.23 What is the second (other) fuel used for cooking? *Please tick all the appropriate boxes.*							
1. None	2. Paraffin	3. Wood	4. LPG gas	5. Dung/ crop residue	6. Coal	7. Ethanol gel	8. Other (specific)

GOTO C.31

C.24 How often is this second fuel used for cooking? *Please tick all appropriate boxes.*				
1. Once a week	2. Last week of the month	3. Less often/irregularly	4. Special occasions, during holidays and celebrations	5. Other (specify)

C.25 When do you usually use your second (other) cooking fuel? *Please tick all appropriate boxes.*				
1. Cooking samp	2. Cooking beans	3. Cooking meat	4. Brewing beer	5. Other (specify)

C.26 Do you buy your second (other) cooking fuel or collect it for free from the surroundings (like coal from a quarry, or wood from fields)? *Please tick the appropriate box.*				
1. Buy	2. Collect for free	3. Mostly buy and sometimes collect for free	4. Mostly collect for free and sometimes buy	5. Other (specify)

C.27 Can your second (other) cooking fuel be bought from a supplier in your area (within settlement)? *Please tick the appropriate box.*	Answer		
	1. Yes		GOTO C.28
	2. No		GOTO C.30

C.28 Is this your supplier(s) you usually buy your	Answer		
	1. Yes		GOTO C.30
			GOTO C.29

second cooking fuel? *Please tick the appropriate box.*	2. No	

C.29 Why don't you use the local supplier to buy your second (other) cooking fuel from?

C.30 Are you satisfied with your second (other) cooking fuel? *Please tick the appropriate box.*	1. Yes	
	2. No	

Comments/Notes:

Space Heating:

C.31 What is the main/regular fuel used for space heating in **winter**? (used for most of the month) *Please tick the appropriate box.*							
1. No fuel, warm clothes and thick blankets, hot water bottle	2. Paraffin	3. Wood	4. LPG gas	5. Dung/ crop residue	6. Coal	7. Ethanol gel	8. Other (specify.

GOTO C.46

C.32 How often is this main fuel used for space heating in winter? *Please tick the appropriate box*						
1. Every day	2. A few times a week	3. Once a week	4. Three times a month	5. Once per month	6. Less often/irregularly	7. Other (specify)

C.33 What are the main reasons for using this fuel for space heating? *Please tick all relevant boxes.*						
1. Affordable/ Cheap	2. Easily available	3. More heat	4. Easy to use	5. Safe	6. Clean, less smoke	7. Other (specify)

NOTE: *If the space heating fuel is different to the lighting and cooking fuels then complete the questions below, from C.34 to C.39. If it is the same, then GOTO C.40, for example paraffin used for cooking and space heating.*

C.34 Do you buy your main space heating fuel or collect it for free from the surroundings (like coal from a quarry, or wood from fields)? *Please tick the appropriate box.*				
1. Buy	2. Collect for free	3. Mostly buy and sometimes collect for free	4. Mostly collect for free and sometimes buy	5. Other (specify)

C.35 Can your main space heating fuel be bought from a supplier in your area (within settlement)? *Please tick the appropriate box.*	1. Yes		→ GOTO C.36
	2. No		→ GOTO C.38

C.36 Is this your supplier(s) you usually buy your main space heating fuel? *Please tick the appropriate box.*	1. Yes		→ GOTO C.38
	2. No		→ GOTO C.37

C.37 Why don’t you use the local supplier to buy your second (other) space heating fuel from?

C.38 Are you satisfied with your main space heating fuel?	1. Yes	
	2. No	

C.39 Why don’t you use the local supplier to buy your main space heating fuel?

C.40 What is the second (other) fuel used for space heating in **winter**? *Please tick the appropriate box.*							
1. No fuel, warm clothes and thick blankets, hot water bottle	2. Paraffin	3. Wood	4. LPG gas	5. Dung/ crop residue	6. Coal	7. Ethanol gel	8. Other (specify.

GOTO C.46

C.41 How often is this second (other) fuel used for space heating? *Please tick appropriate boxes.*				
1. Once a week	2. Last week of the month	3. Less often/irregularly	4. Special occasions, during holidays and celebrations	5. Other (specify)

C.42 Are you able to buy your second (other) space heating fuel from a supplier in your area (within settlement)? *Please tick the appropriate box.*			
	1. Yes		GOTO C.43
	2. No		GOTO C.45

C.43 Is this your supplier(s) you usually buy your second space heating fuel from? *Please tick the appropriate box.*			
	1. Yes		GOTO C.44
	2. No		GOTO C.45

C.44 Why don't you use the local supplier to buy your second space heating fuel?

C.45 Are you satisfied with your second (other) space heating fuel? *Please tick the appropriate box.*	1. Yes	
	2. No	

Energy Expenditure

- *Enumerators must ensure that the quantity of fuels used is always expressed in terms of per month or per week and cost of fuel is always expressed per month*
- *In some instances the enumerator may need to assist respondent with calculating quantities and costs of fuels used per week or per month.*

C.46 On average how much fuel do you purchase per week/month and what does it cost? (Ask only for the fuels used)					
Fuel	**Amount of fuel bought per week/month** (incl. units like litres, kg) *(indicate weekly/monthly)* *(e.g. 5 candles per week or 5 litres of paraffin per week)*	**Fuel costs per month** *(e.g. R20 spent per month candles)*	**Mode of transport used to access fuels** *(e.g. bus, taxi, walk etc.)*	**How often in a week or month is this transport mode used to buy fuel?**	**Total transport cost for all fuels per week/mont h** *(indicate weekly/mont hly)*
1. Ethanol Gel					
2. Candles					
3. Paraffin					
4. Coal					
5. Gas					
6. Wood					
7. Other (specific)					

SECTION D: HOME APPLIANCES

Cooking:

D.1 What is the main appliance used for **cooking**? (**mark with '1'**) Other appliance used? (**mark with '2'**)

Please tick the appropriate box.

