Renewable energy strategies for alleviating energy poverty in informal settlements: A case study of Diepsloot - South Africa

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DECLARATION

I, Pheladi Venda Tlhatlha, declare that the dissertation/thesis, which I hereby submit for the degree (name of degree as on cover page) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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ABSTRACT

Access to modern and efficient energy services is necessary for inclusive economic growth, human well-being and poverty reduction. Energy security and access are recognised for playing major roles in socio-economic development. Eliminating energy poverty goes beyond electrification. It requires consideration of multiple factors such as reducing expenditure, access to energy appliances and equipment, safety and efficiency of energy sources for low -income households. The adoption of small-scale and off-grid systems has proliferated in developing countries, especially in rural areas as alternative options for grid-connected power systems. Renewable energy technologies such as mini-grid systems, solar home systems, solar cookers and appliances provide opportunities for communities to diversify their energy profile and improve their health because these technologies are cleaner and relatively safer than traditional energy sources.

This study explores the challenges under energy poverty and energy use patterns in informal settlements. Furthermore, the knowledge and awareness of renewable energy technologies and alternative energy sources. Diepsloot which is an informal settlement in the City of Johannesburg was used as a case study. Analysing household energy consumption patterns and identifying the energy-related challenges, provides baseline information for addressing these challenges and implementing solutions that are fitted to the context and reality of the communities affected.

The study employed an exploratory approach and a mixed methodology which included both qualitative and quantitative data analysis. For an in-depth analysis, tools such as structured field questionnaires, conversational interviews and direct observations were used. A total of 50 households were sampled in this study. The study found that kerosene was the most used among unelectrified households, while electricity was the most used amongst electrified households. Electrified households reported using secondary energy fuels as kerosene and gas when necessary. The analysis indicated that the majority of the households perceived their household energy usage as inadequate. While most households indicated the most crucial determinants in choosing an energy carrier was affordability, availability and the cleanliness. Energy usage is constrained by factors such as family size, safety and health. The findings reveal that knowledge of renewable energy systems and alternative appliances is limited amongst participants. However, willingness to engage and adopt alternatives is significantly high. Therefore, the study argues through the adoption of renewable energy technology, revised policy framework, capacity building and financial investment energy poverty can be addressed in South Africa.

ABBREVIATIONS

DoE-	Department of Energy
EAs-	Enumerated areas
EBSST-	Electricity Basic Services Support Tariff
FBE-	Free Basic Electricity
FBAE-	Free Basic Alternative Energy
IEA-	International Energy Agency
IEC-	Integrated Energy Centre
INEP-	Integrated National Electricity Programme
IRP-	Integrated Resource Plan
LPG-	Liquid Petroleum Gas
NDP-	National Development Plan
NGO-	Non-Governmental Organisation
RSA-	Republic of South Africa
RE-	Renewable Energy
RET-	Renewable Energy Technology
REIPPs	Renewable Energy Independent Power Producers
SALGA-	South African Local Government Association
Stats SA-	Statistics South Africa
SEFA-	Sustainable Energy Fund for Africa
SEA-	Sustainable Energy Africa
SHS-	Solar Home System
SERI-	Socio--Economic Rights Institute of South Africa
SSEG-	Small-scale embedded generation
UNDESA-	United Nations Development and Security Affairs
WHO-	World Health Organisation

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CHAPTER 1

INTRODUCTION

1. Background

Provision of affordable, reliable, safe and efficient energy supply systems is a major challenge especially in developing countries (Kowsari & Zerriffi, 2011). Having access to adequate and reliable energy is important because it reduces the burden on household members, especially women and children. In addition, it reduces the health and safety risks associated with traditional energy sources/carriers (Kowsari & Zerriffi, 2011). Energy needs vary with climate, region, period, age and sex (Ismail & Khembo, 2015). For example, there is a drastic difference between energy needs for populations living in Sub- Saharan Africa and Europe. The European households have higher space heating energy requirements than Sub- Saharan households. Affordability is another aspect influences choice or the type of energy in different parts of the world. It depends on one's income levels and how far the user is from poverty.

Poverty is an issue that is not centralized around low income; however, it is functional at different levels of income and living conditions and affects people differently. According to the United Nations (1998) fundamentally, "poverty is the inability of having choices and opportunities, a violation of human dignity. It means lack of basic capacity to participate effectively in society. It means not having enough to feed and clothe a family, not having a school or clinic to go to, not having the land on which to grow one's food or a job to fulfil a living, and not having access to credit. It means insecurity, powerlessness, and exclusion of individuals, households, and communities. It means susceptibility to violence, and it often implies living in marginal or fragile environments, without access to clean water or sanitation" (UN statement, June 1998- signed by the heads of all UN agencies). According to Stats SA (2017), over 30,4 million South Africans were living in poverty in 2015. The lack of access to adequate energy sources interlinked with poverty creates a situation referred to as 'energy poverty'.

Energy poverty is defined as the lack of choice in accessing adequate, reliable, good quality, safe and environmentally benign energy services to sustain economic and human development (Reddy, 2008). Bouzarovski & Petrova (2015) stress that "there is a broad range of systemic circumstances that lead to energy poverty these include; institutional factors, political economies, infrastructural legacies, housing structures, income differentials and changes in the affordability of utility services". A large percentage of people in Sub-Saharan Africa are reliant on inefficient energy carriers such as; traditional biomass being, wood, charcoal, and dung which adversely affects their health, well-being, education, and safety and are scarce and costly (Barnard & Schultz, 2015). In Sub-Saharan Africa, solid biomass accounts for the largest energy fuel used. It accounts for 70% of the region's current total final energy consumption (International Energy Agency, 2014). Energy efficiency is broadly defined as using technology that requires less energy to perform the same function.

A key global strategy in addressing energy poverty is identified as electrification. Electrification is often over-emphasised as an approach to tackle energy poverty (GNESD; 2013; 2013, Bouzarovski & Petrova; 2015, Ismail & Khembo; 2015). For instance, in 2013 an estimated that 1.2 billion people lack access to electricity worldwide and 2.7 billion people rely on biomass for cooking (International Energy Agency , 2014). Electrification strategy is desirable because it is one of the most efficient and effective ways to meet basic energy needs and tackle multiple streams of energy utilization. Access to electricity provides for lighting, heating, cooling and cooking, it also enables people to utilize appliances such as cell phones and other telecommunication devices. Conventional electrification is a complex and intensive process; it requires financial viability, labour and infrastructure development and natural resources such as natural gas, coal, and oil. Therefore, ideally, electrification can help alleviate energy poverty, however, most countries including South Africa face numerous challenges in providing it for their population, and hence it is not cheap. Nevertheless, the percentage of households connected to electricity supply stood at 76,7% in 2002 and increased to 84,4% in 2017 (Stats SA, 2017). South Africa has an estimated urban electrification rate of 80% and rural electrification rate of 50%, that indicates that a large portion of the population still has no access to electricity and must use alternative energy carriers (Ismail & Khembo, 2015). Most communities affected by the lack of electricity are those that live in informal settlements or peri-urban settlements and rural areas.

Statistics South Africa defines an informal settlement as “an unplanned settlement on land which has not been surveyed or proclaimed as residential, consisting mainly of informal dwellings” (The Housing Development Agency, 2013). Informality could also include backyard settlements present in formal properties (serviced plots) characterised by overcrowded conditions (Wolpe & Reddy , 2010). Backyards are a common feature of townships and informal settlements, where people rent out space on their properties where extra rooms in the form of formal rooms or shacks are built in the yard. The backyard households usually receive electricity through an extension cable connected to the main house. Backyards are used as a form of income for the landowners. These settlements suffer for the most part from lack of clean water, lack of sanitation, shortage of power, limited ventilation, and health problems such as diarrhoeal and respiratory diseases (SERI, 2018). Informal settlements locally named ‘shacks’ are common on the periphery of large cities due to a multitude of interrelated factors. These include population growth and rural-urban migration, lack of affordable housing for the urban poor, weak governance (particularly in the areas of policy, planning, land and urban management resulting in land speculation and grabbing). Furthermore, unemployment, economic vulnerability and underpaid work, marginalisation and displacement caused by natural disasters and climate change contribute to the proliferation of these settlements. (Marutlulle, 2017). According to the 2011 Statistics South Africa's Household Census, 13,1% (14 450 161 million households) people lived in informal housing in 2011.

The census further indicates that Gauteng had 81.8% of the proportion of municipalities where more than 5% of the dwellings consist of backyard informal dwellings while the Free State had 80%. In the Western Cape, 44% municipalities were affected while only 38.9% of the municipalities in the North West province were affected signifying that the highest proportion of people who reside in informal settlements are mostly concentrated in the largest metropolitan areas (Stats SA, 2013).

Prominent informal settlements in South Africa include Alexandra, Ivory Park, Orange Farm, Diepsloot in Gauteng and Khayelitsha in the Western Cape. According to the Housing Development Agency (2013), the 2011 Census indicated that 62 % of households living in informal settlement enumerated areas (EAs) in Gauteng had piped water in their dwelling or on their yard. An EA is a specific area allocated to one fieldworker to gather survey or census data in an allotted period of time (The Housing Development Agency, 2013). A further 33% could obtain piped water within 200 metres of their dwellings, while 5% had no access to piped water. Households in informal settlement EAs that used to flush toilets connected to the sewage system were 83%, while 5% used a flush toilet with a septic tank or used pit latrines. The remaining 12% had no access to toilet facilities. Conditions in informal settlements are less than ideal for most residents, however, people move to these places with hopes for finding employment opportunities and access to a better standard of life than in rural areas. Currently, approximately 61,4% of the population lives in urban areas, and the projected increase of the urban population in South Africa is set to be 70% by 2030 (South African Government, 2013). Meaning fewer people residing in rural areas and increased pressure on urban municipalities to provide services which include electricity to the bulging population.

The lack of energy in informal settlements is a direct impediment on people's social and economic prospects. When people do not have energy, they face huge obstacles to start any kind of home-based business, make simple activities such as studying, food preparation and storage difficult. One of the key challenges in the energy sector is the prevalence of electricity theft where residents resort to illegal connections from the grid (Runsten, et al., 2018). These connections pose hazardous risks to the community and the people who install them. Incidences of electrocution, burns, and blackouts due to an overloaded system are common in informal settlements as a result of illegal connections (Butera, et al., 2016). Secondly, alternatives to electricity such as kerosene (commonly known as paraffin) and charcoal are intrinsically problematic because they can cause serious health problems and endanger the lives of those who utilize them. Fires, burns and associated fatalities caused using paraffin and candles are common in dense informal settlements. Furthermore, the prevalence of accidental ingestion of paraffin leading to poisoning in children is another problem (Wolpe & Reddy , 2010). According to a World Health Organisation (WHO) report published in 2012, Sub-Saharan Africa had the highest percentage of household indoor air pollution caused by burning solid fuels in poorly ventilated spaces. Energy security is an important aspect to ensure the health and safety of people living in such conditions. The 1998 Energy White Paper emphasized the importance of access to electricity, "energy security for low-income households can help reduce poverty, increase livelihoods and improve living standards". Several studies (Dinkelman; 2011, Munien & Ahmed; 2012, Bouzarovski & Petrova; 2015, Aklin, et al; 2015) have linked improvement in the standard of living with increased access to electricity; hence identifying solutions to address the energy needs of communities could alleviate them from these issues and empower them. A study conducted in Colombia, Poveda & Martínez (2011), indicated that improvements in energy supply per capita had a close relationship with a decrease in poverty.

Eliminating poverty is a shared global development agenda. This was evident in the summits such as the Johannesburg World Summit on Sustainable Development in 2002. This highlighted the importance of eradicating poverty for sustainable development. The adoption of the Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs) in 2015 by nations is another step-in transitioning to a world with less hungry people. SDGs number 1 and 7 aim for eradicating poverty and to ensure universal access to affordable and clean energy by 2030. Access to modern and efficient energy services is necessary for inclusive economic growth, human well-being and poverty reduction. This could be achieved by employing adaptive strategies and technologies. Renewable energy technologies such as small- scale solar generators, solar cookers, and biogas digesters can be retrofitted into communities that lack efficient energy carriers to achieve this purpose. Given the above background, this study raises several questions regarding energy poverty in informal settlements like Diepsloot.

1.1 Research questions

1. What are the household energy use patterns in the Diepsloot community?
2. What are the challenges associated with energy poverty in informal settlements?
3. Which renewable energy strategies can be implemented in informal settlements?

1.2 Research aim

The aim of this research is to investigate energy use patterns, energy poverty challenges and identify renewable energy strategies that can be implemented in informal settlements.

1.3 Research objectives

The aim of this study will be achieved through these objectives:

1. To evaluate the energy use patterns of informal households in Diepsloot.
2. To identify challenges, the community of Diepsloot face in accessing energy.
3. To investigate the knowledge of renewable energy technology in Diepsloot.
4. To identify renewable energy strategies for energy poverty.

1.4 Motivation for research

The purpose of this research is to analyze the energy use patterns and energy-related challenges in Diepsloot and explore energy strategies to reduce the impacts of energy poverty in informal settlements. Such knowledge can play a crucial role in understanding the concept of energy poverty in South African informal settlements. Research needs to be undertaken to contextualize energy needs and solutions to meet these needs. Small-scale renewable energy projects have helped several people across Africa in accessing easier and safer energy carriers, propagation of these energy carriers is very important. The increased uptake of small scale RE projects highlights that renewable energy system, do not have to be on a macro-scale to impact people's lives. They can be implemented on a micro-scale to change the state of energy-disadvantaged communities.

1.5 Organization of the research

This thesis is structured into five chapters. **Chapter one** provides the introduction of this study which includes the motivation, rationale of the study. This chapter also raises the research problem, research aim, and objectives of the study. **Chapter two** deals with the literature review, which outlines the conceptual framework for the study by providing a literature exploration about the information used across the world and literature. **Chapter three** describes the methodologies used with regards to research design, sampling, the collection of data and analysis are discussed in detail. **Chapter four** discusses the observations, results and analysis of the results. Finally, **chapter five** entails a summary and conclusion to the research and further explores recommendations that are informed from the results.

1.6 Conclusion

In conclusion, the provision of adequate and reliable energy systems are important factors for socio-economic development. Energy poverty is a multi-faceted problem that affects marginalized communities such as those that live in informal settlements. Informal settlements are a feature of the urban geography in South Africa due to infrastructural legacies, unemployment and poverty. By critically analyzing the energy patterns and challenges, strategies may be implemented to achieve energy security. The next chapter will detail the literature review of the study.

CHAPTER 2

THE THEORETICAL FRAMEWORK OF ENERGY POVERTY

2.1 Introduction

This chapter reviews the six main themes of energy poverty and energy strategies in South Africa. Methods which energy poverty is measured, energy poverty challenges, energy use patterns, the energy landscape in South Africa and renewable energy and technology trends across the world are explored.

2.2 Measuring energy poverty

Measuring energy poverty is an integral part of understanding the extent of its effect and exposure. Literature is dominated by various approaches to measuring energy poverty. Approaches to measuring energy poverty include using energy as a function of income (or expenditure), physical energy requirements and well-being (Barnes, et al., 2010; Pachauri & Spreng, 2004). The Department of Energy (2012), reported energy-related behaviour and perceptions in the residential sector in South Africa and identified four instruments to measure energy poverty. These included; expenditure-based approach, subjective approach, thermal inefficiency approach and the low income and thermal inefficiency approach.

Expenditure-based approach regards that a household that spends more than 10% of their net income on energy is energy poor. The income and expenditure of households is an important driver and indicator of the type and energy consumption a household can afford. Using household data of Bangladesh, Barnes, et al (2010) found that energy consumption rises with increased household income. In previously defined low-income households, increased income allows households to diversify energy carriers and energy use patterns. For example, a household with an increased income can choose kerosene for cooking and heating because of safety and efficiency rather than using traditional biomass. A study by DoE showed that 43% of South Africans are energy poor, as they spend more than 10% of their income on energy needs, with many households in the lowest Living Standard Measure group (LMS) spending 25% and more of their income on energy (Department of Energy , 2012).

The thermal efficiency approach evaluates the thermal condition of the households relative to their social needs. Thermal efficiency is rated by how much energy is needed to heat up households to an acceptable level, often included in domestic energy costs (Department of Energy , 2012). According to the low income and thermal inefficiency approach, a household is energy poor if it has less than 60% of South Africa's median per capita monthly income, and meets one or more of the following conditions; firstly, the household reports that it is dissatisfied or very dissatisfied with its accommodation. The state of repair of the household is described as "poor". One or more of the following problems are reported with the accommodation: lack of adequate heating, a leaky roof, damp walls, floor or foundations, or damaged or broken windows or doors. Lastly, the health of a household member has deteriorated due to the housing conditions (Department of Energy, 2012).

The subjective approach considers that a household is energy poor if it is characterised by one or more of the following attributes; firstly, the amount of energy the household uses is reported as being less than adequate for its needs. Secondly, the amount of energy the household uses for lighting is reported as being less than adequate for its needs. Thirdly, the amount of energy the household uses for cooking is reported as being less than adequate for its needs. Lastly, the amount of energy the household uses for heating rooms and keeping warm is reported as being less than adequate for its needs (Department of Energy , 2012).

Nussbaumer et al (2012), argues that the most effective approach of measuring energy poverty could be to use a Multidimensional Energy Poverty Index which includes indicators such as access to modern cooking fuels, access to electricity for lighting, a cooking space without indoor pollution, telecommunication means (landline or mobile phone), entertainment/education (radio or television), and household appliance ownership.

2.3 Challenges under energy poverty

Energy is considered important, living without access to affordable and adequate energy carriers leads to multiple challenges. Energy poverty is severely felt by people living in informal settlements; this is because they are often underserviced and degraded. The Housing Development Agency (2013), notes that unemployment rates are prominently higher in informal settlements and that this is consistent with informal settlements acting as ‘arrival cities’ accommodating those seeking an entry point into the labour market. This implies that many people living in informal settlements fall under the low-income category and they experience unique struggles in these settlements. To understand the quality of life in informal settlements Richards, et al (2006) studied the quality of life perceived by residents in four informal settlements in South Africa. The study indicated that the majority of the residents were dissatisfied with their living conditions with the highest level of satisfaction just over 10%. Many are under immense poverty; they lack access to adequate sanitation facilities and water for drinking, hand-washing and personal hygiene. Social challenges, such as crime, also affect residents in informal settlements where they become more fearful at night due to the lack of basic policing, services and infrastructure such as streetlights or paved roads, which exposes them to the risk of victimisation (Richards, et al., 2006). Poor access to services and infrastructure leads to frequent social unrest in the form of community protests that are frequent in informal settlements.

The lack of adequate energy carriers is linked with a decreased level of human well-being (Jose, 2001). Traditional fuels such as kerosene and candles are associated with severe health and safety risks such as burns, fires, scalds and poison incidents. In a quantitative study to assess the relationship between the risk of these accidents, household income, and energy poverty, Kimemia et al (2014), found that for households below an energy poverty threshold, the risks of energy-related accidents rise with an increase in household energy use but falls once households cross this threshold. The risk of fire in townships in South Africa is exacerbated by factors such as the density of settlements, the flammable materials used to construct most shacks. According to UNDESA (2014) in South Africa, each year almost 80,000 young children unintentionally ingest kerosene (spilled from lamps) to the point where they need to be admitted to the hospital. The kerosene attacks the lining of the lungs and causes pneumonia that often leads to death (Lloyd, 2014). Even with treatment, more than half (60%) develop chemically induced pneumonia. Marmot Review Team (2011), performed a study on the health impacts of cold homes in the United Kingdom (households which use less energy to heat their homes adequately) and fuel poverty. It revealed that cold housing has a strong relationship with respiratory and cardiovascular diseases, particularly in winter months. Low indoor temperatures and inadequate thermal efficiency exacerbate these conditions. The impact is exacerbated for vulnerable individuals and the colder the temperature the greater the risk of harm, for instance, temperatures that are lower than 16 degrees appear to impair respiratory functions, while temperatures below 12 degrees place strain on the cardiovascular system (Marmot Review Team , 2011).

The Nelson Mandela/HSRC Study of HIV and AIDS (2002), showed that residents in informal settlements were more prone to diseases such as HIV/AIDS than were residents in formal suburbs (Richards, et al., 2006). The high rates of HIV among residents of informal settlements importantly point to structural drivers of the epidemic, especially poverty. Adequate household energy for sustained physical wellbeing and energy levels are essential to fighting the effects of the disease. The indoor environment is very important for people living with HIV, the use of biomass fuels indoors leads to respiratory problems, due to the incomplete combustion that produces dense smoke, and this is also exacerbated by the poor thermal efficiency of shacks. Therefore, the use of cleaner energy carrier could be a contributing factor to healthier individuals living with HIV.

The relationship between energy poverty and gender dimensions are crucial to evaluate because women and children are the most vulnerable and marginalised groups in developing countries (Munien & Ahmed, 2012). The burden of energy poverty is heavily felt by women and girls because of the associated gender roles that shape their responsibilities and day-to-day activities (Rewald, 2017). Gender-based roles do however vary depending on the geographical region; however, most studies indicate that women are tasked with the role of collecting firewood more than their male counterparts, this is especially pertinent in rural households (Rewald, 2017).

To perform their tasks, women rely heavily on their own human energy with the help of tools and animals, especially if they do not have access to other forms of energy. Lack of transportation technologies, water pumps, modern cooking fuels, electric appliances, and other tools that require energy access mean that women in poor households must exert much more of their own energy. In addition, women are tasked with preparing the food, which includes, crushing, farming and grinding before preparation and distributing the food to their families. These duties are often heavy burdens and barriers for young girls, who are expected to go to school or studying for tests and exams. In a study on the effects of rural electrification in Kwa- Zulu Natal, Dinkelman (2012) found that female employment significantly rose as electrification rates increased. Because electrification acts as a labour-saving technology more women had time to seek employment.

2.4 The energy landscape of South Africa

The South African government largely focuses on electrification as the means of providing energy security in the country (Department of Energy , 2012). The government aims to reach a 97% electrification rate by 2025 through a combination of on-grid and off-grid technologies, especially solar home systems (International Energy Agency , 2014). Currently, 90% South Africa's electricity generation is derived predominately from coal, with approximately, 5% from nuclear, and 5% hydropower, solar and wind derived (International Energy Agency , 2014). A critical challenge is planning and implementing energy strategies that have simultaneously growth in terms of social and economic aspects, notwithstanding the consideration for environmental damage. The post-apartheid government has made strides in electrifying many homes previously without access and at a relatively affordable price through various policy measures such as the White Paper on Energy Policy which was promulgated in 1998 and the Integrated National Electrification Programme (INEP). South Africa's policy covers both the supply and demands the country is projected to have. The energy capacity derived from renewable energy was planned to be 15% and a priority level two in the policy. However, the White paper has outlived its usage and it has not been revised since 2008 (Department of Energy, 1998). In 2014, renewable energy contributed less than 2.5% to total primary energy consumption (Department of Energy, 2015).

One of the major constraints with conventional energy carrier infrastructure is the baseload capacity. It is not efficient enough to cater for a growing population and economy. The national electricity supplier Eskom had planned to build additional power plants before 2008, however, due to a multitude of reasons including ineffective planning and investment, the country experienced an energy crisis with rolling blackouts between 2008 and 2015. This subsequently led to a scheduled 8% annual tariff increase to fund for the planned power plants which are Medupi and Kusile, which will only be fully operational by 2020. This increase in tariffs makes electricity less affordable to those who have access and less attainable for those who do not have access. The energy sector is under pressure to sustain the electricity access for the households that are connected to the grid and provide electricity for the population that does not have access to electricity.

Given that there is pressure on service delivery and economic instability in the country, there is a need to consider alternative sources of energy to power the country. It is evident that non-renewable grid-based electricity supply is insufficient to meet energy demands in South Africa. To tackle the problem, the Integrated Resource Plan (IRP) 2010-2030 proposed that South Africa would reduce its dependency on a coal-based electricity generation from 90% to 65% by 2030 and transition to alternative generation options (Department of Energy, 2015). Thus, electricity generated using nuclear would account for 20% of the total share in 2030 and 14% would be generated from renewable sources like wind, solar and hydropower. To provide opportunities for the private sector to invest in renewable energy the Renewable Energy Independent Power Producer Procurement Programme (REI4P) was initiated by the government, which allows companies to bid for renewable energy projects on the condition that they supply electricity to the national grid at a fixed price (Ismail & Khembo, 2015).

2.4.1 Pro-poor energy policies

The main objectives set out in the National Development Plan (NDP) include eliminating poverty, reducing inequality, increasing energy security and enhancing socio-economic and environmentally sustainable growth by 2030. The energy sector is a key strategy to address social and economic problems such as poverty and standard of living because this sector could generate higher and adequate energy systems with more efficient and clean energy. At a policy level, South Africa has attempted to address the energy needs of the low-income households through Free Basic Electricity (FBE) in 2003 and the Free Basic Alternative Energy (FBAE) in 2007 (Department of Energy , 2012). Through these policies, municipalities are responsible to provide free basic energy within the parameters of the Electricity Basic Services Support Tariff (EBSST) Policy which entitles indigent or poor households to 50 kWh of free basic electricity per month, although municipalities might choose to provide more at their own cost (Stats SA , 2017). Ruiters (2009), argued that the amount provided by the FBE is generally inadequate to meet the needs of the poor. For example, a small refrigerator would use more than 50 kWh if run for 24 hours a day and depending on the size of the household more energy would be required to meet basic needs, the policy, however, does not take that into account.

The Free Basic Alternative Energy provided households with R56.29 per month of alternative fuels/technology such as paraffin and Liquefied Petroleum Gas (LPG). However, the number of households receiving FBAE is still small, because municipalities struggle with administration and monitoring of the programme (SALGA, n.d.). Although these programmes benefitted several low-income households, they did not alleviate the struggles of those households because most households must still substitute other basic needs such as food to top up or use alternative fuel sources for additional energy needs such as space heating.

The DoE has set out Non-Grid Electrification guidelines for the electrification of un-proclaimed areas. Informal housing has been categorised in terms of how viable they will be for electrification. Category

1 is housing found on suitable land (complies with the set criteria and is likely to go through in situ upgrading) and will be subsidised for electrification. Category 2 are settlements that do not need immediate relocation and will, therefore, go through the process of regularisation which is pre-formalisation (putting basic services with plans to relocate in future) will be subsidised if the settlement will not be relocated in the next 3 years. Category 3 are houses on unsuitable land (do not comply with the set criteria, areas such as on dolomite land, in toxic areas, or in a dangerous area) and need relocation. Settlements that have been there for a reasonable amount of time will be considered on a case by case basis upon application by the department.

2.5 Energy use patterns in informal settlements

Energy access is disproportionate across age, race, region and dwelling types in South Africa. Using the National Income Dynamics questionnaire, to determine energy poverty in South Africa, Ismail & Khembo (2015) found that the Black African populous is more energy poor than other races in South Africa. Rural and informal households are more likely to be energy poor than urban households. more educated people tend to be less energy poor than uneducated people (Ismail & Khembo, 2015). Households with higher living standards largely have access to more reliable energy carriers and energy end-use equipment in comparison to lower living standard households, this is indicated by figure 2 which shows energy carriers for basic needs for cooking, space heating, water heating and lighting in different household standards. The lack of efficient energy carriers leads to increased expenditure and time spent on preparing food or heating up.

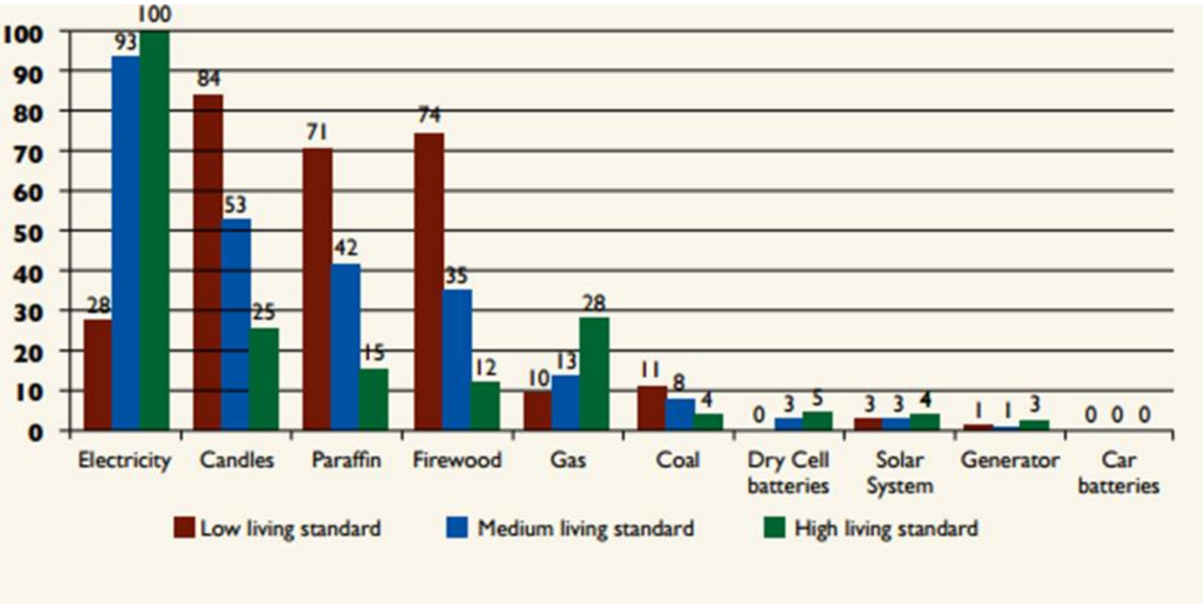

Figure 1: Use of energy carriers for lighting, cooking or heating, by living standard level (percent using) in South African households, (Department of Energy, 2012).

As indicated in figure 1 that most households who fall under the low-living standard category use candles, firewood, and paraffin as a major source of energy. SALGA (u.d) summarised statistics based on the Department of Energy (2012) household energy patterns study, which showed that two-thirds of unelectrified households rely on candles as the main lighting source while the remaining third rely mainly on paraffin. In urban informal settlements, two-thirds of households use electricity for cooking (68%), while close to third (27%) of households rely on paraffin, non-electrified households use paraffin and firewood as the dominant energy carrier for cooking (50% and 40% respectively) (SALGA, n.d.). For space heating, 12% of households use paraffin and 9% use firewood. Coal, gas and other sources are utilised by less than 5% of households for space heating.

A common model to describe household fuel choices is the 'energy model' which ascribes differences in energy-use patterns between households to variations in economic status (van der Kroon, et al., 2013). The energy ladder model which is depicted by figure 2 below, states that households start at the lowest phase of the ladder, where the household energy carrier is distinguished by using universal combustion of biomass in a form of agricultural residues, dung, and wood. The second phase is defined by the shift to so-called transitional fuels such as charcoal or kerosene, while the adoption of more modern energy forms like LPG, natural gas, or electricity constitutes the final step on the energy ladder model up the energy ladder (Treiber et al, 2015). The linear model predicts a positive relationship between socioeconomic development and adoption of and a transition to more efficient, cleaner, and costlier energy carriers. It implies a complete transition from one fuel to another as income and access increases. On the contrary, Treiber et al (2015) and van der Kroon et al. (2013) found that in reality, the energy transition is more complex than the energy ladder model suggests. Rather, trends indicate that when there is access to multiple fuel sources, energy diversification is achieved, meaning that households mix different fuels depending on the task and efficiency of the energy carrier. They concluded that 'people's ability to afford and access energy increases energy diversity'. This is explained as the energy stacking model (figure 2), the usage of a combination of multiple energy carriers and conversion technology depending on the budget, preference, and need (Kowsari & Zerriffi, 2011). Energy stacking is persistent in low-income households and informal settlements (Wolpe & Reddy , 2010). As Treiber et al (2015) explain, households choose different fuels based on in terms of the task needed, cost-effectiveness and efficiency. Multiple fuel choices could also be an indication of lack of energy security in a selected fuel source, having access to electricity does not indicate affordability thus it could be supplemented with additional fuel choices to ensure energy security.

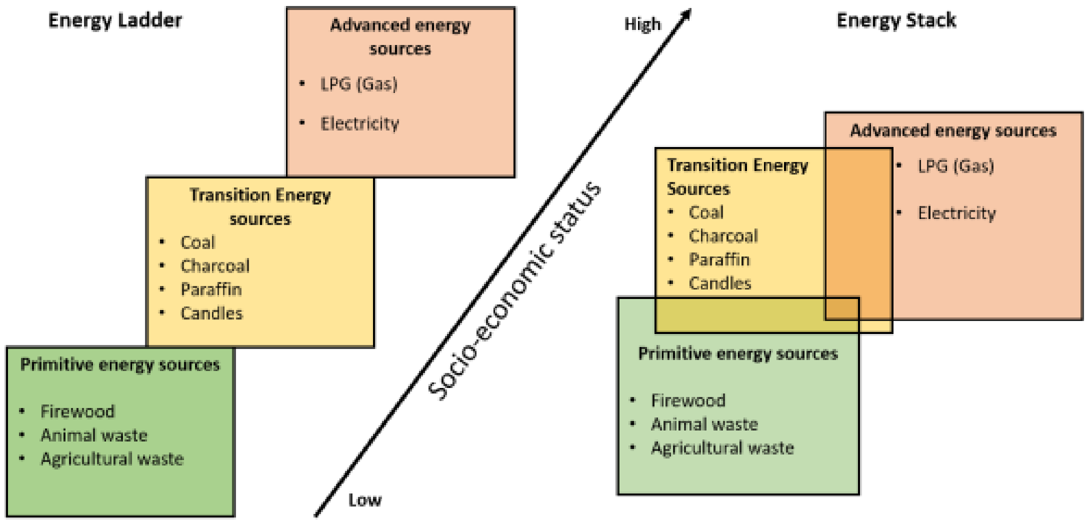

Figure 2: Energy transition process: Energy ladder model versus Energy stacking model (van der Kroon et al. 2013).

Limited access to energy services directly influences the type and access to technological options to use in homes, such as cell phones, computers, electric stoves, washing machines, and others. Without a telephone, people have a hard time staying in touch with friends and family. Furthermore, without television or radio, they lack access to informative or entertaining programs. A study by Pachauri & Spreng (2004), highlights that two levels of energy services need to be considered when evaluating energy access. The first level is direct access where households have physical access to electricity through a secure connection to the grid. The second level is the indirect access, which refers to access to equipment such as heaters, stoves, and lamps which transform end-user energy into heat, mechanical drive, and light. The indirect access to energy is often neglected; however, it should be prioritised to be affordable and accessible to the end-user since the cost may be too high for households living under the poverty line. As Clark & Drimie (2002), articulates "electricity access is not the panacea of energy poverty".

2.6 Renewable energy trends

Renewable energy resources are defined as those “derived from natural processes” and “replenished at a faster rate than they are consumed” (IEA, 2017). Solar, wind, geothermal, hydro, and some forms of biomass are common sources of renewable energy. Globally, renewable energy is being prioritised as a major key in alleviating energy poverty in communities (REN21, 2017). The main attractions of renewable energy are its ability to provide clean energy, its accessibility, and affordability to impoverished communities that are off-grid. Renewable energy carriers have minimal damage to the environment and are cheaper. Solar PV is becoming increasingly competitive with diesel generation, as well as with other renewable technologies (IEA, 2014). Although concentrated solar power (CSP) has one of the highest average costs of energy generation today, it is still an attractive option for remote areas when the transport costs for diesel are high (IEA, 2014). Immense solar electrification potential lies in Sub-Saharan Africa due to the high solar radiation which averages to 6 – 8 kWh/m2/day (Longe, et al., 2013). The CSIR 'Least-cost electricity mix for South Africa by 2040' study, found that having 70% renewable energy by 2040 was not only technically feasible but also the cheapest option for South Africa (being at least 40% cheaper than new baseload coal). This would mean a more affordable and efficient, not to mention a safe and healthy, electricity supply for the public. Despite this enormous drive for renewable energy, the momentum of driving our consumption on renewable energy has been stagnant (Brent & Kruger, 2008).

Renewable options alone cost less over time, benefiting from technological advances and a larger scale of production. By 2040, the delivered cost of diesel would have to be less than $0.50 per litre to be competitive with the anticipated cost of generation from solar PV (World Energy Council , 2016).

For the poorest communities, smaller solar technologies, such as solar lamps, can provide an invaluable initial step towards electricity access. On-grid and off-grid solutions that are less capital-intensive and require less investment in infrastructure account for around 30% of the total (World Energy Council , 2016). Renewable energy technologies are regarded as particularly suitable because they can provide small-scale solutions and decentralized energy supply that meet the needs of the population most widely affected by energy poverty. Renewable energy technologies have advanced however, there are still constraints surrounding the development and integration into energy systems. Importantly, as Aklin, et al (2015) points out despite the appealing characteristics of solar micro-grids (and off-grid systems in general), there is little systematic evidence regarding their actual benefits, especially in South Africa.

2.6.1 Case Studies of Renewable energy (RE) *projects*

The RE systems implemented often rely on local resource availability, it would be difficult to implement systems such as small hydro or wind technologies in informal settlements due to space limitations and availability of the natural resource. Therefore, this study highlights RE systems that would be most feasible for informal settlements in South Africa.

Ishack: Solar home utility model

Solar Home Systems – are designed to meet the needs of a single household. These systems are made up of solar photovoltaic panels, a battery, charge controller and sometimes an inverter. It is an interim relief project that operates in the informal settlements of Ekanini and Longlands in Stellenbosch. It has a solar home system that consists of 100 W solar panels, battery and DC appliances such as lights, phone chargers, and TV. It uses a pay as you go, model, which means that the beneficiaries of the system pay for it monthly, however, the Stellenbosch Municipality provides the FBE subsidy to reduce the cost of the SHS to the household and this is paid directly to Ishack (SEA, 2017).

Some of the challenges associated with the Ishack project include the limited education to the limits of the Solar Home Systems for households using them. Making sure the batteries last as long as possible while still providing a certain level of utility, this means enforcing limits on output and appliance use. Winter is the most challenging time, as the systems rely on solar energy to recharge. When this doesn't happen, systems may cut off to protect the battery meaning that households must use other energy sources when the SHS is not operational.

Often solar appliances are used in combination with SHS. These are devices, often lights, which have a small built-in solar panel and battery. These appliances are typically portable and generate enough electricity to power themselves.

Energy Shops/ Integrated Energy Centres

The Desert Research Foundation of Namibia conducted a project that was aimed at encouraging entrepreneurship and enhancing access to modern energy services in the off-grid and informal settlements of Namibia (Wuppertal Institute , n.d.). This was achieved through supporting the establishment of "Energy Shops" which used solar systems and were operated by selected community entrepreneurs. The Energy Shops/Energy Kiosks – use solar photovoltaic energy to provide services such as, charging facilities for customer devices (such as cell phones and rechargeable electronics) and generates electricity to charge battery packs, which customers lease and take home for use and the operation of small business such as hair cutting. The entrepreneurs were given business management and technical operations training for the usage of the solar business systems (Wuppertal Institute , n.d.).

A similar concept to energy shops is the establishment of Integrated Energy Centres (IECs) or community energy service centres. Which serve as community information hubs and energy shops. There are different operational models of operating IECs, in South Africa, most are built as a one-stop energy shop owned and operated by the community Co-operative (Machogo, 2016). They are also organised as a community project funded by Petroleum Companies and such as Sasol or Engen and operated in collaboration with local Municipalities and the Department of Energy. They provide services such as the selling liquid paraffin (IP), liquid petroleum gas (LPG), candles, petrol and diesel from oil companies at affordable prices to mostly rural community. Although these IECs are not providing RE appliances, they plan to incorporate them into their products. Initiatives such as the Solar Turtle demonstrate the conceptual idea of community energy service centre into practice, which include the facility to charge batteries to be used in home systems, as well as charging of appliances such as cell phones and lanterns, along with refilling of LPG for cooking (Runsten, et al., 2018). An example of a similar solution applied in rural settings is the Solar Turtle. In the context of informal settlements on land unsuitable for housing, such centres could offer the advantage of providing the energy services from another site which is more compliant with the institutional framework. The service is thus not provided to the problematically located household directly but rather to the people that due to their situation may have little option but to reside there (Runsten, et al., 2018).

Efficient firewood-stoves

The WWF (2016) conducted a case study for sustainable livelihoods through more efficient energy equipment in Kenyan farming households and found that by providing households with fuel-efficient cooking stoves, the overall demand for firewood decreased by 50%. Each stove saved up to 6 tons of CO2 per year compared to the conventional open fireplaces. The stoves provided are similar to the Tikikil stoves that were rolled out in Ethiopia and are helping thousands of people use less firewood for cooking. Another case study by WWF was based in Madagascar where they initiated a programme that promoted energy efficiency measures, such as solar cookers and efficient wood stoves and distributed energy-saving lightbulbs which resulted in reduced electricity expenditure, lower greenhouse gas emissions and increased awareness of the benefits of solar and efficient fuel stoves in the communities.

Micro/mini-grids

Micro/Mini-grids – consist of one or several energy generation sources (Solar, Hydro, and Wind), storage, and a distribution network, which connects multiple users to electricity. The energy is stored and shared amongst a fixed number of households and or businesses. Mini-grids are best suited for dense urban areas where the users are all clustered together. The prevailing business model is for a business to build, own and operate the system, selling time on it to the end-users. The Kenyan government's rural electrification master plan from 2008 supports the retrofitting of existing diesel-based decentralised power stations into hybrid schemes with solar PV. One such mini-grid solar photovoltaic scheme (13kWp) was constructed in two rural communities in Makueni County. The mini-grid system electrified mostly businesses in a trading centre, rather than households. According to Bahaj, et al (2019) after electrification there were relative increases in the number of businesses and business income. Comparing the households in the areas around the trading centres, perceived wealth increased more around the electrified trading centre.

2.7 Renewable energy strategies in South Africa

The National Integrated Energy Plan is the instrument that is used to prioritise energy in SA, the plan has 8 key national integrated energy objectives. Emphasizing the objective to minimise the cost of energy through electricity reticulation (tariff setting, cross-subsidization); human settlements (housing delivery); public transport (limited) which are mandatory local and municipal functions. Another objective is to increase access through electrification, FBAE, human settlements (thermal efficiency), public transport and spatial planning. Renewable energy technologies are strategically chosen to facilitate the achievement of energy targets. The mere availability of a renewable energy resource does not mean that resource can readily be used as an energy carrier. To utilise a resource several factors, need to be considered: the conversion system, quality of the fuel, conversion cost, transport cost as well as the size and location of the demand. The South African Renewable Energy Resource Database (RRDB) is based on the analysis of a comprehensive data set, which covers the whole of South Africa. National-level data is useful in identifying potential resource types and localised densities or areas of highest probability. The RRDB incorporates a focused and detailed analysis of specific areas. The identified energy resources are wind, solar, hydropower, biomass and waste-to-energy, biofuels, geothermal and cogeneration. Local projects for renewable energy are further shown in table 1.

Table 1: Overview of renewable energy projects currently underway in South African municipalities, (SALGA, n.d.).

Renewable energy projects	
Solar water heater installation	• Low-pressure solar water heaters (SWH) are being installed in some municipalities (e.g. Chief Albert Luthuli Local Municipality (LM), eThekwini Metro, Polokwane Municipality) as part of the national solar water heater programme run by Eskom & the DoE. • High-pressure SWH campaign being run by City of Cape Town (endorsement programme).
Solar PV installations	1. Some larger municipalities (and provinces) are installing PV on municipal building rooftops for grid feed-in.
Solar PV traffic lighting	2. Pre-feasibility studies are being carried out on the installation of solar PV panels on traffic lights in a couple of municipalities (Msukaligwa LM, Mbombela LM & Midvaal).
Bio-fuels	3. Feasibility studies on potential biofuel projects have either been conducted or are in the process of being carried out in some municipalities. Some of the municipalities (Umvoti Local Municipality, EThekwini, Ingwe Local Municipality) are working with sugar producers and Eskom around the development of such projects. While some are community-run projects.
Rural Off-Grid PV electrification	4. Most rural municipalities indicated that their municipalities are recipients of the national small-scale solar PV installation programme being run by Eskom & the DoE.
Municipal waste-to electricity	5. Several municipalities (Emnambithi/Ladysmith Local Municipality, Emalahleni LM) have conducted, or are in the process of conducting, feasibility studies on landfill gas to electricity. However, one municipality that has completed such a study indicated that no developers seem interested in carrying out

	the project although the feasibility study indicated a potential for this. 6. SALGA & GIZ are aiding Umjindi municipality (Mpumalanga) on developing a waste- to -electricity project. 7. Studies on the generation of electricity for on-site operations from wastewater indicate feasibility.
Wave energy/power	8. Hibiscus Coast Local Municipality indicated that it was investigating generating 40GW electricity from the Agulhas Current System (Indian Ocean).

In 2015, the Department of Energy released its 2015-2030 strategic plan which seeks to bring at least 280 000 new grid and off-grid connections within its budget cycle (Department of Energy , 2015). Furthermore, urban areas have been identified as new priority areas where off-grid connections will be established. The clean energy programme is the strategic programme central to renewable energy and Energy Efficiency & Demand-Side Management (EEMSM) initiatives. It seeks to manage and facilitate the development and implementation of effective renewable energy initiatives (Department of Energy , 2015). The programme targets include having 15 MW of renewable energy deployed off-grid and 105 000 of solar home systems installed (Department of Energy , 2015). The challenging aspect with this plan is that the deployment of major infrastructural plans is targeting electrification backlog for permanently occupied residential housing, conversely, informal settlements are not considered formal residential housing.

On a regional level, local governments and municipalities are tasked with implementing the national strategies. Implementation is a challenge because of the restrictions placed by the national legislative environment. “This includes not clearly specifying the role/mandates of municipalities in implementing energy efficiency and renewable energy measures”. For example, some policies might set targets for the implementation of energy efficiency and renewable energy at a national level, without clearly identifying the municipal mandate in this regard. If municipalities are expected to contribute, as broadly identified in the policy, these need to be translated into specific Key Performance Areas (KPA’s) within municipal management systems. The Municipal Financial Management Act (MFMA) is also complex in relation to municipal procurement abilities for both energy efficiency and renewable energy technologies” (SALGA, n.d.).

The South African Local Government Association (SALGA) identified strategically important energy efficiency interventions, considering municipal ‘reach’, impact on energy savings and addressing poverty, these are:

1. Efficient lighting in low-income housing

2. Ceiling retrofit (thermal efficiency) in existing low-income housing stock

3. Efficiency retrofit (SWH or heat pump) of residential mid-high-income water heating appliances – through endorsement and other schemes

4. Efficiency retrofit of Heating, Ventilation, and Air Conditioning (HVAC) systems in the commercial sector – through information and other schemes

5. Efficient lighting across all sectors.

Some provinces like the North West and the Western Cape have developed their local renewable energy programmes. It is evident that energy efficiency is primarily active on the demand side whilst renewable energy is active on the supply side. The implementation of these programmes needs to be thoroughly investigated although national policy aims to alleviate energy poverty for all South African residents. The informal sector is not addressed in totality. For instance, Southern African Development Community (2016) suggests the creation of innovative micro-credit financing for cooking/heating/cooling RE and EE projects and off-grid electrification, to upscale adoption of sustainable energy equipment such as ICS4 and solar lanterns by the poor and other disadvantaged groups. The housing subsidy backlog influence infrastructural and energy plans, thus if the housing backlogs drag longer the energy plans would also fall behind.

2.8 Conclusion

This chapter explores the methods of measuring energy poverty, while many scholars argue for a standard measurement framework, there is currently no consolidated framework within literature. The inconsistencies within these various methods make it difficult to have clinical analysis of the extent of the problem. Furthermore, this chapter discusses the energy landscape of South Africa and draws from case studies to showcase the renewable energy solutions that some developing countries are utalising to alleviate the problem of energy poverty. There are great lessons to learn from in terms of the shortfalls of the pro-poor energy policies that South Africa has implemented. There is a need for the current renewable energy strageties to be more encompassing for all forms of informal settlements.

CHAPTER 3

STUDY AREA & METHODOLOGY

3.1 Introduction

The methodology elaborates the processes and instrumentation the study deployed to collect and analyse data. An exploratory approach to collect data on understanding household energy consumption patterns, factors that influence energy decisions and renewable energy knowledge was applied. Furthermore, analysing secondary data from various literary sources such as statistical reports at national and international levels, reports of government agencies and advisory bodies and research papers on the topic of renewable energy strategies are not overlooked.

3.2 Study area

Diepsloot township dates from 1994 and is situated in the northern periphery of Johannesburg, is shown in figure 3. It was originally developed for the temporary relocation of settlers from nearby informal settlements but has since become an established formal residential area. The township is divided, one part (Diepsloot West) was developed into sites and serviced, while the other (Diepsloot One), is intended for temporary settlement (Benit, 2002). Diepsloot One has more of the characteristics of a shanty town: shacks abound, and poverty and the lack of facilities are widespread (Benit, 2002). With an estimated population of 138,329 people (Stats SA, 2017), Diepsloot is home to a diverse group of people from various regions in South African, has also immigrants from various Southern African countries. The majority of the population is young adults who make up 55% of the population. There are over 24,737 informal houses in Diepsloot, and the temporal nature of the settlements is a constraint when it comes to developing and improving service and infrastructure.