	1. Gas		**2. Paraffin**		**3. Wood**		**4. Coal**		**5. Other - specify**
(a)	Gas ring & cylinder		Paraffin wick stove		Wood stove		Coal stove		
(b)	Gas stove		Paraffin primus stove		Wood mbawula		Coal mbawula		

D.2 If you could choose from any (whether have it or not), what would you choose as your **best** appliances for cooking? (**first choice mark with '1', second choice mark with '2'**)

Please tick the appropriate box.

	1. Gas		**2. Paraffin**		**3. Wood**		**4. Coal**		**5. Other - specify**
(a)	Gas ring & cylinder		Paraffin wick stove		Wood stove		Coal stove		
(b)	Gas stove		Paraffin primus stove		Wood mbawula		Coal mbawula		

D.3 If your most preferred appliance stated above is not used by you for cooking, then what are the reasons for you not using such appliances?

Note: *Enumerator to raise awareness of clean fuels and appliances for cooking.*

D.4 Are you aware of any of the following fuels or appliances?

Please tick all the appropriate boxes.

1. Bioethanol gel	2. Solar lamp	3. Solar-powered cooker	4. Wonderbag/ hotbox	5. Diesel/petrol generator	6.Other (specify)

D.5 What is your experience or perception of any of them? *Please complete for each fuel and appliance listed.*	
1. Bioethanol gel	
2. Solar	
3. Wonderbag/hotbox	
4. Diesel/petrol generator	
5. Other (specify)	

D.6 Which appliances would you rather **not** use for cooking (whether you have it or not)?

Please tick the appropriate box.

	1. Gas		**2. Paraffin**		**3. Wood**		**4. Coal**		**5. Other -specify**
(a)	Gas ring & cylinder		Paraffin wick stove		Wood stove		Coal stove		
(b)	Gas stove		Paraffin primus stove		Wood mbawula		Coal mbawula		

Space Heating:

D.7 If using an appliance, what is the main appliance used for heating the house? **(mark with '1')** Others used? **(mark with '2').**

1. Wood/ coal stove		2. LPG (Gas) heater		3. Paraffin heater		4. Wood mbawula		5. Coal Mbawula		6. Other (specify)	

D.8 Choose the appliance you most prefer for heating the house (whether you have it or not)?

Please tick the appropriate box.

1. Wood/ coal stove		2. LPG (Gas) heater		3. Paraffin heater		4. Wood mbawula		5. Coal Mbawula		6. Other (specify)	

D.9 If your best preferred appliance stated above is not used by you for space heating, then what are the reasons for you not using such appliances?

D.10 If you have a cell phone how do you charge it?

SECTION E: HEALTH AND SAFETY IN ENERGY USE

E.1 Has anyone in this household had an accident related to fuel use or appliance use in the last 5 years? *Please tick all the appropriate boxes.*	
1. Yes, fatal accident/s (resulting in death(s))	
2. Yes, serious accident/s	
3. Yes, minor accident/s	
4. Yes both serious and minor	
5. No	
6. I don’t know	

E.2 If yes, what kind of accident occurred? *Please tick <u>all</u> the appropriate boxes*	
1. Lightning	
2. Gas cylinder exploded	
3. Burn from touching hot plate/stove	
4. Child drank liquid paraffin	
5. Stove knocked over	
6. Flame burn	
7. Candle fell over	
8. Stove exploded	
9. Fire	
10. Burn by boiling water	
11. Other (Specify):	

E.3 Do you think that smoke from burning coal or wood is a problem for your health?	1. Yes	
	2. No	

E.4 Do you experience air pollution in your house?	1. Yes		→ GOTO E.5
	2. No		→ GOTO E.6

E.5 What causes the air pollution in your house?

E.6 Do you experience outdoor air pollution in your community?	1. Yes		→ GOTO E.7
	2. No		→ GOTO E.8

E.7 What causes the air pollution in your community?

E.8 Which of the following common illnesses is the household suffering or suffered from in the past? *Please tick all appropriate boxes and specify number of members suffering/suffered from each disease*.	
1. Asthma	
2. Lung infection, bronchitis	
3. Eye disease (redness, burning)	
4. Burns	
5. None of the above	

SECTION F: IMPORTANCE RATING & AWARENESS

F.1 State what you consider to be the three most important characteristics to you from the following list with regard to fuel use. **Rank using 1 to 3** next to your choice (where 1 is very important and 3 are least important. *Households may have to see this table for ease of ranking.*	
Safety	
Availability of energy/ source	

Cleanliness of fuel, air and low smoke level (effects on health)	
Energy vendors or shops are conveniently situated (reliable supply of fuel)	
Cost of the stove/appliances	

GENERAL

Any general comments?

THANK YOU FOR YOUR TIME!