Granted, housing improvements have been made in the area with an estimated 5 000 formal housing units under the Reconstruction and Development Programme (RDP), self-built houses on serviced sites, and a small number of bank-financed houses (Johannesburg Development Agency, n.d.). Basic service delivery has improved, with more than 74% and 61% of the residents having access to flush toilets connected to the sewerage system, and electricity for lighting respectively (Stats SA, 2017).

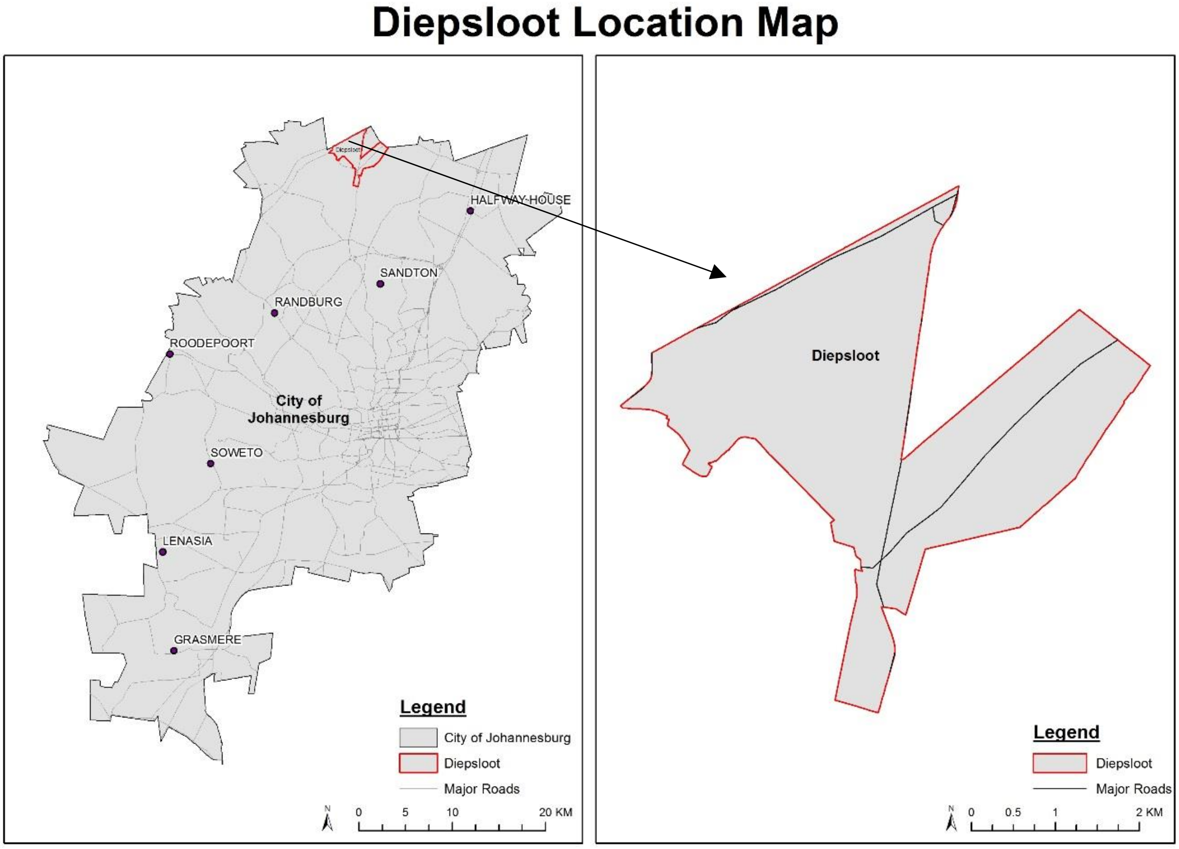

Figure 3: A map of the city of Johannesburg showing the location of Diepsloot.

3.3 Research design

The research design provides the structure of the activities that happen within the research process. A well- structured research design articulates the type of data required, sampling techniques, and the methods used to collect the data and how the data is analysed. This research is categorized as an exploratory study. The main aim of exploratory research is to identify the boundaries of the environment in which the problems, opportunities or situations of interest are likely to reside and to identify the salient factors or variables that might be found there and be of relevance to the research (van Wyk , 2012). The nature of this research is that it cannot provide conclusive analysis of the extent of the topic at hand however it lays a foundation for future research.

The emphasis was to gain deeper insights on energy perceptions and patterns in informal settlements, considering the demographics of the study area. The research employs structured questionnaires, conversational interviews, and direct observations to identify the challenges and barriers of available energy options, assess the energy patterns and explore the knowledge and perception of alternative energy options. Similar to a study by Butera et al (2016) and Andreasson (2014), the questionnaire is a key component of this research will cover several aspects of energy use patterns and income and size of each household and energy carriers used for heating, lighting, and cooking, the cost and procurement methods for each energy carrier as well as appliances available and knowledge of other energy carriers.

3.4 Data collection

This study follows the quantitative and descriptive methods, with a small component of a qualitative approach for a deeper analysis. Both open-ended and close-ended questions were featured in the study to achieve the established objectives. The closed-ended questions are important because they allow the respondents to have binary answers and they cut down the response time, which most participants prefer. Open-ended questions allow the respondents to provide more opinions, feelings, and understanding of the topic and it allows the researcher to get more information and context on questions that may be related to the closed-ended questions. Table 2 shows a summary of the questionnaire used in this study, details are shown in appendix A.

Table 2: Summary of questionnaire sections

Section	Description
Section 1	Energy use patterns information such as sources of energy and choice of energy and includes demographics such as education level, dependent and income source.
Section 2	Energy access and usage challenges, at various levels on a household level, community, and the power provider
Section 3	Knowledge of renewable energy carriers and the acceptability of the technology

3.4.1 Instrumentation

A research instrument is a tool such as a questionnaire, maps, checklists, experiments, case studies scale and tests designed to collect and measure data. The instrument used for achieving the aims of the research was a structured questionnaire and illustrative diagrams. The illustrative diagrams are additive tools to assist the researcher in having better communication for a subject matter that might be difficult to explain in verbal terms.

3.4.2 Quantitative data collection

Quantitative research explores a specific and clearly defined hypothesis and questions that test for confirmation or disconfirmation of that hypothesis (Newman & Ridenour, 1998) Quantitative data is often providing numerical data and can be explored statistically and result in a generalisation of the larger population. Section one of the questionnaire predominately contains questions that will provide the researcher with data that can allow for statistical interpretation. Section one of the questionnaire mainly features quantitative type of questions, with the aim of extracting information on household demographics and explore the energy carriers used for heating, lighting and cooking and the influence of fuel choice. Furthermore, the expenditure on energy as well as which appliances were available in each household.

3.4.3 Qualitative data collection

A qualitative methodology emphasizes attitudes, behaviours and supports the study objective which is to explore the perceived implications of energy- poverty and energy-related challenges in informal settlements. It seeks to investigate local knowledge and understanding about a given issue. It is often non-numerical covering images, expressions of verbal and nonverbal cues and videos. Section two of the questionnaire is qualitative, it was developed to understand possible issues (i.e. affordability, quality of health, cost of energy fuels) regarding energy usage from literature sources. While section three makes use of diagrams/illustrations to guide respondents in associating the technologies available so that they can respond to the set questions, see Appendix B.

3.5 Data sampling

This study targeted household members living in informal settlements. To gain in-depth knowledge of the community the study included both electrified households and non-electrified households in the sampled population. The sampling size selected was 50 households, with equal distribution between electrified and non-electrified. For the purpose of this study, a household "consists of a person, or a group of persons, who occupy a common dwelling (or part of it) for at least four days a week and who provide themselves jointly with food and other essentials for a living (Stats SA, 2003). In other words, they live together as a unit". For example, people who shared the dwelling, but who bought food or other essentials separately, will be counted as separate households. This distinction had to be made due to the nature of living in informal settlements, some households have backyard dwellers within the same yard. The pre-requisite of participation was an adult (18 years or older). One participant served as a representative for a single household. Ideally, the household head would be the research participant in question. The head of household is the person that the household regards as such and is usually the person who assumes responsibility for decision-making in the household.

A convenient and stratified sampling technique was employed in this study. The convenient sampling was used because of the familiarity and knowledge of the community, as the authors had previously worked in the community. This sampling approach was followed because the purpose of this study is to generate an illustrative case and not to make a generalization (Etikan et al., 2016). The samples were selected ensuring a representation of households that are both electrified and non-electrified. The strata involved sampling houses from four different extensions in the area, namely extension 4, 5, 12 and 13. To facilitate efficient data collection, a local NGO (Philile Foundation) that works in the community was approached to enter the study community by introducing the study project and explaining the purpose of the study. A registration form was distributed for those who were willing to participate in the study. Furthermore, the researcher relied on the door to door approach to obtain participants of the study. Observations were noted during the interviews, especially regarding non-verbal cues (Kobus , 2015). The researcher collected data from the period of May 2018 to April 2019 and ensured that the data was collected during the weekdays and the weekends.

3.6 Data analysis and interpretation

The collected data from the questionnaire was captured and coded in SPPS for statistical analysis. This was used summarize and describe quantitative data into graphs and/ or tables that can be used to visualize and present raw data. A descriptive analysis was conducted to reveal the profile of the households sampled and energy patterns and choices. Tested energy challenges and their effect on households using constructs were later analyzed into percentages presented in tables. The analysis also aimed at exploring the associations between various parameters (i.e. the relationship between the energy source and income). Fisher's exact test was used in order to find the strength/extent of influence of these aspects in accessing energy in the study area. The Fishers exact test examines if there is a difference between the null hypothesis and the alternative. It is called an exact test because it identifies exactly the difference from the null or no difference hypothesis; other tests such as the chi-square are approximation (Connelly, 2016). Thus, Fisher's exact test often is used with small samples because it is more accurate than the chi-square test (Connelly, 2016).

The researcher tested for the following hypothesis:

1. H_1: There is a positive relationship between the level of household income and the knowledge of renewable energy.

The null hypothesis for this test is :

1.1 H_0: There is no relationship between the level of household income and level of knowledge of renewable energy.

2. H_1: There is a positive relationship between the level of education and the knowledge of renewable energy.

The null hypothesis for this test is :

2.1 H_0: There is no relationship between the level of education and level of knowledge of renewable energy.

3.7 Ethics

Having ethical considerations is crucial when conducting studies that involve human participants; a consent procedure must always be adhered to. The researcher followed the requirements of the Ethics Committee of the Faculty of Natural and Agricultural Science at the University of Pretoria. As a standard practice, a background and a brief explanation of the study to the participants will be provided. Furthermore, the following aspects regarding the process were stressed; that consent to participate is voluntary and can be withdrawn at any stage, identities will be anonymous and confidential, and that no remuneration would be provided for their participation and this was purely for academic reasons. A detailed ethical consideration included:

3.7.1 Confidentiality and anonymity of Information

The participants were not requested to give their names against their consent, and identification numbers will be used to ensure participants' anonymity. Only the supervisors and the researcher will have access to the data which will be stored securely for a five-year period of study.

3.7.2 Informed consent

The researcher explained the aims and significance of the study as well as the rights of the participant. Consent will be gained from the participant prior to the study. The privacy of the participants will be protected by ensuring that the information collected is used for this study only. No identity will be disclosed.

3.7.3 Right to withdraw

The participants were informed about their right to withdraw at any time and stage of their involvement in the study and this should not cause harm if the participant withdraws.

3.7.4 Right to no harm

The information disclosed by the participant in the questionnaire will not be made available to anyone, in particular, the immediate supervisor of the participant. It will be generalized in the report to be submitted to the University of Pretoria. To ensure validity and reliability for distribution the research instrument was cross-checked by the supervisors and the Ethics Committee (NAS). Furthermore, it was pre-tested among a group of peers and corrected before the study commenced.

3.8 Limitations to study

This study is limited by the questionnaire data and the potential for inaccuracy is likely in such a study. The major constraint with social studies is that it requires openness and responsiveness of the community or people that are partaking in the research. It is often difficult to get people to willingly participant without a reward or incentive because this study was purely for academic purposes. With the upcoming May 2019 Presidential elections, community members were concerned about people coming into the community and questioning thinking that it might be a political scheme to solicit votes. Language is often a barrier of communication because the community of Diepsloot is comprised of different people from all over South Africa and across the continent. The English language is often not the medium of conversations in townships and informal settlements. Thus, a merger of languages had to be used to articulate the questions within the questionnaire. During the community meeting, the researcher enquired about the most spoken language in Diepsloot. She was informed that IsiZulu was the prominent language, thus the questionnaire was also translated into Isizulu.

3.9 Conclusion

In conclusion, a mixed-method approach combining both qualitative and quantitative data was used to indicate the energy use patterns and renewable energy knowledge in the Diepsloot. A questionnaire was used as the instrument for data collection. The structure of the questionnaire allowed the researcher to understand the subject matter from the participants' experiences.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents results gathered from the residents of the Diepsloot informal settlements regarding the current state of energy access and related energy services. The first section provides the socio-economic profile of the participants. The second section details current energy patterns, different energy carriers used for cooking, heating and lighting. Section three explores the energy challenges on different levels in the community. The final section presents findings on the knowledge of renewable energy systems.

4.2 Demographic profiles of respondents

In this study, a total of 50 households were interviewed, with an equal representation of electrified and unelectrified households. Table 3 presents the demographic profile of the respondents. The results from this study revealed that 46% of the households were female-headed and 54% were male-headed household and all participants were black Africans. The percentage of respondents that reported a household size of 4-6 people was 50%, those with a household size of 1-3 people were 38% and those with more than 7 people living in a household was 12%, shown in table 3. The household composition i.e. size directly influences the energy requirements of the households. Larger households have higher total energy consumption (Kowsari & Zerriffi, 2011). Equally, if there are more members in the household who are working, the household has more disposable income and there can be shared responsibilities in procuring energy.

Dwelling size (the number of rooms) is likely to influence household energy consumption based on the amount of energy used for space heating in winter and lighting. The percentage of households that had one room was 42%, those with 2-4 rooms in their household were 36% and 22% had 5-7 rooms in their households. The individual and household income are deemed as one of the most influential factors shaping behaviour, choice and expenditure (Ateba, et al., 2018). Income is directly linked to employment opportunities, the results indicated that respondents 48% reported full-time employment as their source of income followed by 18% who had part-time jobs, 14% were self- employed, 12% were on social grant, 2% received pension and 6% identified as ‘other” which the respondents said they are unemployed or seeking employment. The researcher was interested in the collective household income because it is more representative of expenditure, it is seldom that working persons in households operate in isolation. From the results 32% of the households earned between R0 – R2153, while 26% earned between R2154- R 3965 and about 32% of households earned between R3966- R10081. Only 2 % of households earned above R28000. According to Stats SA, households at low-income groups are classified as earning R0 – R18 000 per annum or households with an income below R1 500 per month. The income results indicate that most households fall into lower income brackets.

Table 3: Demographic profile of participants

Participants		
	Count	Percentage (%)
Female	23	46
Male	27	54
Household size		
1-3	19	38
4-6	25	50
More than 7	6	12
Number of rooms		
1	21	42
2-4	18	36
5-7	11	22
Income source		
Full time	24	48
Part-time	9	18
Self- employment	7	14
Social grant	6	12
Pension	1	2
Other (Unemployment)	3	6
Income bracket		
R0- 2153	17	34
R2154- 3965	13	26
R3966- 10081	16	32
R10082- 28038	3	6
R28039+	1	2
Highest level of education		
No matric	27	54
Completed matric	16	32
Completed tertiary level	7	14

The results in terms of education, the majority of respondents had no matric, with a percentage of 54%, while 32% had completed matric and those who have completed a tertiary education at 12%. Research has associated the level of education to income, thus the higher levels of education the more likely to have access to more modern energy systems. Also, higher levels of education are linked with increased access to information, knowledge of new technologies and environmental awareness. Ntanos, et al (2018) cited a study by Lui, et al (2013) which "revealed that household income, knowledge of renewable energy, and education is positively associated with willingness to pay for renewables, while age and perception of neighbours non-participation have a negative impact on willingness to pay". This study appreciates Ntanos et al (2018) approach but finds it inapplicable in the study area situation, simply because the respondents don't have established renewable energy systems to pay for. Hence, an association was investigated between, income, knowledge of renewables and education. As indicated by the Fisher's exact tests below (table 7 and 8), there is no association between income and knowledge of renewables since the p-value = 0.104 > 0.05 level of significance.

Table 4: Crosstabulation results for household income levels and knowledge of renewables

Monthly household income and Knowledge of REs							
Count							
		Knowledge of REs					Total
		None	Solar	Solar +Other	3 REs	4 REs	
Monthly household income	R0- R2153	0	9	6	1	1	17
	R2153-R3965	0	8	4	1	0	13
	R3965-28038+	2	8	3	5	2	20
Total		2	25	13	7	3	50

Table 5: Fishers exact test results

Chi-Square Tests						
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	9.597[a]	8	.294	.302		
Likelihood Ratio	11.030	8	.200	.320		
Fisher's Exact Test	7.953			.387		
Linear-by-Linear Association	.445[b]	1	.505	.560	.283	.054
N of Valid Cases	50					

An analysis of the relationship between education and knowledge of REs reveals no significant relationship between these variables, the results are shown below in table 6 and 7. Thus we accept the null hypothesis, there is no relationship between the level of education and the knowledge of renewable energy.

Table 6: Crosstabulation results for education levels and knowledge of renewables

Highest level of education and Knowledge of REs							
Count							
		Knowledge of REs					Total
		None	Solar	Solar +Other	3 REs	4 REs	
Highest level of education	No matric	2	15	8	3	0	28
	Completed matric	0	8	5	2	1	16
	Completed tertiary level	0	2	0	2	2	6
Total		2	25	13	7	3	50

Table 7: Fishers exact test results

Chi-Square Tests						
	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	14.773[a]	8	.064	.060		
Likelihood Ratio	14.468	8	.070	.095		
Fisher's Exact Test	11.285			.104		
Linear-by-Linear Association	7.219[b]	1	.007	.008	.005	.003
N of Valid Cases	50					

4.3 Household energy patterns

4.3.1 Energy expenditure and appliances

Households require a minimum amount of energy to meet human comfort including cooking, lighting, space-heating, and the operation of household appliances and devices (Kaygusuz, 2011). Firstly, the monthly energy expenditure for cooking, lighting and heating is assessed. Figure 4 details monthly energy expenditure, it shows that 54% of the respondents have a monthly energy expenditure of R500 or less, while 38% had an expenditure between R501- R1000 and 6% spent between R1000- R2000.

The implication of high energy expenditure is the reduction in the amount of disposable income households have for other amenities.

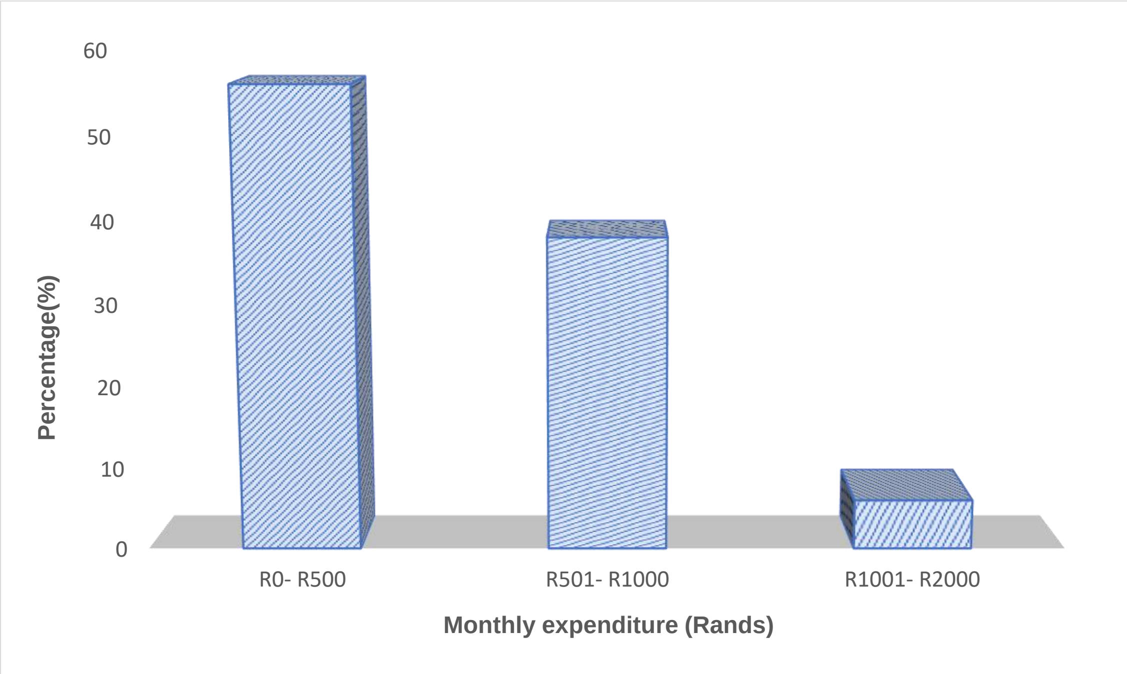

Figure 4: Percentage breakdown of the distribution of the respondents according to monthly energy expenditure, this includes cooking, lighting and space heating.

Household appliances such as fridges, electric stoves and microwaves are appliances that provide households with convenience and remove time constraints associated with non-electric appliances because of their efficiency and mechanical power. Kaygusuz (2011) points that the use of household appliances depends on electricity or battery availability and the income levels of the population vis-à-vis the costs of acquisition of such appliances. Thus, it is important to evaluate the total number and the types of appliances within a household as part of the Multidimensional Energy Poverty Indicators. As seen below in figure 5 the most abundant appliances are cell phones (96%), flat iron (66%), television (54%) and refrigerator (52%) and radio (48%). It is evident that telecommunication/ media appliances are very common even in informal settlements. The study also noted only 48% of households had five or more energy appliances, 12% had four appliances, 6% had three appliances, 20% had two and 12 % only had a cell phone and 2 % had none. Interestingly, some non-electrified households reported having electrical appliances but could not utilize them and those that could, made use of dry cell batteries (mainly for radio and lights) which were at an additional cost.

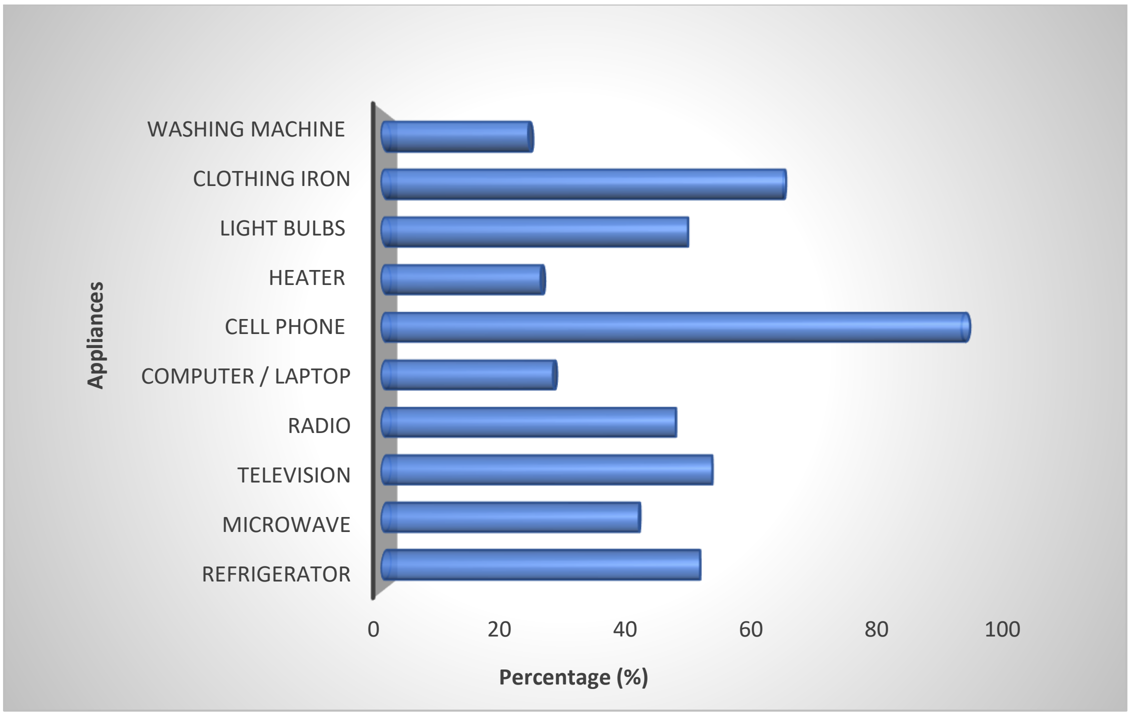

Figure 5: Showing appliances found in households in the study area in percentages.

4.3.2 Cooking

Energy for cooking is a necessity without which household cannot function, households need it for food preparation (Stats SA, 2013). The use of kerosene as an energy carrier was predominant 38% among non-electrified households. While 28% of electrified households used electricity for cooking. Overall only 6% of households used gas for cooking, while biomass was used by a small percentage of 2% of the households. The use of multiple energy carriers or energy stacking is prevalent among households, even those that have access to electricity. For example, 10% of households used electricity and kerosene for cooking, 10% used electricity and kerosene, these were energy mixes used among electrified households. Some (4%) non-electrified households used a mixture of both kerosene and biomass for cooking. Solar and gas were used by 2% of the households. One household used gas, paraffin and solar for cooking. Notably most households that used multiple energy carriers articulated that they interchanged between energy carriers when their primary option was unavailable. For instance, those that primarily used electricity would switch to either gas or paraffin when there is load shedding or power outage.

It was interesting to note that several participants reported using gas either because it was a way of saving on electricity or because it was a safer alternative to kerosene. Consequently, this meant that gas was utilised as a secondary option and not a primary option. Gas is categorised as a modern energy carrier and most developed countries use it as a main energy source, however, in South Africa it still has low uptake in terms of household energy usage. According to literature, LPG uptake is constrained by the cost and the perception of it. It is perceived to be more dangerous than paraffin on the fear that the cylinder might explode (Mohlakoana & Annecke, 2009). The uptake of LPG as a primary source of energy was spear-headed by Eskom and the Department of Energy during the 2005-2006 national blackouts and despite these programmes, household use of LPG amounts to only 3% of the national LPG consumption (Joemat-Pettersson, 2015).

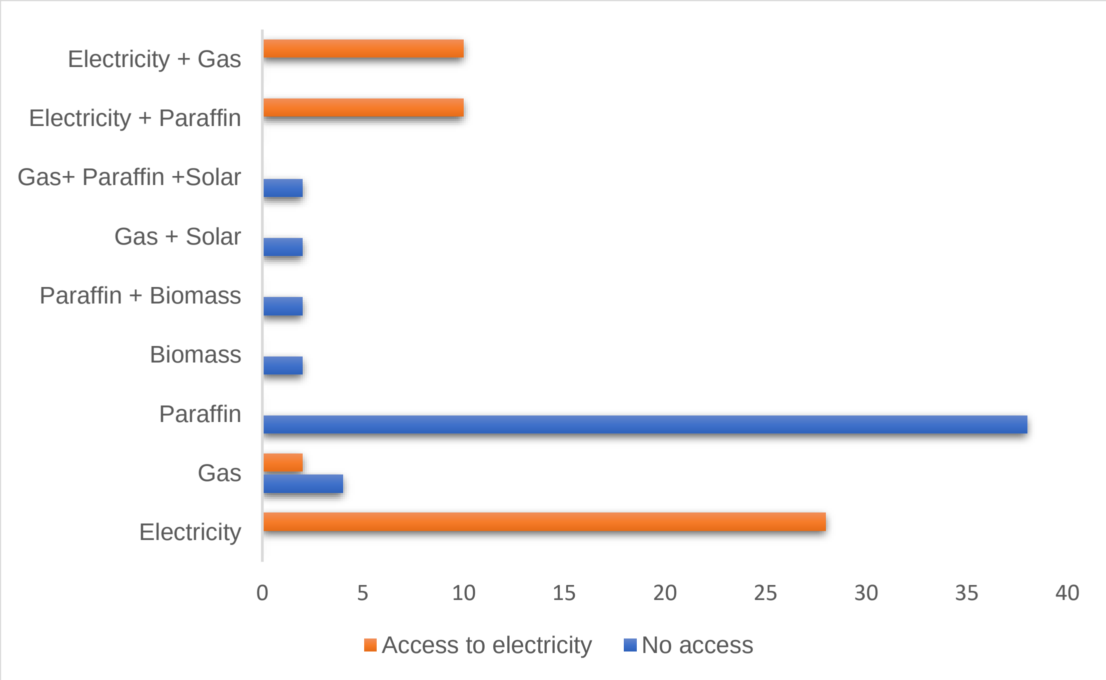

Figure 6: Percentage breakdown of the distribution of the respondents according to the type of energy carriers used for cooking.

A percentage of 32% of households reported using kerosene stove as their main equipment for cooking. Lloyd (2014) details that the associated problem with paraffin stoves is that they suffer from numerous design deficiencies. They can heat the fuel in the fuel tank to above the flashpoint, and if that occurs there is a risk of a very severe fire, in which the hot paraffin burns at a rate sufficient to give over 1MW. At that heat rate, the temperature inside a typical home will exceed 400 degrees Celsius within 40 seconds, and the home will be destroyed within 15 minutes (Lloyd, 2014). The electricity stove was used by 24% of the households. The gas stove and homemade stove were used by 12% and 2% respectively. Households that used a combination of electric and microwave stoves were 8%, 6% used a combination of gas and electric stove. A small percentage (2%) of household used a mixture of microwaves, paraffin and electric stoves, and a combination of paraffin and home-made stove. It is evident that households with access to electricity revealed the use of multiple cooking equipment, this exhibits a degree of freedom that is granted by access to electricity. The results of the energy equipment are shown below in figure 7.

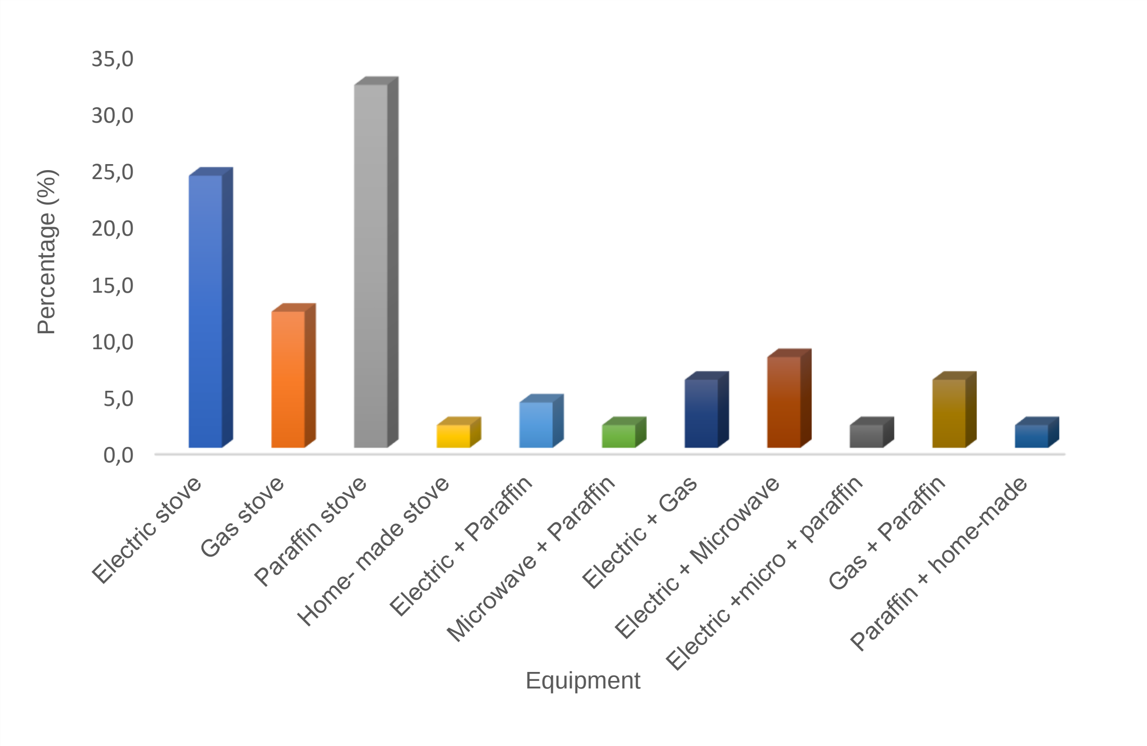

Figure 7: Energy equipment used for cooking by households in percentages.

Majority of households (82%) cooked more than 7 times a week, while a minority of households cooked between 1-2 times (2%), those who cooked 3- 4 were (10%), this is summarised in figure 8. The implications of the number of times a household cooks per week are explained by Sola (2016), who highlights how energy access influences cooking practises. For instance, for unelectrified households cooking more than three times in a day might be mandatory due to the lack of efficient food storage methods, ideally in the form of refrigeration. It affects the choice of food (i.e. meal ingredients) and cooking methods and patterns as households might have to select food that requires less preparation time and food that can easily be stored (i.e. canned food) without spoiling. Notably from these results, it shows that the majority of electrified and non-electrified households cook more than 7 times per week, deducing that the characteristic of the number of times households cook may due to other exogenic factors rather than lack of energy.

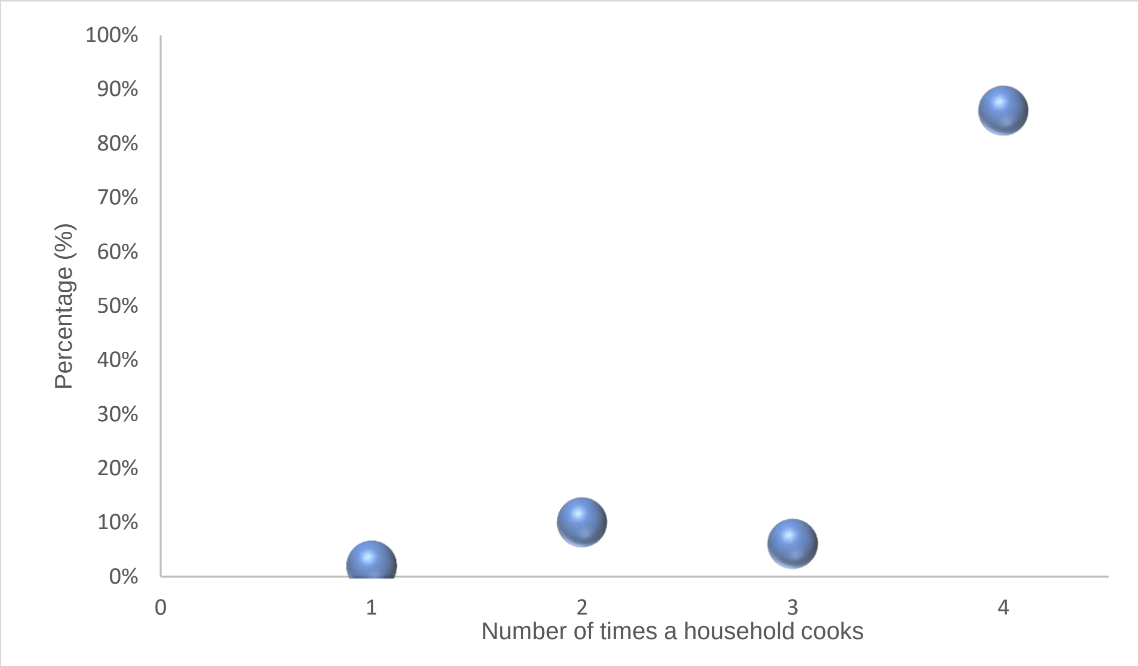

Figure 8: Number of times households cook per week

Both endogenous and exogenous factors influence energy choice. Exogenous conditions influence household decisions regarding their energy systems by affecting the choice available to households and incentives to choose one energy technology or fuel over another (Kowsari & Zerriffi, 2011). The exogenous factors in this case were; availability of energy carrier, the cleanliness, lack of smoke by the energy carrier and efficiency. The participants were asked to choose a factor that was most important when selecting an energy carrier. Most households reported that the most important criteria in choosing an energy carrier for cooking were the affordability, with 32% of the households choosing this reason, availability was second 30%. The cleanliness and the lack of smoke of the energy carrier were selected by 12% of the households, while 8% and 7% of the households choose efficiency and safety as the reason for selected energy carrier.

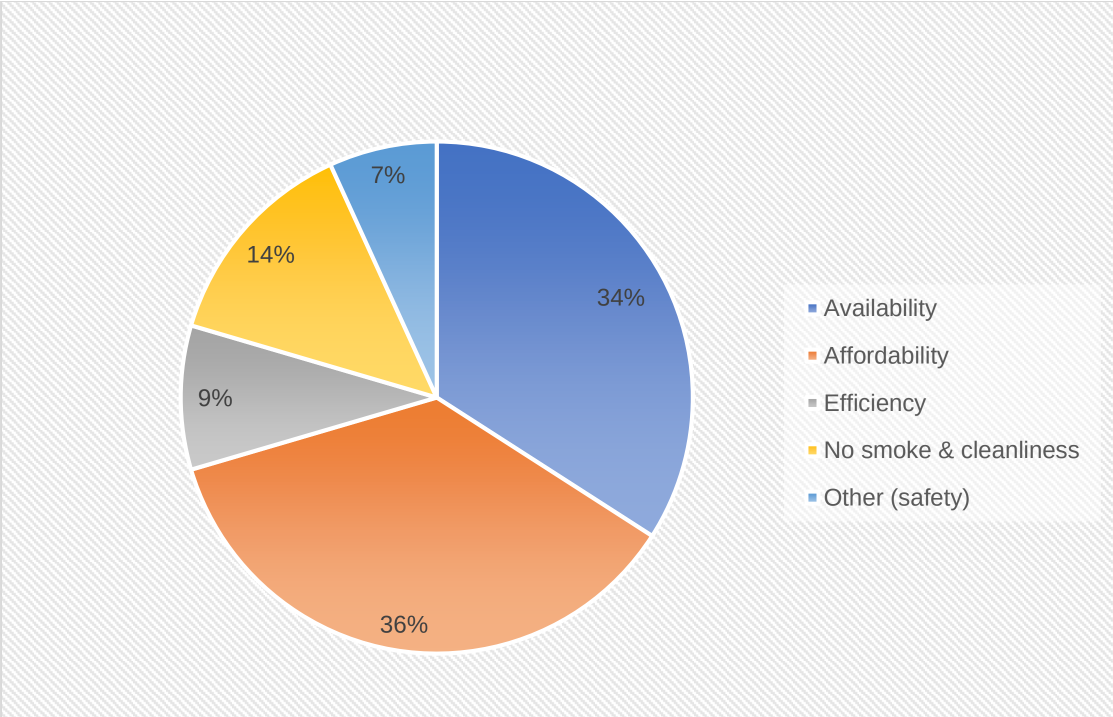

Figure 9: Showing responses to the criteria for choosing a source of energy for cooking.

Based on the subjective approach as one of the ways to indicate energy poverty, a household is considered energy poor if it is characterised by reporting that the amount of energy needed for the household is inadequate. Adequacy in this study is defined as the amount of energy necessary to meet the household needs. Thus, the participants were asked to indicate if they perceived the amount of energy used was adequate for their cooking needs. The results in figure 10 indicate that, in total, 58% of the participants reported that the energy amount was inadequate while 42% indicated that it was adequate for their households. However, an in-depth analysis of figure 10 shows that there is a substantial difference in terms of the perception or expression of inadequacy for energy cooking requirements between electrified and non-electrified households. More participants (36%) from unelectrified households reported inadequacy in comparison to participants from electrified households.

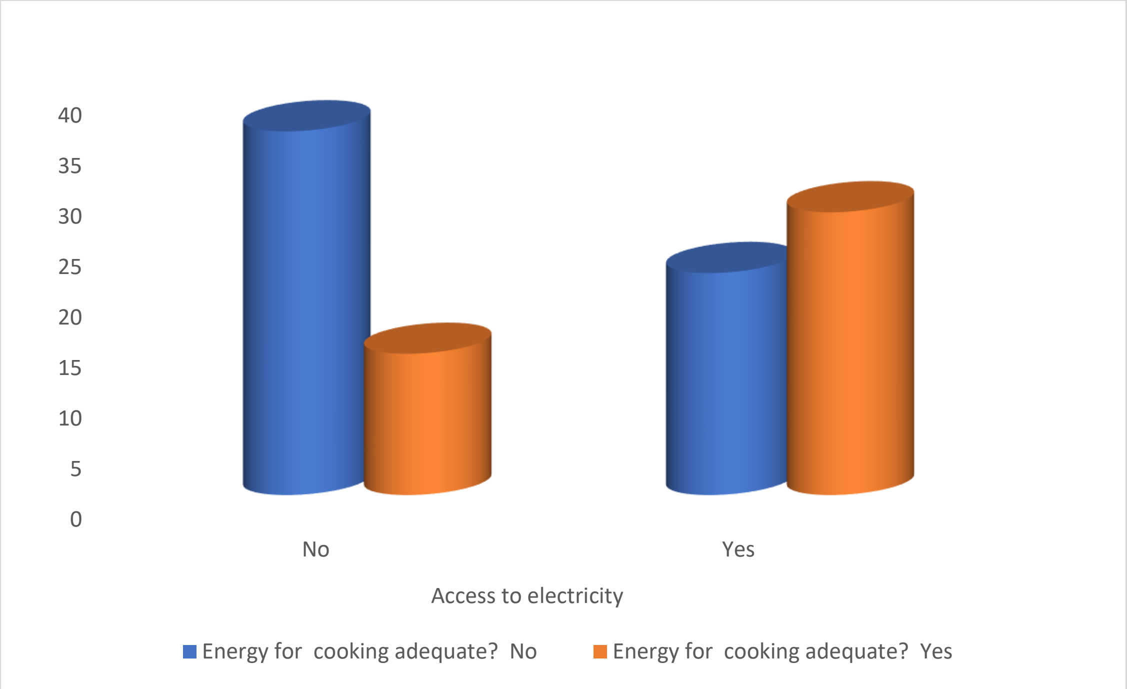

Figure 10: Showing respondents' perception of the adequacy of energy used for cooking in households.

From the 58% of participants who expressed that energy used for cooking was inadequate. The findings were further assessed by asking the participants to explain why they perceived the amount of energy used in their households inadequate. From the results it evident that the understanding of the term 'adequacy' was not limited not the amount of energy used but also associated with the performance or the interaction the participants had with the different energy carriers they used in their households. Some of the responses included the cost of energy being too expensive (20%) and their fuel choice selection due to the lack of alternatives to use. Safety was also a concern amongst participants, kerosene mostly associated with risks of being flammable. Some participants expressed the limitations posed by certain energy carriers such as kerosene and firewood, the limitations were related to the type of food that can be cooked. For instance, a common staple food in South Africa is samp (dried corn kernels) it requires more fuel and to cook in comparison to rice or maize meal, thus often the fuel supplied by kerosene stoves is inefficient for this type of food.

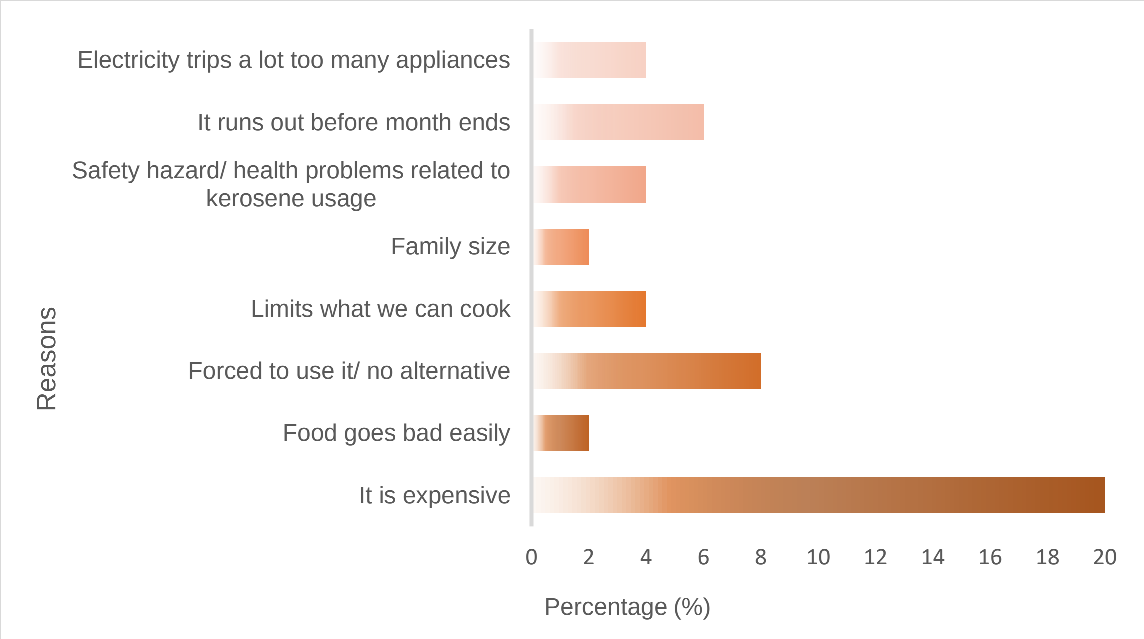

Figure 11: Showing reasons why participants perceived energy inadequate for household cooking needs.

4.3.3 Lighting

The study was also interested in household lighting and reasoning behind such energy choices. As indicated in figure 7, approximately 40% of the households used electricity as an energy carrier for lighting and 8% used a mixture of electricity and candles. The electrified households explained that candles are used as a secondary or replacement source of lighting. For non-electrified households, 26 % used candles and 10% used paraffin for lighting. Solar lights and cell batteries were respectively used by 4% of the households. A small percentage of households used multiple energy sources, 2% of households respectively used a mixture of candles and cell batteries, solar and cell batteries, paraffin and candles. From figure 7, it can be noted that a variety of lighting sources are used in non-electrified households while energy sources for electrified households are more homogenous because most households use electricity as the main lighting source.

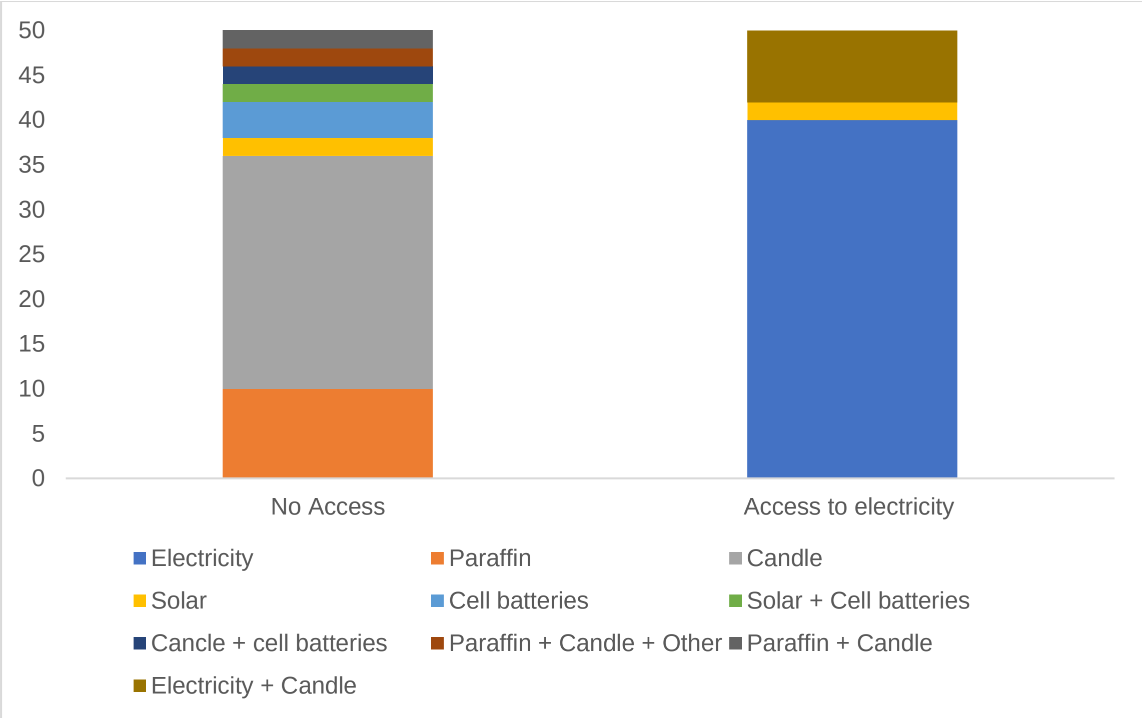

Figure 12: Percentage breakdown of the distribution of the respondents according to the type of energy carriers used for lighting.

The participants were asked to choose a factor that was most important when selecting an energy carrier for lighting. Figure 13 shows that 42% of the households classified affordability as high priority when it came to choosing an energy carrier for lighting, the second-highest priority was availability (40%), while 26% of households chose an energy carrier based on its cleanliness and lack of smoke. A percentage of 6% chose efficiency and flexibility as a high priority respectively, and 6% of the respondents choose other which most expressed it to be the safety of the energy carrier.

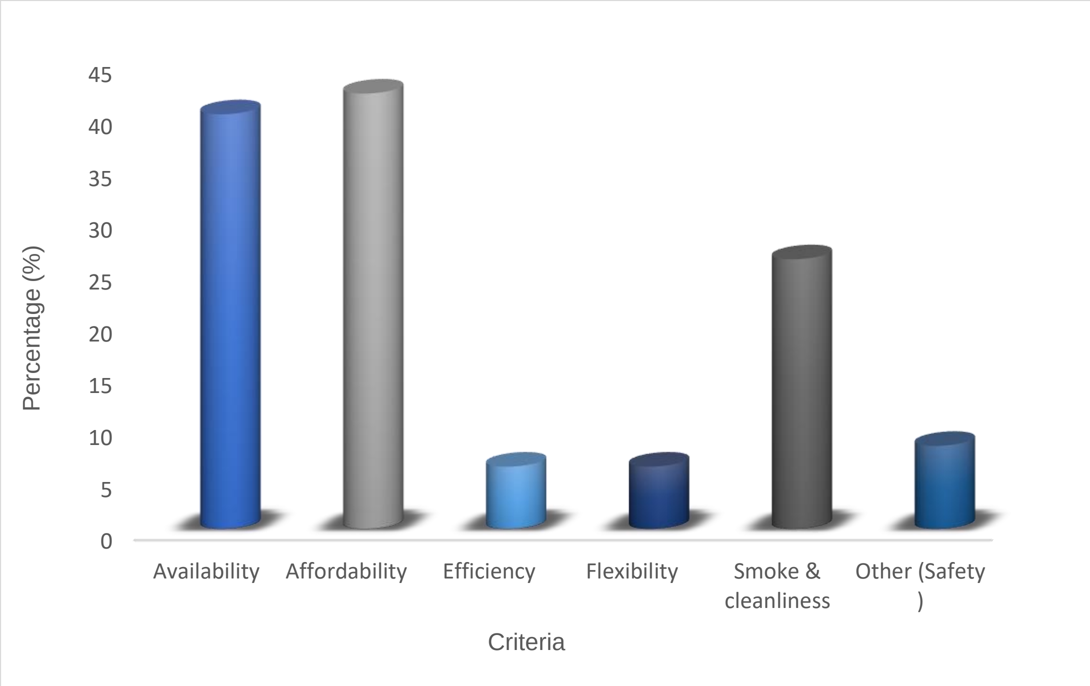

Figure 13: Criteria for choosing lighting energy carrier.

Figure 14 captures the results on the perception of the amount of energy used for lighting. It shows that the majority (58%) of the participants expressed that the energy used for lighting is adequate for their households, while 48% expressed that it was inadequate. From those that expressed adequacy, 40% were from electrified households and 18% were from unelectrified households. In contrast to figure 10, more households perceived lighting to be adequate for their needs than for cooking, this might be due to the small share of energy consumption and cost associated with lighting in comparison to cooking.

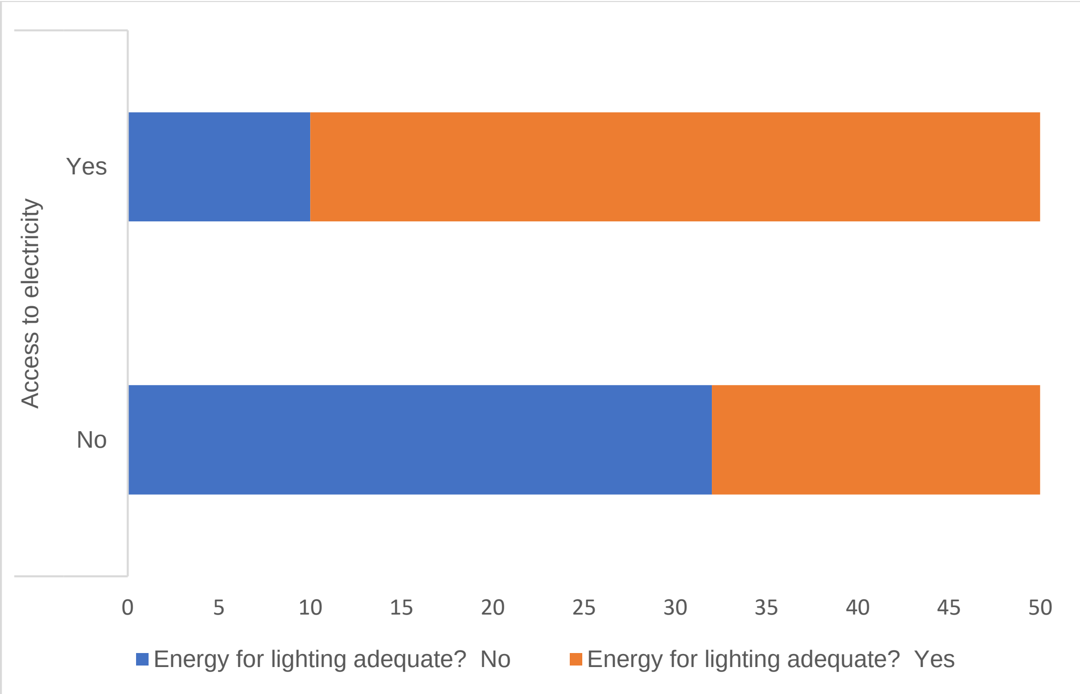

Figure 14: Showing households responses towards adequacy of energy used for lighting.

The findings from figure 14 were further analysed into investigating why 42% of participants reported that, the energy used for lighting for their households was inadequate, this is shown in figure 15. Among the reasons why some participants expressed energy for lighting being inadequate included; the cost of the energy carrier (reported being expensive), the danger of using candles as it may lead to fires and the low illumination received from candles which makes it harder to study at night or conduct other activities that need light. This can cause negative impacts on the education and performance of children living in informal settlements.

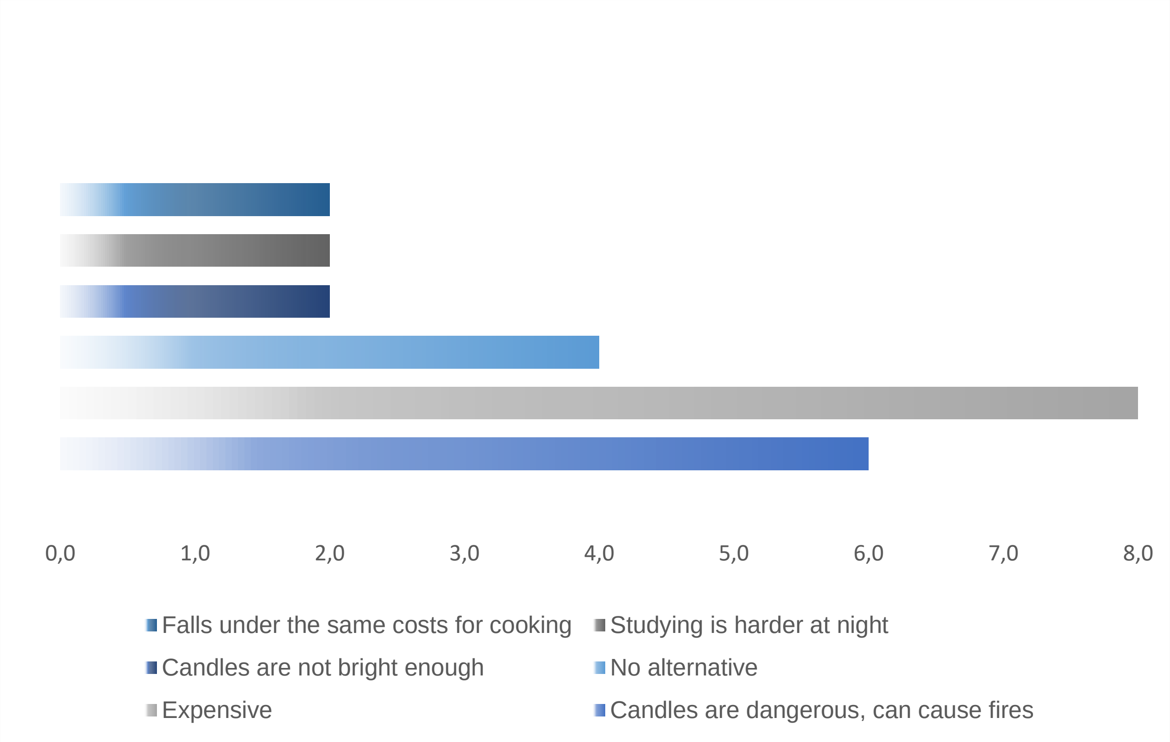

Figure 15: Showing reasons why participants perceive energy to be inadequate for household lighting needs

4.3.4 Space Heating

Space heating is an energy-intensive thermal application, energy carriers used for heating are illustrated in figure 16. Most households primarily employed non-electric energy carriers for space heating, particularly biomass and kerosene. Biomass was employed by 18% of unelectrified households and 6% of electrified households. Several participants described that using biomass for heating as an inconvenience due to the cost of firewood or charcoal and the time it takes to collect the firewood. Firewood was collected from the surrounding veld areas or bought from the local vendor. Kerosene was used by 14% of unelectrified households and 10% of electrified households. Electricity was used by 10% of the participants, 8% used gas, and 10% (other) indicated that they had no form of space heating in their households. Space heating is energy-intensive especially in winter therefore most households reported choosing alternative energy sources or none, for heating to save energy costs because of electric heaters and appliances consume a lot of electricity. Two households used more than one energy source to heat their space, one household (2%) used a combination of electricity and kerosene while another (2%) used a combination of kerosene and biomass. Although blankets are not generally classified as energy carriers, some households cannot afford to heat their homes and only utilise blankets. The percentage of households that used only blankets was 20%.

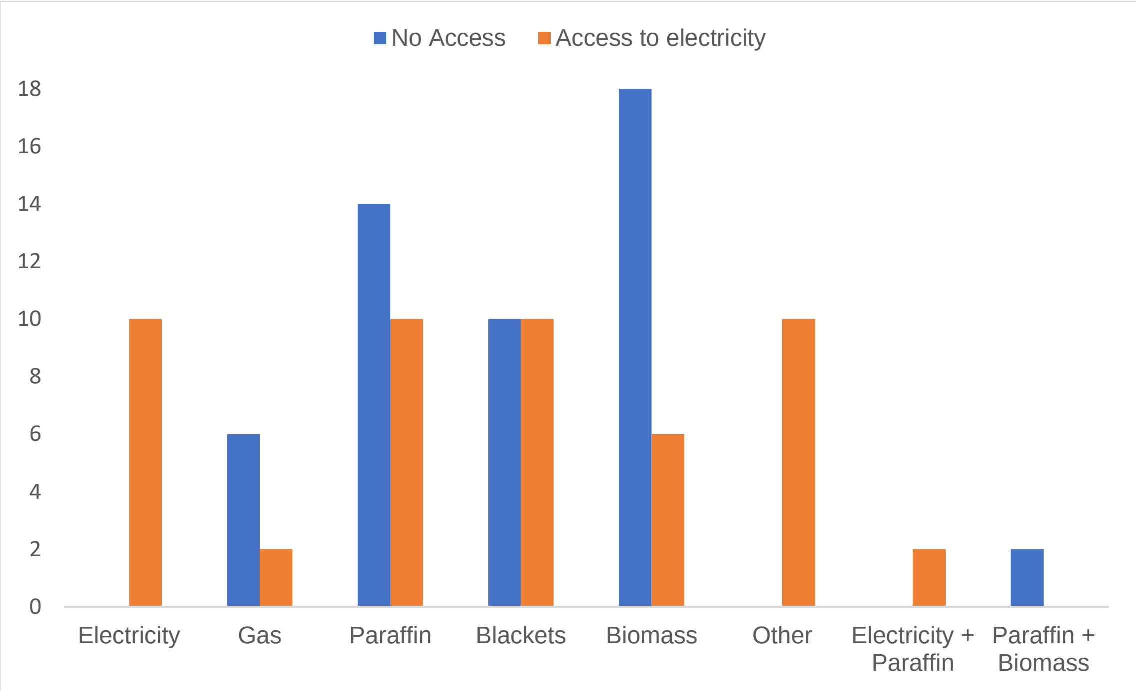

Figure 16: Percentage breakdown of the distribution of the respondents according to the type of energy carriers used for space heating.

In response to whether the amount of energy used for heating was adequate for their household energy needs. Figure 17 shows a comparison in terms of the percentage of participants who perceived the energy used for space heating inadequate and those who perceived it adequate. In total 54% of households reported the energy used for heating is inadequate for their household energy needs while 46% reported it adequate for their needs. In comparison, more participants from unelectrified households perceived (34%) the energy they utilised for space heating inadequate than those from electrified households (20%). On the other hand, 30% of participants with access to electricity perceived their energy adequate, while only 16% of the participants from unelectrified households perceived it inadequate.

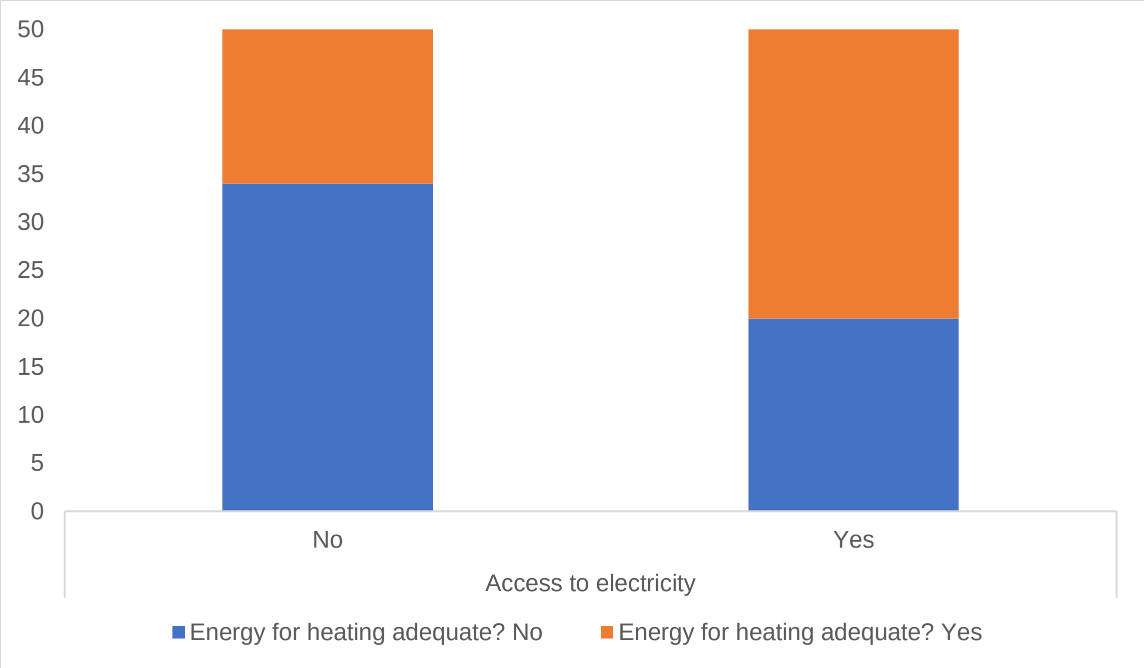

Figure 17: Showing households responses towards adequacy of energy used for heating.

Similar to the perceptions shown in figure 10 and 14, most participants who expressed inadequacy in terms of energy for heating needs, highlighted the cost as the main reason they found the amount of energy they used as inadequate. As indicated in figure 16, biomass (i.e. firewood) is predominantly used by participants as an energy source used for space heating. Thus, the main challenges related to space heating relates to the usage of firewood. Participants perceived firewood and coal to be expensive, and firewood to be inconvenient. Participants explained that firewood can only be used outdoors which means that a person would have to be outside to keep warm, however, they would be no warmth inside the house. Furthermore, the collection of firewood is labour intensive and scarce resource in peri-urban environments unlike in rural areas.

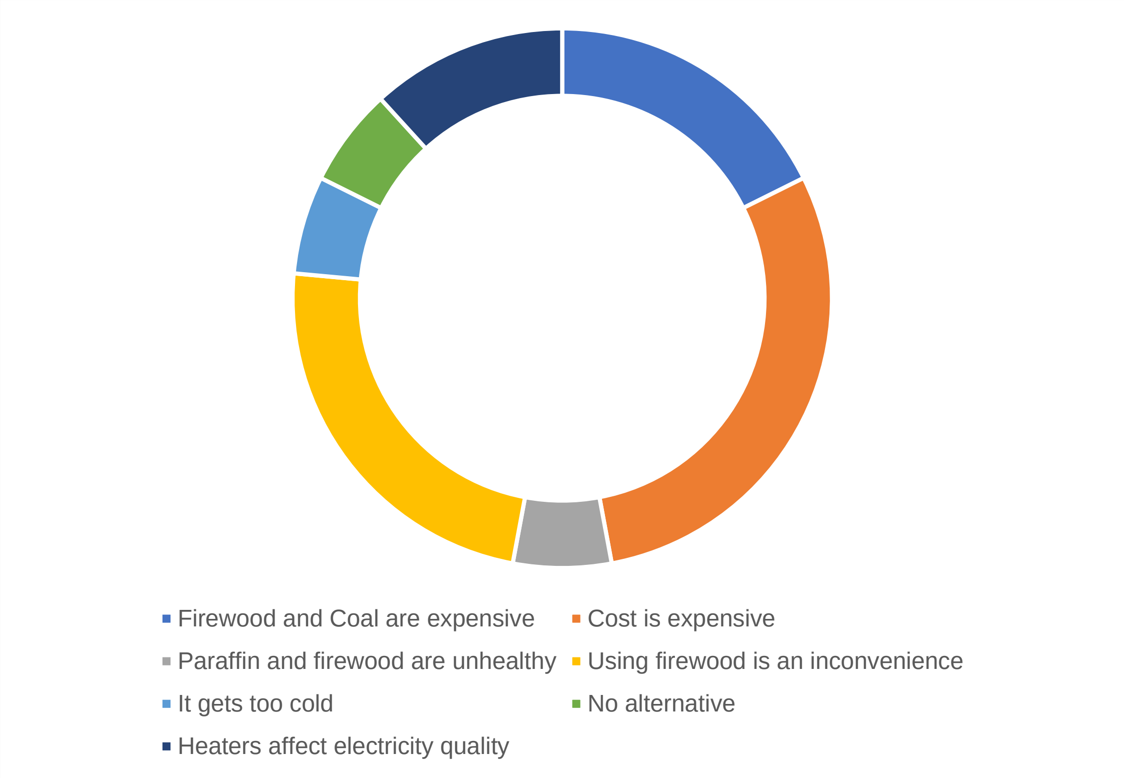

Figure 18: Showing reasons why participants perceive energy to be inadequate for household space heating needs

4.4 Results of energy-related challenges

4.4.1 Household level

Besides understanding the sources of energy used in the community based on cooking, heating and lighting which is detailed in section 4.2 to 4.3, the study also sought to explore the energy challenges faced by the participants related to energy access or use. The study used constructs to understand energy-related challenges, making use of existing literature to gauge the opinions of identified energy challenges. The subjective responses of the problems were analysed, overall due to the difference between electrified and un-electrified housing, there is a significant degree of responses that were neutral, especially ones that were related to formalised electrification challenges. Table 8 shows the energy-related challenges on a household level. When asked if the participants can afford the associated monthly energy costs, 56% said that cannot afford energy costs while 34% said that they could afford it. Most households had no awareness of Free Basic Electricity or Free Basic Alternative Energy, thus most reported being neutral about this aspect. They learned about it through the process of the questionnaire. Respondent 15 reported that, *"Free Basic Electricity, we used to have it, but they told us we have to reapply"*. While 14% indicated that the FBE/ FBAE was inadequate for monthly energy costs and 8% indicated it was adequate for their monthly energy needs. The consequence of the lack of awareness is the limitation to the amount of energy a household has access to. In terms of Free Basic Alternative Energy policy lack of information about it could be because it has been predominantly phased into rural areas and not urban informal settlements due to capacity constraints, lack of skills and budgeting by the responsible municipal official (Runsten, et al., 2018; Visagie, 2008).

When asked about how they perceived their energy carriers effect on the quality of health, 52% of the participants expressed an impact on the quality of health due to the energy available while 42% had no impact and 6% of participants were neutral about the problem. Quality of health was generalised as a subjective opinion or experience expressed by the participants in relation to health and safety concerns that are related to the use of energy fuels or equipment. A concerned participant 49 expressed that "*My grandmother has asthma caused by paraffin*". Participant 12 stated "*Paraffin is very unhealthy, if I fall asleep using it something might happen". The fumes are unhealthy and even the paint container could lead to health problems".* Another participant 4 stated *"The smoke hurts our eyes when we use firewood*". The prevalence of health-related illnesses due to the use of inefficient energy fuels is well-cited in literature, respiratory infections, burns and poison incidents (Francioli, 2018; Kimemia, et al., 2014; Lloyd, 2014) The difficulty with identifying health issues in informal settlements is that they could be caused by several environmental factors besides energy fuels.

A percentage of 56% of the participants agreed that the energy carrier they utilize can make their households, susceptible to fires. This is significant because one of the most cited problems associated with non-electric energy carriers (candles and kerosene in particular) used in informal settlements and rural areas is the risk and susceptibilities to cause household fires (Francioli, 2018; Makonese & Bradnum, 2017; Wolpe & Reddy,2010). Even though fires can be caused faulty electric wires, overloading of plugs and appliances, most participants reported the risk of fire in association to non-electric carriers (Francioli, 2018). The high density of households within a small plot (in close proximities to each other) of land makes trickling effect of community loss of in informal settlements prevalent. Safety concerns over energy fuels were expressed by participant 20 who recalled having her house burn down causing detrimental effects because she lost everything and had to start over again, beginning with rebuilding her home and buying new furniture and appliances. In her words "*Smoke inhalation is dangerous for health. Our house has burned down before due to paraffin usage, we had to start over".*

A large portion of the respondents (60%) indicated that owning appliances can become a challenge due to the cost of these appliances and the electricity usage associated with the appliances. These results are in line with the findings in sub-chapter 4.3 which indicated that only 48% of the households owning more than 5 electricity appliances, refer to figure 11. For unelectrified households, some respondents expressed that they must use their neighbours' appliances such as refrigerators to store mainly meat, milk and fresh produce. The researcher observed that the local shops provided a service for charging phones for the residents. A service which the residents must pay for and ultimately affects the disposable income for other needs.

Table 8: Showing percentages of participants responses pertaining to household-level energy-related challenges.

Household energy challenges	Disagree	Neutral	Agree
I cannot afford to pay for the monthly energy costs	34	10	56
The FBE/ FBAE is enough for monthly energy costs	14	78	8
House wiring is troublesome	36	50	14
Quality of health of the individuals in the household is significantly affected by the energy available	42	6	52
Prone to House fires due to unsafe energy carriers	40	4	56
Owning/ using energy appliances that require electricity is a challenge	36	4	60
Energy equipment used consumes a lot of power	22	46	32

4.4.2 Community level

Table 9 lists the different challenges related to energy on a community level. Challenges relating to safety are great, with a striking majority of the respondents (70%) agreeing that police response is slow in the community due to lack of lighting in the community. Access to public services such as police and ambulances are a necessity regardless of where you reside. The consequence of inadequate energy services such as streetlights creates vulnerable environments where crime can thrive due to limited access to security and service delivery such as public service response to emergencies. Furthermore, the lack of street lighting constraints entrepreneurs and street vendors from operating their businesses in the evening, thus, limits their income (Levänen, et al., 2016). Most participants expressed frustration at the lack of this service because the police are supposed to protect them as residents and adequately respond to emergencies. According to participant 23 "*Police are scared of the dark, even ambulance struggle to come in the community at night"*. Participant 12 explained that "*Cops say they do not patrol because there is a lack of lighting*". Whereas participant 24 reported that "*Ambulances don't come when there is no electricity".* Poor streetlighting, no tarred roads, no streets between shacks and no clear reference point-unnumbered shacks are among the challenges police and health officials face in accessing informal settlements (Madienyane , 2013). It is important to note that inadequate social services were reported even among participants who lived in the formalised housing extensions of the community. These are households with access to electricity, streetlighting and tarred roads. Participant 49 suggested that *"Police response is bad regardless of lighting".* Participant 37 sadly stated that "*The municipality, Eskom & police have poor service, we take care of ourselves*". These results show that alone energy access does not influence access to social services, but it does have a differential influence on the severity of the consequences of inadequate social services. The lack of these social services intensifies the perpetual insecurity, poor health and violence that exist in informal settlements.

Crime is a dominant problem in settlements all over South Africa and while crime is not fundamentally an energy related problem, it proliferates in communities who suffer from energy poverty (Madienyane , 2013). Participants expressed the vulnerability and fear of theft and house-break-ins. This in turn affected the perception of purchasing or owning solar energy equipment and generators. In terms of crime, participant 6 speaks on the issue voicing that if alternative energy options (solar energy equipment) were accessible to him, she would opt not to use them because of the associated risk of them targeted by criminals in order to obtain the equipment. In the words of participant 19: *Solar panels are stolen, we sleep with one eye open because it is too dangerous. It is not safe to have them because the crime rate is so high that if we had them, they would just steal them*. Similar sentiments were expressed by participant 2 and 35, whom respectively reported that "*Generators and solar panels end up being stolen so people resort to selling the equipment*" and "*where there is light, it is safer. We have experienced a church break-ins and solar panel theft break-ins frequently".*

Illegal connections to grid electricity are prevalent in the community with 54% of the respondents acknowledging it as a challenge because it creates an unstable grid system and consequently electricity connection trips. The problem of electricity in informal settlements is exacerbated by the prevalence of backyard dwelling and increased energy consumption during winter months. In the words of participant 14, "*We experience a lot of winter outages, backyards are too many in the neighbourhood and electricity trips a lot*". Similarly, participant 12 reported that "*In winter experience load shedding or transformers bursting due to heaters and backyard dwellings".* As a consequence of essentially multiple households consuming electricity from a single metered supply and irregular load produced by the illegal connection voltage outages occur (Butera, et al., 2016). Furthermore, energy stacking occurs to compensate for the shortcomings of the utility during scheduled load shedding and the waiting period to fix the electricity connection due to power outages.

In terms of acquiring pre-paid electricity, 56% of the respondents indicated that it is relatively simple to obtain because there are multiple vendors in the community, and it can also be purchased via cell phone banking. Similarly, acquiring alternative energy fuels such as paraffin or gas was expressed to be simple, 58% of participants expressed that is not difficult to obtain from community vendors. While the majority of participants noted that acquiring paraffin is not difficult, some noted that they had problems with the quality of the product that they received. Participants reported a difference in quality or grades of kerosene in terms of how it ignites and the smell of it. Participant 19 suggested that "*Some paraffin seems fake, it blocks noses and makes eyes sore in children*". Participant 23 agreed with 19, he articulate that "*Paraffin affects the children, it has different grades. The Spaza shops (community shop/vendor) sell the cheapest grade*". According to Lloyd (2014), the problem with paraffin could be a matter of the energy equipment or appliance used rather than the kerosene quality. Counterfeit, illegal and unsafe energy appliances are widely common in South Africa, the metal used in these appliances corrodes rapidly and thus, most appliances have a shorted lifespan and increased risks (Lloyd, 2014). The dissemination of information about counterfeit is the responsibility of the government, however; from the perception of the participants they had did not have information on the counterfeit kerosene stoves. Although, these types of stoves are usually cheaper than the standardised equipment. Thus, more household could be opting for them due to cost considerations (Lloyd, 2014).

Table 9: Showing percentages of participants responses pertaining to the community- related energy challenges.

Community related challenges	**Disagree**	**Neutral**	**Agree**
Police official's response is slow/ enough due to lack of lighting	14	16	70
Walking in the neighbourhood at night is challenging due to lack of lighting	8	4	88
Crime and mugging rate are high	6	2	92
Theft of cables and illegal connections are prevalent in the community	20	26	54
Getting pre-paid electricity vendors is difficult	56	34	10
Getting alternative energy carriers from community vendors is difficult	58	8	34

4.4.3 Municipal level

At a municipal level, there are some associated problems related to energy services, an array of challenges can arise from poor energy services and this could be related to various factors or a combination such as; human-behaviour, operational and strategic issues. Table 10 depicts results on challenges related to the utility/ municipality based on operational challenges. Overall communication and education related to energy are low in the community. When asked about the communication and knowledge of FBE by the municipality or power utility, 46% of the respondents agreed that there was lack of information whereas 48% were neutral about the topic and 6% disagreed with the statement that was made. Importantly, 74 % of the participants expressed that there is a lack of information about using energy more efficiently on a community level, while 14% disagreed with the statement.

The majority who make up 54% expressed that power costs were increasing, on the other hand, 8% disagreed that power costs were increasing and 36% were neutral. The increase in the cost of fuel sources impacts the budget of the household and the money the household must allocate to acquire a particular fuel source. The power supply was perceived as unreliable by 38% of the respondents while 24% found it reliable. Several participants reported dissatisfaction due to the frequency of power outages and/or load shedding in the community. Participant 37, who was an elderly female expressed that "*Eskom takes a long time to fix transformers, sometimes electricity goes for more than a week*". Additionally, participant 39 reported that *"Multiple connections trip the electricity, we have spent 6/7 days without electricity, and it is worse in winter".*

Table 10: Showing percentages of participants responses pertaining to municipal- related energy challenges.

Municipal related challenges	**Disagree**	**Neutral**	**Agree**
There is a lack of communication and education on FBE/FBAE by the local municipality or power provider	6	48	46
There is a lack of information and education about energy efficiency	14	12	74
There is a lack of information and education on alternative energy carriers	10	10	80
Power provider puts a lot of pressure to pay	38	46	16
There is no standard rate to pay for power	30	48	22
Bribery for power supply is common	30	44	26
Power costs keep increasing	8	36	56
The power supply is unreliable	24	38	38
Slow response when power is cut off	20	34	46
Experience frequent power outages	45	25	40

4. 5 Knowledge of renewable energy

The study sought to gain some insight into local knowledge and perspectives about renewable energy equipment. The researcher used this part of the questionnaire process as a tool to underpin the level of awareness of the presence of renewable energy options as a source of electricity. Also, renewable energy equipment as an alternative to the options available to them in the community, with an emphasis on solar energy equipment that is available in South Africa as options.

The study explored the acceptance of alternative energy options if they were accessible in the community. The study sought to ascertain what information about renewable energy, if any, was available to the respondents. The findings illustrated in figure 17 below, indicate that 92% of the respondents had knowledge about solar energy, followed by 30% biogas, 22% wind energy, 12% hydropower, 4% had knowledge on micro-grids and all the respondents had no knowledge of geothermal energy.

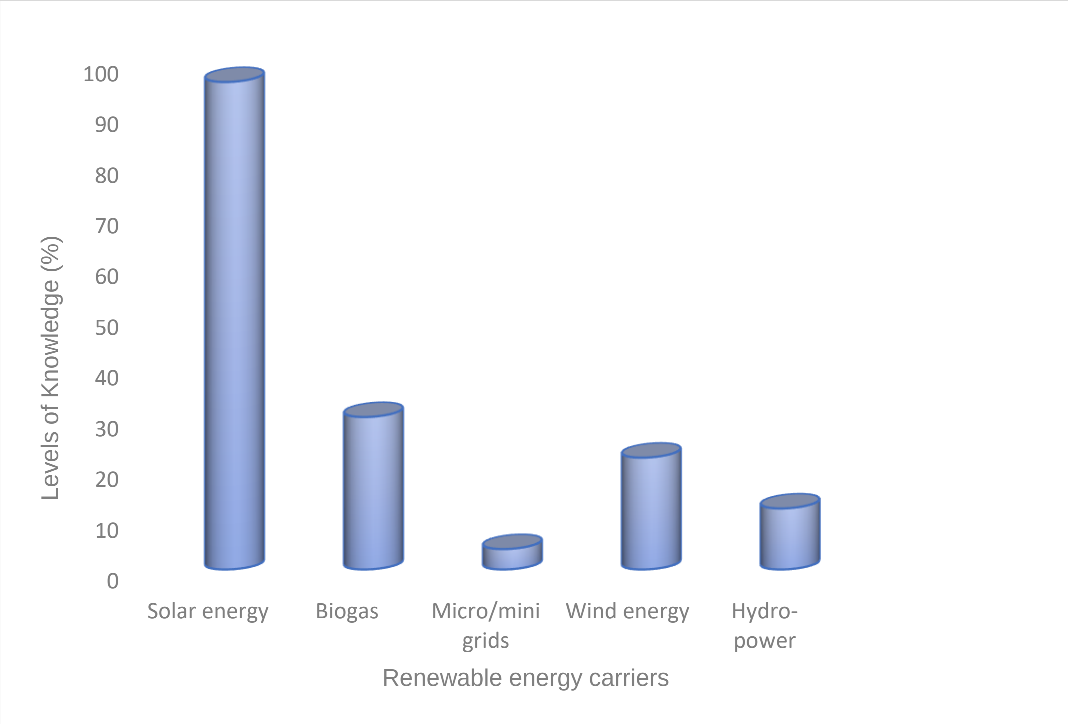

Figure 19: Knowledge of renewable energy carriers.

A high proportion of the participants indicated that they have never used any renewable energy technology or know people that have used it before. On average, 68% of the respondents had never used any renewable energy carrier, while 32 % said they have used solar energy. This was explored in order to explore the significance of the diffusion of innovation model. Which has a broad empirical basis and describes a social communication process through person to person and media channels that influence individual decisions on adoption of new technologies. The theory assumes a linear progression of knowledge, awareness, intention and behaviour that results in the adoption of technology. Thus, if more people learn about renewable energy and its advantages and it is adopted more in the community the theory advocates that more people will be using the technology. In the study, these sentiments are not visible. As there is little or no awareness programs about REs. Person to person and media channels have not included these messages in the communication and even if they did, such communication may be in English which is not widely spoken in the study area. The modes of communication are also varied that include many radio stations that broadcast in several languages.

In an example about the critical success factors for every cookstove programme in communities Makonese & Bradnum (2017) suggests that you need, (i) participation of communities; (ii) determination of user needs; (iii) study of existing practices; (iv) mimicking field results in the laboratory – 'bringing the kitchen to the lab'; (v) commercialisation and dissemination. However, it is important to note that sometimes adoption of new technologies is not always linear it can be constrained by factors such as social setting, cultural practices and traditions.

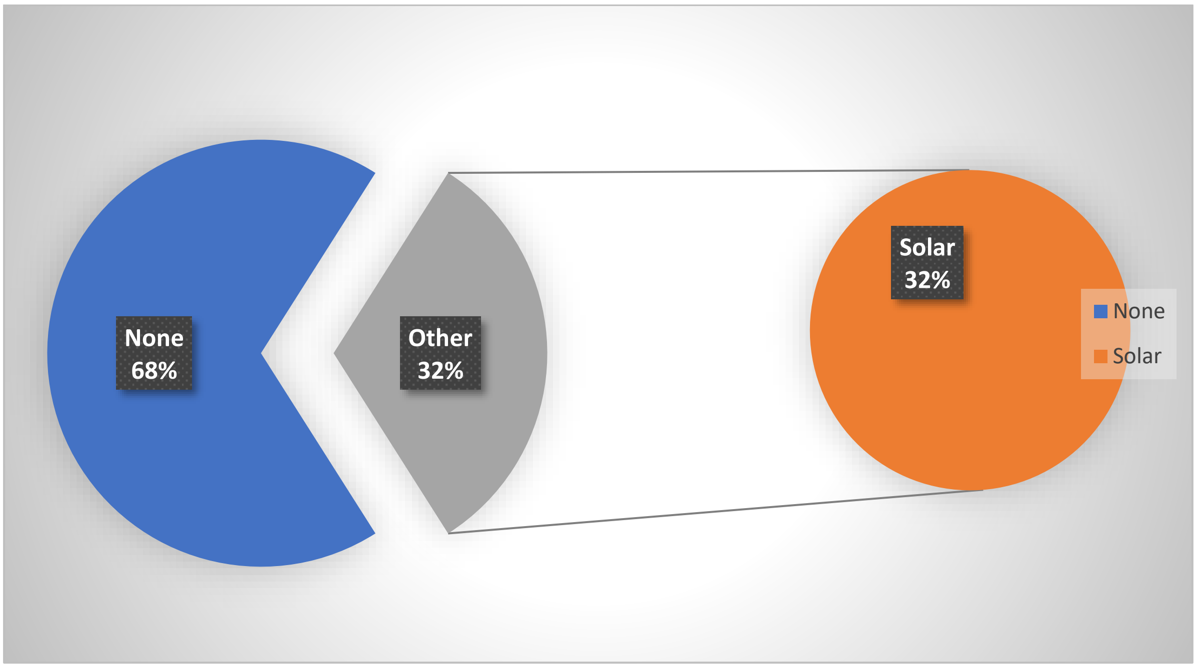

Figure 17: Showing percentage breakdown of renewable energy used in households.

4.5.1 Energy equipment

Investigating the knowledge or awareness of the types of energy equipment is important because it gives an indication of whether the uptake of technological options is as a result of lack of access or education about them, or the reluctance to uptake alternative technological options. The study not only wanted to highlight energy equipment that utilises renewable energy but also ones that may use traditional energy carriers or modern carriers but are more efficient. Some energy solutions could be low-cost mechanical options that improve energy efficiency within households. The identified energy equipment for cooking was the rocket stove, the wonder bag/ keep it in bag and the solar cooker. The rocket stove is a cooking woodstove that is designed to reduce fuel consumption (volume of wood) and pollution emissions, there are variations of the stoves in the market. One example of this stove is the Tshulu stove, the prototype was co-designed with the assistance of rural dwellers (Makonese & Bradnum, 2017). The findings indicate that 14% of the respondents had knowledge about the rocket stove.

The wonder bag or keep it in bag or hot box is an insulated slow cooking bag, 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 wonder bag 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 (SEA, 2017). The retail cost of a wonder bag ranges from R350-400. Figure 19 shows that 24% of the households had knowledge about the wonder bag.

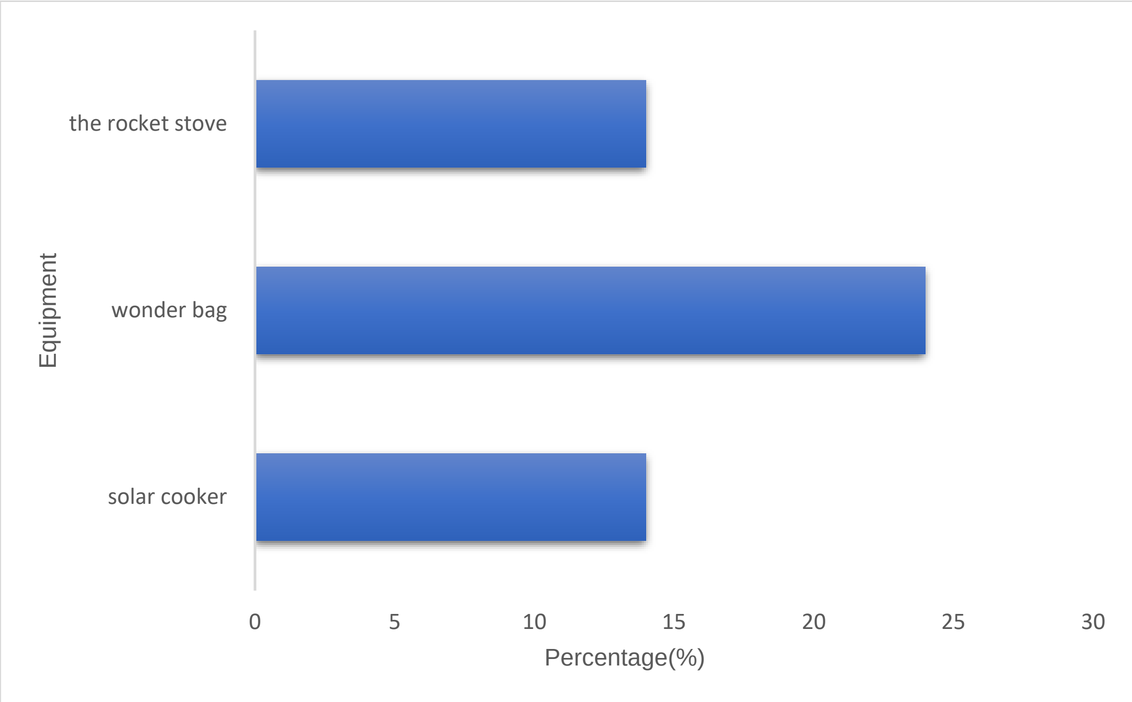

Figure 18: Knowledge or awareness of alternative cooking energy devices.

The above revelation further emphasises the lack of awareness on energy-saving alternatives. The assumption is, that when people are aware then use also increases. It is highly recommended that people are made aware of these alternatives and it is probable that the usage will increase.

According to SEA (2017), lighting has the lowest energy consumption in the household. Energy equipment such as Compact Fluorescent Lamps (CFLs) and LED lights are efficient lighting options for electrified households. They are cost-efficient, have a longer lifespan than traditional incandescent lamps and last more than eight times longer than incandescent lamps. It is particularly interesting that only 14% of the households reported having the energy-saving lights considering that there has been a massive rollout campaign by Eskom to use them. This is an aspect which can be debatable by asking oneself several questions. Why the adoption of energy-saving lights has been having there been low? How can the community be made to accept the energy-saving bulbs? Are they accessible? These were not questions raised in the study, though at one a respondent passively commented that they don’t give off enough light. It was interesting to know that lighting solar led lamps were known by 38% of the respondents, firstly because the percentage is higher than energy-efficient light bulbs campaign was backed up by the South African government and secondly because they are easily accessible in the retail market. According to SEA (2015), households were observed to have reverted back to the old, cheap, inefficient bulbs once the efficient bulb has died or broken.

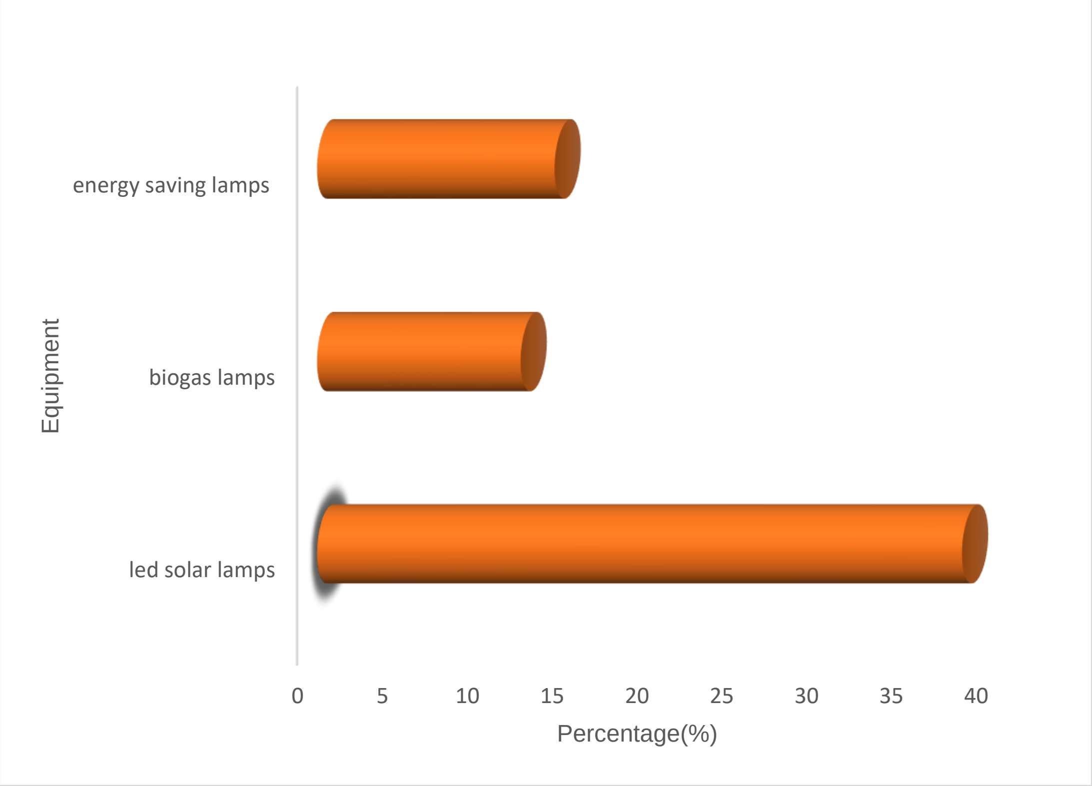

Figure 19: Knowledge or awareness of alternative lighting energy devices

The Solar Water Heaters (SWHs) are renewable energy equipment that uses thermal energy from the sun for the purposes of heating a property's hot water supply. SWHs can function in both residential and commercial applications. They have been introduced by the South African government for the new low- income households. Which makes it understandable why with 64% of the households had knowledge about solar water heaters, they are mounted outside thus visible to see. Interestingly, some participants indicated that they had seen them in the surrounding neighbourhoods but were unaware of their functions. The Tshisa Box is a low-cost alternative to a conventional solar water heater. It uses the sun to heat up about 10 litres of water in 4-5 hours and the water is safe to consume since it is disinfected by the sun's ultraviolet rays. It does not require any domestic plumbing system and no installation, which would be suitable for the unelectrified households (Project 90 by 2030, 2017). Only one household (2%) had knowledge about the Tshisa box.

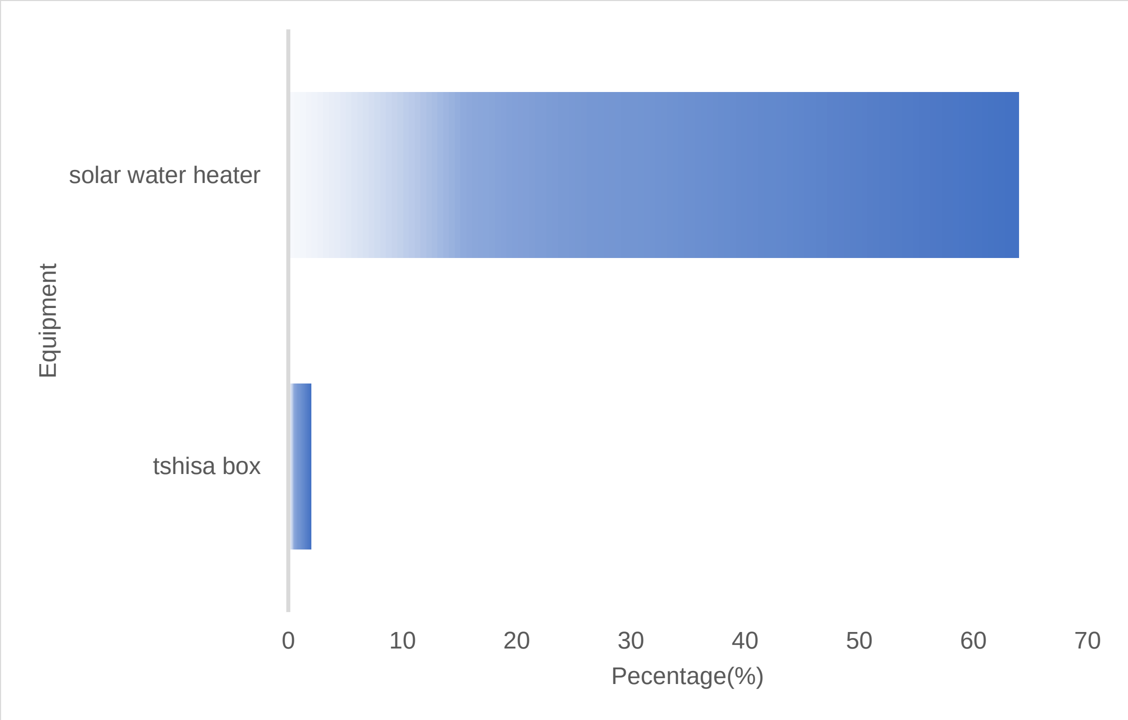

Figure 20: Knowledge or awareness of alternative water heating devices

In an attempt to investigate the role of government in promoting energy efficiency and energy education initiatives or programs, the researcher asked about energy campaigns that the participants take been involved in. More than a third (88%) of the residents said that they have never been a part of an energy campaign by the government, this is illustrated by figure 22. Those that indicated that they have been in some campaigns (12%) mentioned the Eskom campaign about introducing energy-saving fluorescent bulbs and receiving pamphlets on energy use and efficiency. There was also a campaign on Mbaula (space heating stove) and how to use it. Two households mentioned an initiative the NGO Greenpeace Africa and their project called Project Sunshine which partnered with a local NGO called Philile Foundation to provide solar street lights surrounding the NGO. This presents an opportunity for the government to create awareness campaigns to attain social acceptance of new technologies and fuels and improve energy conservation. There is a huge introduction of labelling energy-efficient appliances through awareness programmes, however, the target market seems to be middle-class consumers since the physical marketing strategy is localised in retail outlets such as Makro.

In a study by Simanauskaitem (2013) about REs disseminated in local communities in the Western Cape, revealed that majority of the participants received information through conventional sources such as local newspapers, radio and television; formal education; social networks being family and friends. A minority of the participants received information through the internet (depends on age), the municipality and project developers of the RE projects. The lesson that can be drawn from the study by Simanauskaitem (2013) is that there are several methods of disseminating information and these should be explored as a means to increase the impact of energy campaigns. Also relating it to the access of communication of new technology since most households indicated that they have access to cell phones (96%) and radio (48%), this could be effective ways to communicate new technologies or energy efficiency tips.

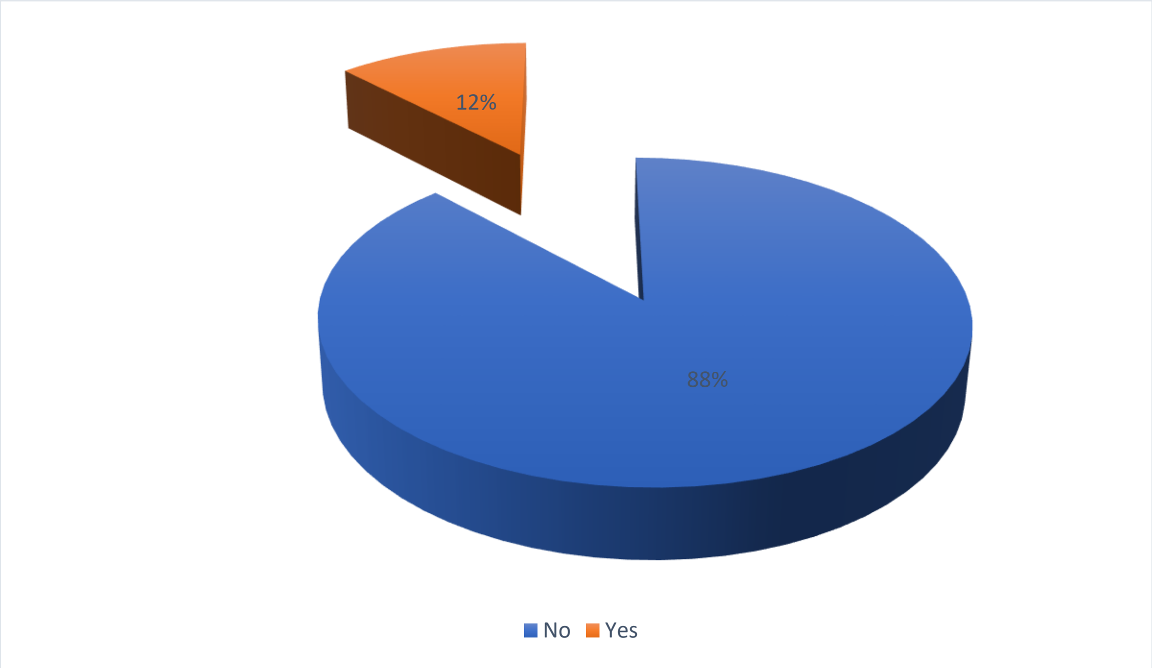

Figure 21: Involvement in energy campaigns by government

4.6 Conclusion

This chapter has presented the results and discussion of factors influencing energy usage and access including the household and community views on energy availability and challenges. From the results and discussion above, it is evident that energy challenges in informal settlements are varied. Overall the findings indicate that the respondents struggle with energy security and the challenges are varied and extensive. While there is a level of knowledge regarding renewable energy in the community, it is limited.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The aim of this study was to highlight the energy use choices, specifically energy fuels used for cooking, heating and lighting and identify energy-related challenges faced among households in Diepsloot. The study further interrogated the knowledge of renewable energy technology and alternative end-user energy equipment. Also, to explore the acceptability of alternative energy options. The aim of this chapter is to summarize the findings of the study, meet the last objective which is to provide recommendations and solutions to energy poverty challenges and to discuss the limitations and further research opportunities that could arise from this study.

5.2 Summary of findings

5.2.1 Energy patterns

Considering that 50% of the households had access to electricity, it was interesting to note the substantial difference in the energy sources used between electrified and non-electrified households. Particularly, the low percentage of households that use firewood for cooking yet those that do use firewood are unelectrified households. The significance of households using less traditional energy fuels and more transitional and modern fuels is that there will be a low percentage of indoor air pollution incidences caused by burning solid biomass. Also, lowering the associated health risks associated with burning solid biomass. Generally, most households use kerosene as a fuel source for cooking followed by electricity. A range of energy sources are used for among unelectrified households, the majority use candles and paraffin for lighting. Electricity is the most utilised for lighting among households who have access to it.

Unelectrified households mostly used kerosene and biomass for space heating. The results from this study are similar to a study conducted by Stats SA (2013) on the household energy patterns for South African households. The results indicated that despite the geographical location, economic status and income level, households without access to electricity are much more likely than households with access to electricity to use solid fuels for space heating and water heating. Only a few households used gas for heating both for unelectrified and electrified households. Despite the associated benefits of using LPG, which include it being clean, fast and efficient, a low percentage of households across the energy usage spectrum (cooking, lighting and heating).

Several households exhibited energy stacking properties, this includes households that have access to electricity. Having access to electricity allows for diversification and flexibility in energy choice, this is evident in electrified households choosing other energy carriers for their energy usage. These findings mirror the observations found in literature (Francioli 2018; Kowsari & Zerriffi, 2011; van der Kroon, et al., 2013). These results contradict the energy ladder model which assumes access to modern forms leads to a linear fuel transition from traditional energy sources, to transitional energy sources and to modern energy sources. Rather, the results support that the energy stacking theory which suggests that households utilize various energy fuels to meet their energy needs even when they have access to modern energy sources. Factors such as insurance against modern energy systems failure and reducing vulnerability against modern energy prices are the causes of energy-stacking (Kowsari & Zerriffi, 2011).

Affordability and availability were the most influential criteria in selecting household energy choice in terms of cooking and lighting. A small percentage of households prioritised efficiency and the cleanliness of the energy source. The preference of an energy source is closely linked to the question of adequacy of energy source, especially amongst non-electrified households. The results indicate that on average 55 % of households perceived the energy they used for cooking, lighting and heating as inadequate. This suggests that their energy consumption is constrained by several factors which include affordability, safety and health risks. Many households reported the reason for inadequacy as 'the lack of alternatives/ or being forced to use the energy source'. Consequently, this leads to households to use less desired and more dangerous energy sources because they are more affordable and accessible to them.

5.2.2 Energy challenges

This study shows that several energy-related challenges exist in Diepsloot. It is notable that there is segregated knowledge of electricity or energy services among electrified and non-electrified households in Diepsloot. While it can be argued that there is a lack of knowledge among unelectrified households about energy options, it also indicates a lack of communications about energy in the community. The most noted energy-related challenges are linked to municipality and utility service delivery. This is a problem with multiple complexities because Eskom is the utility responsible for providing electricity for Diepsloot while the municipality is liable for providing FBE/FBAE and other services in the community.

Crime is not fundamentally an energy-related challenge, however, the lack of lighting predominantly in non-electrified households makes residents in Diepsloot vulnerable to crime. The lack of lighting affects the services rendered by the municipality to Diepsloot. The darkness creates anonymity. The implication being residents who are afraid of being out at night or even in their own households.

Household perceptions regarding the dangers and impact of energy fuels such as kerosene and candles and biomass (firewood) similar to those reported by Francioli (2018). Moreover, Francolio (2018) revealed that a low percentage of fires are caused by non-electric energy sources in formal dwellings. This suggests that access to electricity reduces the dangerous energy-related incidences.

This study indicates that the stability of connections via backyard dwellers and frequent power outages affects the quality of energy received by formal households, as expressed in the participant's dissatisfaction in the electricity quality. The incremental cost of energy leads to households who cannot afford their monthly energy requirements. These findings have implications on the way we associate access to modern energy carriers and quality of services rendered by those carriers. Basically, it shows that the quality of the energy services supplied matters. The benefits associated with access are limited if the associated energy service is poor.

5.2.3 Renewable Energy uptake

Overall, there are low levels of utilising renewable energy technology and alternative energy sources. Solar energy is the most utilised (32%) and known RE source by the participant, households use solar for mostly for lighting and entertainment (radio). In terms of alternative energy sources for cooking the wonder bag was known by several participants. The results concerning the energy-efficient lights emergence of energy. A lack of education and awareness for RET equipment was evident. Importantly, an almost unanimous decision made by the participants of this study, is that if RE technology was available and accessible, they would opt to use it. These findings have an implication on the strategies and how the strategies are to be employed in informal settlements. This research, however, did not explore the acceptability of RE, or even if residents will be willing to pay for the proposed RE technology and alternative equipment.

5.3 Recommendations

The assumption that electrification is the ultimate solution to energy poverty is inconsistent with findings from various literature (Gaunt, et al., 2012, Francolio, 2018). Most of the challenges faced by residents of informal settlements are not isolated from other service delivery related challenges. Energy, water, sewage, housing, crime and unemployment issue that are interconnected in relation as to how they influence the standard of living and these issues are more apparent low-income households, because of their vulnerability. Thus, moving forward, these challenges should be tackled in an integrated manner. The recommendations in this dissertation aim to tackle energy issues in three-folds, they first address short term solutions to the energy access/provision problems that informal settlements face and secondly address energy efficiency in formalised housing and thirdly long-term solutions to energy problems.

This research identified the following strategies for addressing energy poverty and increasing uptake of renewable energy and efficiency interventions:

5.3.1 Governance and political will

Energy is highly political and as one of the most important factors that considered South Africa, energy access is crucial. The financial budget for cities and municipalities are set at a national level, however, implementation is a local level. Most politicians and municipal officials are reluctant to provide funding to informal settlements due to the fear that it would be an indication of settlement permanency. Runsten et al (2018) note that local government initiatives could exemplify good practices for implementing sustainable development projects that overcome national barriers. For instance, the City of Cape Town took an effort to extend services to backyard dwellers and the exploration of the possibility of doing so also to households living on private land (Runsten, et al., 2018).

Results from table 4.1 to 4.3 show us that energy challenges are broader than access to electricity or modern energy carriers, it also relates to the quality of the service that is delivered encompassing the energy carrier. Maintenance and adequate service delivery are very essential for the improvement of quality of life for people residing in informal settlements. At a basic level municipality must develop a sense of urgency when it comes to education and awareness of energy-saving measures and available alternative energy options. In light of the frequent load shedding events, it is crucial that the government and its local municipalities enable its citizens to have options of not being in the dark or left destitute. For instance, the local municipality could initiate 'A Litre of Light campaign, where the municipality educate the residents about creating low-cost lighting alternatives, using a plastic bottle (2litre) and water and embedding it to the iron shack roof with the top part of it protruding outside to capture sunlight. It provides households with indoor lighting during the day. The capital cost of this type of campaign would be low since the only costs that would be incurred by the municipality would be planning workshops or distribution or propagation of the educational material or social media campaigning. The costs incurred by the residents would be acquiring a plastic bottle which can be a recycled bottled and a sealant for waterproofing. Furthermore, energy programmes related to increasing the uptake of modern energy options such as LPG and compact fluorescent lights need to be re-visited, evaluated and continued because these are proven to increase energy efficiency.

Terrapon-Pfaff, et al (2018) make the point that with any established sustainable energy projects or campaigns there needs to be comprehensive monitoring and evaluation guidelines. In the long-term interventions are supposed to provide a combination of economic growth, improvements in living conditions, empowerment, social welfare, capacity building and environmental protection. Which makes evaluation a challenging task particularly if the municipalities are not functioning efficiently.

5.3.2 Policy and regulatory environment

In most countries, the government is the driver of new energy dissemination and provide the legal framework by formulating a policy that can be translated into practice. According to SEA (2017), the majority of policies concerning energy for low -income households are outdated in South Africa. Runsten, et al (2018) suggests that policies such as the FBAE and non-grid electrification policies need to be revisited to include urban dwellers and have provisions for backyard dwellers. Municipalities such as Stellenbosch and Nelson Mandela bay have piloted the adoption of interim strategies using the FBE policy to provide SHS to informal households. In short, FBAE subsidies need to be redirected to cleaner energy sources. In Kenya, the government adopted a VAT and import tax exemption for solar products. Since the exemption of VAT and import tariffs, the demand for solar products has increased and this resulted in a 25-30% reduction of the cost of power, allowing more people access to energy (Hansen, et al., 2015).

There needs to be a development of new regulatory frameworks that allow for community-owned decentralised energy systems. Because it would decentralise the control of energy systems by the state and enable communities to have ownership of energy systems. It would be beneficial to have these in place for guidelines, especially if the projects are commissioned by the community. Currently, there are regulations in place for Small- Scale Embedded Generation (SSEG). Small-scale embedded generation (SSEG) refers to power generation facilities, located at residential, commercial or industrial sites, where electricity is generally also consumed (SALGA, 2017). These are mainly solar photovoltaic (PV) systems but include also other technologies such as wind and biogas. An SSEG customer generates electricity on the customer's side of the municipal electricity meter, where the generation equipment is connected to, and synchronised with, the municipal electricity grid (i.e. 'embedded') (SALGA, n.d.). Although the adoption of SSEG is positive for energy diversification, the regulations do not address community-owned systems, whether small or medium-sized.

For informal settlements which are eligible for government-funded housing, awareness should be raised that the acceptance of fuels other than electricity through policies such as the FBAE does not exclude future electrification (Visagie, 2008). The provision of legal energy alternatives is crucial, it could lead to a reduction in incidences related to illegal electricity bridging and cable theft.

5.3.3 Technology

The most highlighted interventions needed for low- income housing include a combination of renewable technology, energy-efficient measures, efficient energy equipment, thermal insulation and site orientation. It is difficult to acquire a renewable energy system that encompasses all energy needs, especially in instances where grid connections are not feasible practical interim solutions could be provided such as decentralised energy systems such as solar home systems, micro-grids, biogas cookers and lights and solar kiosks can work but they must match local needs and be site-specific. The technical capabilities of these alternative options are varied, and unrealistic expectations should be managed. For instance, rooftop solar panels are weather dependent and have limited power capacity, if a SHS is installed the limitations should be specified to the household that will utilise it.

Energy-efficient measures such as buying appliances that have a higher grading, switching off the water heater(geyser) and appliances that are not in use, are methods of reducing energy expenditure for electrified households. Thermal insulation forms part of passive strategies for energy efficiency, by adding a ceiling insulator and reduces the energy needed for heating in winter and thus reduces energy costs. Additionally, building houses that are north oriented allows for the use of natural light. It is equally important to stress that RETs and passive energy strategies should be integrated from the design and conception of low –income housing projects. Ignoring these considerations will lead to more energy inefficiency in the future.

This research proposes the adoption of alternative end-user energy equipment explored in this research and others for informal households. For cooking the available energy options include efficient biomass stoves, LPG two-plate stoves, solar cookers and hot box (Keep-it-in bag). Lighting options include solar lights/ lamps, a litre of light, LGP lamps. For space heating, alternative options include LPG heaters. Additionally, for water heating solar water heaters (solar geyser) and hot water boxes (tshisa box) (SEA, 2017).

5.3.4 Capacity Building

Community buy-in and acceptance of the energy systems is important because it influences the viability of the projects. Unfamiliarity and lack of knowledge of new technology might lead to local opposition of alternative options. Considering the service delivery protests caused by the expectation of electricity as the primary source of administrating energy needs and the lack of knowledge about REs. Studies have noted that often renewable energy projects run the risk of the technology being stolen or vandalised due to multiple reasons including tribal disputes and selling of parts for revenue. In Papua New Guinea, under a wantok system rooted in tribal traditions, clans there share resources. Solar panels, which benefit a particular house or individual instead of the community, assault this system of wantok. Tribal communities have therefore smashed hundreds of solar panels or, worse, threatened their owners with violence (Sovacool, 2012). When technology such as solar water heaters or related RE infrastructure are installed in some households and not the entire community leads to feelings of frustration, tension and neglect which results in the vandalization of the installed infrastructure or technology (Ikejemba & Schuur, 2018). Similarly, Dubbeld (2017) noted that in Cape town one of the major problems is theft of these technologies soon after installation. This often leads to a reluctance by stakeholders and investors to initiate projects in low- income communities. The lack of demonstration and dissemination of these technologies' leads to scepticism, thus there needs to be extensive awareness campaigns for new technologies or alternative fuels to obtain social acceptability. One aspect that is often highlighted in terms of ensuring the success of sustainable energy projects is the provision of capacity development. This is in terms of education, awareness and training about the new technologies.

Capacity development in the developing world is often championed by Non-Governmental Organisations (national and international) and community-based organisations. In countries such as Brazil and Colombia some parts of South Africa capacity development through the establishment of Energy Practitioners Networks. These networks are comprised of key actors that work in spaces that seek to improve energy services for unelectrified and underserviced areas. These practitioners work for NGOs, as energy entrepreneurs, for small to medium-sized enterprises or independent experts. They collaborate and engage with various stakeholders to such as community-based organisations, government, community members and researchers. These networks facilitate knowledge exchanges, skills transfer, practise to policy workshops, technical training and research (Wuppertal Institut, 2016). For example, RedBioCol is a network for energy from biomass-based in Colombia. The Colombian Biomass Network aims to improve the perception of biomass technology, including bio-digesters and gasifiers, through the dissemination of various benefits of the technology in different areas of Colombia where the network has members (Wuppertal Institut, 2016). Establishment of energy networks in informal settlements could assist in improving knowledge on engagement with the local government regarding energy problems and understanding the structure and policy frameworks in place. Capacity development also needs to be prioritised within government institutions and structures, the role of municipalities must be made clearer in national policy and guidance (directive) issues as to the articulation of the policy at the local level.

It may be argued that informal settlements are an embedded part of the South African urban geography and it is due time to holistically transform the strategy we use to alleviate challenges such as energy poverty. It might be a contentious strategy; however, we should consider assisting informal settlers on the principles of housing design and educating the masses on erecting housing that will be more efficient, based on the materials that are available. For instance, thermal ceiling insulator can be made of easily obtained materials. Building more efficient housing and shacks has the potential to assist people in the conditions that they find themselves. A realistic approach would be to promote diversification of energy sources by promoting knowledge, awareness and accessibility of alternative energy options and allow the consumer to decide which one is more suitable for their households and voluntarily switching to the new technologies or systems.

5.3.5 Financial investment and funding

The capital cost of decentralised energy systems is the biggest challenge to introduce them into low-income households and informal settlements. Funding is mostly constrained by investment barriers by the private sector, policy and regulatory red tape by the government, and the limited capital residents have, to invest in alternative energy systems. For projects that are funded by the private sector (i.e. banks, companies) they must demonstrate feasibility and scalability and that usually means extensive audits or proposals that will indicate profits and stability. The Sustainable Development Goals are a commonality that can be leveraged for collaborative funding for sustainable energy projects. Organisations and communities could apply for international grants such as the Sustainable Energy Fund for Africa. The Sustainable Energy Fund for Africa (SEFA) is a multi-donor trust fund administered by the African Development Bank - anchored in a commitment of USD 95 million by the Governments of Denmark, the United States and the Norway - to support small- and medium-scale Renewable Energy (RE) and Energy Efficiency (EE) projects in Africa. Dubbeld (2007) highlighted various funding sources that may be available for RE interventions, these include The Development Bank; The German Development Bank (GTZ); The National Electrification Programme and private funding from various corporate and donor organisations.

It is equally important to consider the life-cycle costs of implemented energy interventions, although the maintenance of systems such as solar systems are minimal. It is also important to consider the long-term costs of operations such as cost of maintenance after installation of batteries and investors should be encompassed in any implemented energy intervention.

Central to the topic financing modern energy systems for low-income households and improving energy efficiency, Dubbeld (2007) suggests that it might be more crucial to implement renewable energy interventions in middle and upper incomes households first. The selection of upper-income households in particular, because their energy consumption is higher in comparison to those found in informal settlements and poor households. She argues that by making RE systems mandatory for high-income households and implementing a cross-subsidization strategy where the wealthy pay for grid electrification/ RE interventions of low-income households through an increased base rate (Dubbeld, 2007). This will lead to reduced energy consumption and electricity demand from the coal-fired grid electricity by middle-to upper-class households because they have increased capacity through RE systems and thus reducing the energy service demand. The reduced capital expenditure for middle to upper-income households on energy services can be redirected to infrastructure development for the poor. The implementation of these strategies is likely to yield better outcomes mainly because it limits the need for poor households to pay for these services. The additional advantage is the increase in the social acceptability of REs due to increased adoption in wealthy households.

South Africa has a unique financial savings group scheme called Stokvel's, which is an unexplored avenue for funding for energy systems would be by establishing a centralised energy fund (energy Stokvel) for investing in Renewable Energy Independent Power Producers (REIPPs) companies and decentralised systems. The purchasing of energy-efficient appliances and end-user devices could empower communities to ensure that energy. Bearing in mind that Stokvels are usually functional for specific reasons, the business model would have to resonate with the community that it seeks to influence and get buy-in. The idea of ownership of communal energy systems is not unique to South Africa, but the premise of energy democracy is to put these types of systems in place.

5.3.6 Access to markets and supply chain

The public sector creates the enabling environment, entrepreneurs enter the market with innovative models, and communities are (Methvin & Philipp, 2017). There is an emergence of climate-smart business opportunities, the prevalence of large transnational corporations investing in renewable energy. Most of the RE projects initiated in South Africa and other developing countries are formed as bilateral agreements between local NGOs and international donors such as governments, companies and institutes. One of the major criticisms of these projects is that bilateral development donors are driven by national interests as well, meaning they may desire to build markets for export, or use their own technology as a visible affirmation of their approach to development, more than the desire to help the poor (Martinot et al., 2002).

In the case of countries such as Germany, a global leader in renewable energy, one study noted that the bulk of technology transfer activities took the form of pilot projects or testing and demonstration projects, with little interest in diffusing the knowledge or technology to local companies or communities (Martinot et al., 2002). In other words, there is a lack of knowledge and technology diffusion in terms of production and manufacturing capacity of the countries (mostly in the global south) receiving RETs. Which in turn constraints the local markets who want to adopt the technology. Therefore, it is essential to evaluate the bilateral agreements for RE projects and ensure that they are not inhibiting growth in local markets by gatekeeping the technology. Rather the partnerships should build technical knowledge and transfer technology.

The development of an efficient maintenance plan for the technologies installed in communities or households should be in place. A proposed way this could be a good way to target the social development aspect by increasing employment of renewables by training the local people to become maintenance vendors for community systems. This will limit transport costs for the company installing these systems.

The development of small- to medium enterprises as vendors for the technology supporting and enhancing local entrepreneurship is important. It is recommended that small cylinder filling sites be established through already existing SMMEs in the local community. It is important that a reputable gas supplier is appointed to develop and support such filling sites will ensure that legal and safety requirements are adhered to.

5.4 Future research opportunities

In future research, it would be prudent to investigate effective mechanisms for information dissemination of renewable energy technologies. Furthermore, to know the levels of social acceptability in places where these technologies are in place. There is a need to explore the underlying policy and implementation blocks within the municipalities in relation to energy services in informal settlements and to monitor the progress of the national and municipal energy strategies set by the government.

5.6 Concluding remarks

Informality needs to be recognised as a part of urban geography. This study emphasised similar studies that have been conducted by scholars, NGOs and international organisations on energy poverty research, this research indicates that there is a multitude of options when it comes to energy poverty solutions. Rather than re-iterating these solutions we need to systematically investigate the drivers, complexities and challenges of the adopted and adopting RE projects. Then, perhaps it is time we postulate why these strategies are not being implemented in the broader context of South Africa, and with that how to unpack it further to have more energy democracy in South Africa. These are the final thoughts that I struggle with as I conclude this research. Trade-offs must be made regarding the provision of energy services in South Africa; immediate concerns should be tackled first such as replacing fire-prone energy fuels such as candles and kerosene with safer alternatives. Overall, this study has presented strategies that have the potential to improve the lives of the urban poor through the adoption of renewable energy technologies and other energy-efficient measures.

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APPENDIX A: QUESTIONAIRE

***Declaration or consent information*:**

My name is Pheladi Tlhatlha and I am a student doing a Master's degree in the Faculty of Natural and Agricultural sciences at the University of Pretoria. The aim of this research is to understand energy poverty and investigate renewable energy strategies that can be implemented in informal settlements. The questionnaire that will be used involves asking about household energy use, the energy use patterns and energy challenges in informal settlements. The results will be used to produce a mini dissertation to fulfil the requirements for M.Sc. Environmental Management. The survey takes about 30- 45 minutes. Your participation is anonymous, voluntary and can be withdrawn at any stage. If there any questions, feel free to ask. So, if I have your permission, I will continue with the questionnaire. Thank you in advance

Title of study:

Renewable energy strategies for alleviating energy poverty in informal settlements: a case study of Diepsloot - South Africa

Target: Adult household head

A. ENERGY USE PATTERNS OF INFORMAL HOUSEHOLDS IN DIEPSLOOT

1. Head of household

a. Female	1
b. Male	2

2. Highest level of education?

a. No matric	1
b. Completed matric	2
c. Tertiary level	3

3. How many people live in your household?

a. 1 – 3	1
b. 4 - 7	2
c. > 7	3
d. 7+	4

4. How many rooms does your household have?

a. 1	1
b. 2- 3	2
c. 5- 7	3

5. What best describes your income source?

a. Full time employment	1
b. Part-time employment	2

c. Self-employed	3
d. Social support grant	4
e. Pension	5
f. Other	6

6. What bracket best describes your monthly income?

R0 - R 2 153	1
R 2 153- R3 965	2
R3 965- R10 081	3
R10 081- R 28 038	4

7. What bracket best describes the monthly expenditure on energy sources (including cooking, lighting and space heating)

R0 - R 150	1
R 150- R500	2
R 2000- R 3000	3
R 3000+	4

8. Which energy sources do you use for cooking?

Electricity	1
LPG,	2
Kerosene/Paraffin	3
Solar system	4
Cell batteries	5
Firewood, straw, dung, charcoal	6
Other sources	7

9. What type of equipment or stove do you use for cooking?

Electric stove	1
Gas stove	2
Paraffin stove	3
Other	4

10. Reasons for choosing a particular energy carrier as main fuel for cooking?

Affordability & availability	1
Availability	2
Affordability	3
Efficiency & cost-effectiveness	4
Flexibility	5
No smoke & cleanliness	6
Other	7

11. Which energy sources do you use for lighting?

Electricity	1
LPG,	2

Candle	3
Solar system	4
Cell batteries	5
Firewood, straw, dung, charcoal	6
Other sources	7

12. Reasons for choosing a particular energy carrier as main fuel for lighting?

Affordability & availability	1
Availability	2
Affordability	3
Efficiency & cost-effectiveness	4
Flexibility	5
Smoke & cleanliness	6
Other	7

13. Which energy sources do you use for heating?

Electricity	1
LPG,	2
Natural gas	3
Kerosene/ Paraffin	4
Blankets	5
Firewood, straw, dung, charcoal, other	6
Other sources	7

14. Which appliances do you have in your household?

Stove	1
Refrigerator	2
Television/ Radio	3
Computer / Laptop	4
Cell phone	5
Heater	6
Light bulbs	7
Generator	8

15. How many times a week do you cook?

a. 3	1
b. 5	2
c. 7	3

16. Do you consider amount of energy you use on cooking adequate for your household needs?

a. Yes	1
b. No	2

17. If no, why not?

……

18. Do you consider amount of energy you use on lighting adequate for your household needs?

a. Yes	1
b. No	2

19. If no, why not?

……

20. Do you consider amount of energy you use on heating adequate for your household needs?

a. Yes	1
b. No	2

21. If no, why not?

……..

B. CHALLENGES OF ENERGY ACCESS AND USE

22. From the list below, what do you consider as a challenge in using and accessing the form of energy

Challenges	**Agree**	**Neutral**	**Disagree**
Household level			
I cannot afford to pay for the monthly energy costs			
Alternative energy sources are inadequate for the household needs			
The FBE/ FBAE is inadequate for monthly energy costs			
House wiring is troublesome			
Quality of health of the individuals in the household is significantly affected by the energy available			
House fires are prone due to unsafe energy sources			
Owning/ using energy appliances that require electricity is a challenge			
Energy equipment used consumes a lot of power			
Community level			
Police official's response is slow/ inadequate due to lack of lighting			
Walking in the neighbourhood at night is challenging due to lack of lighting			
Crime and mugging rate is high			
Theft of cables and illegal connections are prevalent in the community			
Bribery for power supply is common			
Getting pre-paid electricity vendors is difficult			
Getting alternative energy sources from community vendors is difficult			
Municipal/ Power provider level			

There is lack of communication and education on FBE/FBAE by the local municipality or power provider			
There is lack of information and education about energy efficiency and alternative energy sources			
Power provider puts a lot of pressure to pay			
There is no standard rate to pay for power			
Bribery for power supply is common			
Power costs keep increasing			
Power supply is unreliable			
Slow response when power is cut off			
Experience frequent power outages			

Comments
………
………
………

C. KNOWLEDGE OF RENEWABLE ENERGY SOURCES AND ACCEPTABILITY

23. Do you have knowledge about these alternative energy sources?

Solar energy	1
Biogas	2
Micro/mini grids	3
Wind	4
Geothermal	5
Hydro-power	6

24. Have you ever used any of the above alternative energy source?

……..

25. Do you have knowledge about these alternative energy appliances/ end-user devices?
    a. For cooking

Solar cooker	1
Solar cooking bag (Wonder bag)	2
The Rocket Stove	3

    b. For lighting

LED solar lamps	1
Biogas lamps	2
Compact Fluorescent Lights	3

    c. Water heating

The Tshisa box	1
Solar water heater	2

26. If these alternatives were available/ accessible would you opt to use them?

a. Yes	1
b. No	2

27. If no, why not?
   ……………………………………………………………………………………………………
28. Does anyone in your neighbourhood use alternative sources of energy?
   ……………………………………………………………………………………………………
29. What source of energy do they use?
   ……………………………………………………………………………………………………
30. Have you been involved in any energy campaign by government?
   …………………………………………………………………………………………………….
31. Briefly explain what the campaign was about?
   …………………………………………………………………………………………………….

APPENDIX B: RENEWABLE ENERGY ILLUSTRATIONS

1. Solar energy

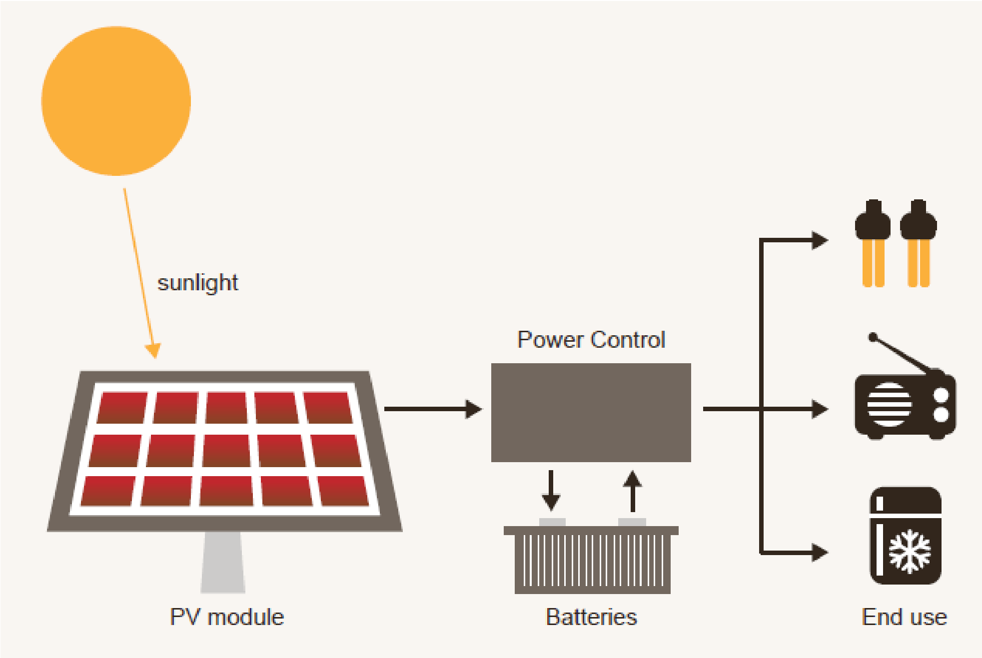

Figure 20: Schematic view of a PV-System for off-grid applications (Wuppertal Institute , n.d.)

2. Wind energy

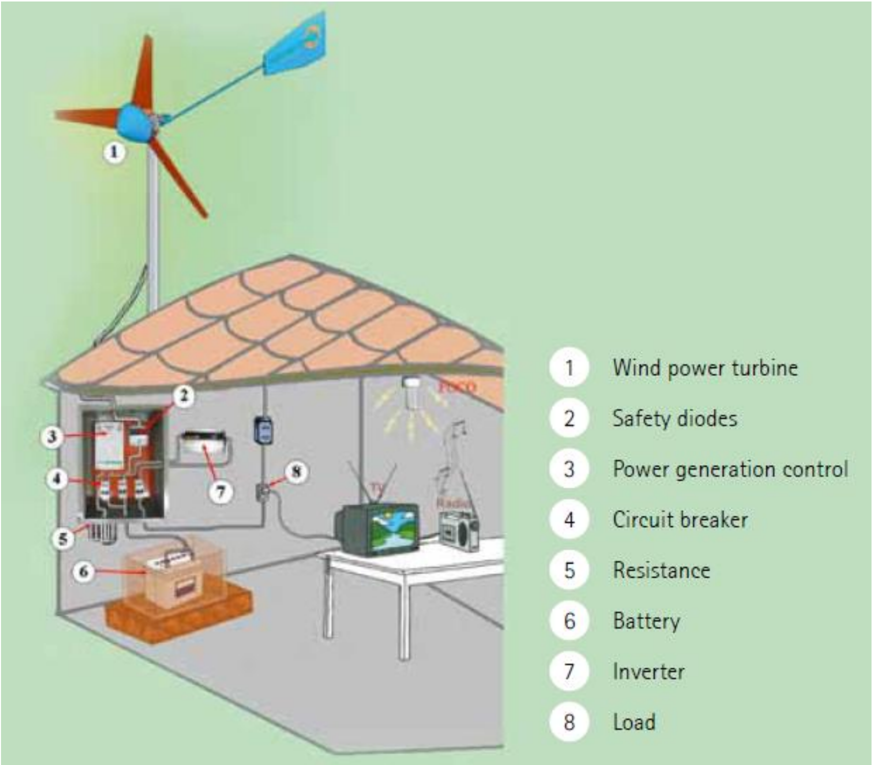

Figure 21: Schematic view of a wind power system for off-grid applications. Source: Soluciones Prácticas, technical handbook prepared during the project in "El Alumbre". (Wuppertal Institute , n.d.)

3. Biogas energy

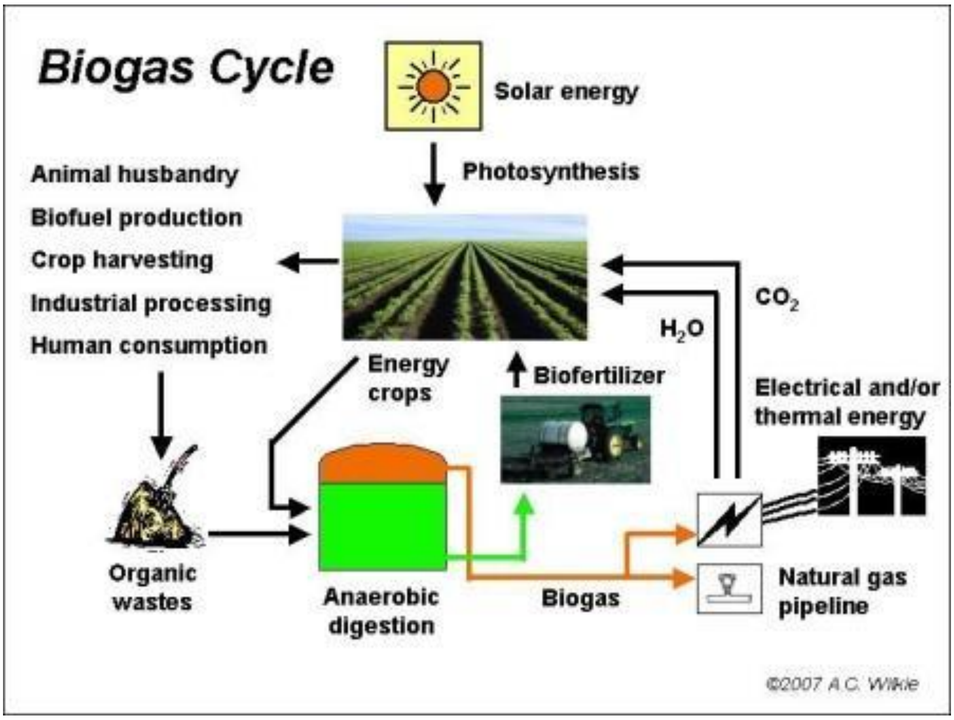

Figure 22: Schematic diagram of biogas cycle (Winkle, 2007)

4. Microgrid energy

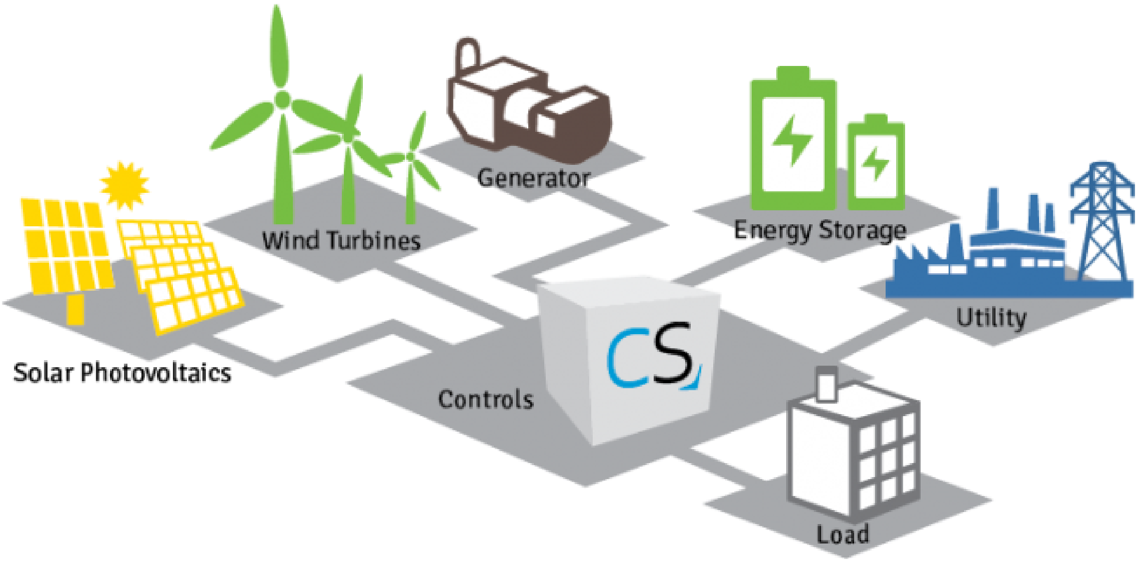

Figure 23: Schematic view of microgrid system image adopted from (https://www.solup.com/microgrids-next-evolution-grid/)

5. Hydropower

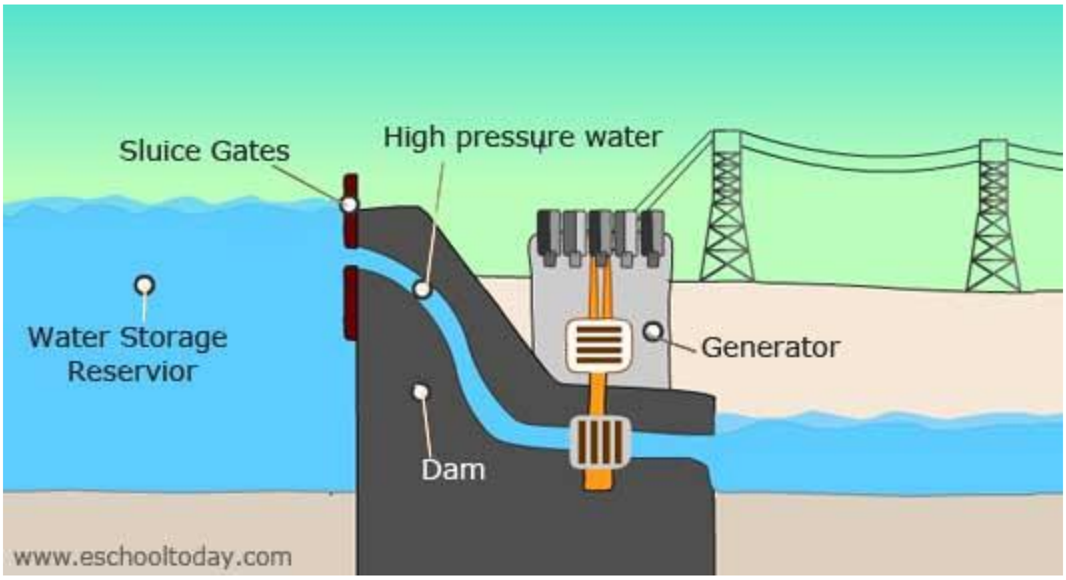

Figure 24: Schematic representation of a hydroelectricity

Section 2: Energy Appliances

1. Solar cookers

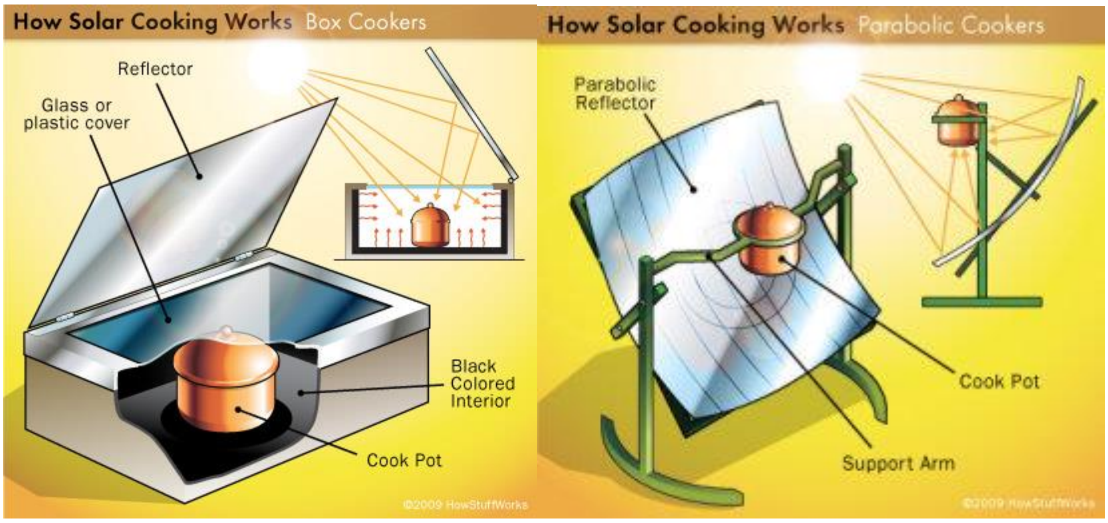

Figure 25: Depicting solar cookers (image adopted from https://science.howstuffworks.com/environmental/green-science/solar-cooking1.htm)

2. **Keep it in bag/wonder bag**

Figure 26: Keep it bag or Wonder bag (Project 90 by 2030, 2017).

3. **Rocket stove**

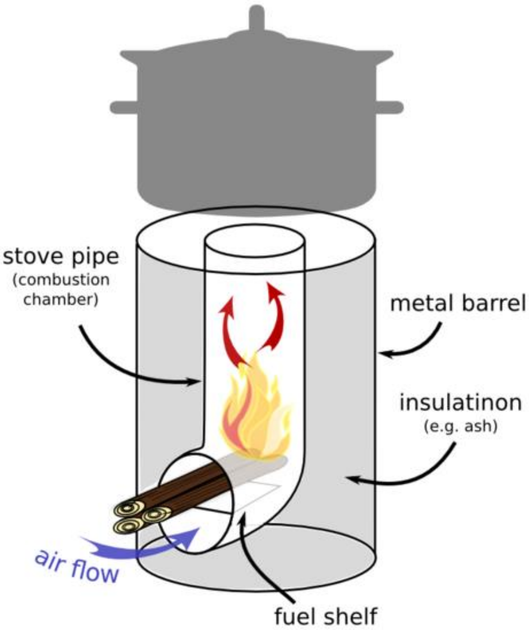

Figure 27: Rocket stove image adopted from (https://commons.wikimedia.org/wiki/File:Rocket_stove.png)

4. **Solar light/lamp**

Figure 28: Solar lamp image adopted from (https://www.amazon.com/Solar-Light-Bulb-Powered-Portable/dp/B07GWH2X49)

5. **Biogas lamp**

Figure 29: Biogas lamp (image adopted from: https://www.made-in-china.com/showroom/samuelxie07/product-detailgqcxIPWDHlVh/China-Biogas-Lamp-ZD800-400-.html)

6. Compact Fluorescent bulbs

Figure 30: Compact Flourescent bulb, image image adopted from (https://www.lightbulbwholesaler.com/c-560-compact-fluorescent-light-bulbs.aspx)

7. Tshisa box/ hot box

Figure 31: Tshisa box (image adopted from: http://tshisa.co.za/tshisa-box/)

8. Solar water heater

Figure 32: Solar water heater image adopted from (http://s3.amazonaws.com/ferryenergy/200-solar-water-heater-price.html)

APPENDIX C: QUALITATIVE RESULTS

Challenges and perceptions of participants

Ambulances don't come when there is no electricity. Repair of electricity boxes takes time, up to weeks.
Crime is high they even steal solar panels. Gas is expensive. Solar is inaccessible. Cops say they do not patrol because there is a lack of lighting.
Paraffin is dangerous, it can cause fires
Eskom is slow to respond. We experience a lot of winter outages. Backyards are too many in the neighbourhood, electricity trips a lot.
Eskom takes a long time to fix transformers, sometimes electricity goes for more than a week. Paraffin is unhealthy. Kettle and iron consume a lot of energy. Municipality, Eskom & Police have poor service, we take care of ourselves.
FBE do not get it anymore, bridging common and causes the whole street to go off. Police response is bad regardless of lighting. My grandmother has asthma caused by paraffin.
Free Basic Electricity, had it previously, told they need to reapply for it In winter we experience load shedding Transformers bursting due to heaters and backyard dwellings
I have a lot of back rooms to cover the energy costs
My nose gets blocked at night, I have allergies, makes me uncomfortable and irritated. Solar knowledge is available however the system is just costly.

Multiple connections trip the electricity, we have spent 6/7 days without electricity, it is worse in winter. Electricity is safer than others. Stove consumes a lot of energy. Ambulance and Police have poor service.
Paraffin affects the children; it has different grades. The Spaza shops (community shop/vendor) sell the cheapest grade. Studying at night is difficult due to lack of good light sleep. Food goes bad because of lack of refrigeration. Police are scared of the dark. Even ambulance struggle to come in the community at night.
Paraffin affects the eyes, creates a burning sensation
People from power providers look for bribes to assist. More education would be helpful to assist owners.
Smoke inhalation is dangerous for health. Our house has burned down before due to paraffin usage, we had to start over.
Smoke is not good for the children. Generators and solar panels end up being stolen so people resort to selling the equipment.
Solar panels are stolen. Some paraffin seems fake, it blocks noses and makes eyes sore in children. We sleep with one eye open because it is too dangerous due to house break-ins.
Stove consumes a lot of electricity.
The cost for solar panels (small ones) is high, we have given up on it. Children have moved to Cosmo City for a better life because of lack of electricity. There is a lack of entertainment in the form of television.
The electricity tariffs are expensive

The smoke hurts/ irritates our eyes when we use firewood
There have been complaints about the lack of electricity, people wanting electricity.
In winter we experience frequent power outages
They have given out pamphlets about energy efficiency around the community.
Transformers bust due to overloading of electricity
Where there is light, it is safer. Experienced a church break-in Solar panel break-ins/ theft