University of Pretoria

A NOVEL SYSTEMS APPROACH TO ENERGY POVERTY IN SUB-SAHARAN AFRICA: A SOUTH AFRICAN INFORMAL SETTLEMENT CASE STUDY

by

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my original work and that I have not previously in its entirety, or part, submitted it at any university for a degree.

Signature: -------------------------------------

15th September 2020.

Date: -------------------------------------

ABSTRACT

Mitigating energy poverty requires a multi-criteria decision protocol integrating socio-economic, cultural, environmental, and technical systems, influencing energy access, and consumption. Situations of energy poverty are typical in rural and urban poor households, particularly in sub-Saharan Africa. These situations are commonly prevalent in informal settlements, sprawling across the periphery of South African metros. Majorities of informal households lack access to grid-electricity and consume local energy sources for their energy needs. There are ongoing government efforts directed to mitigating energy poverty among energy-poor households, such as informal households, through policies and subsidies. Socio-economic and cultural environments also redefine the extent to which energy poverty is mitigated in these households. At present, informal households are constantly and rapidly growing, and as a result, compromise policy effectiveness and other functional strategies, targeting to mitigating energy poverty in these households, and achieving universal energy access in South Africa.

Accordingly, this research study adopted a multidisciplinary approach to understanding related matters of energy poverty based on energy policies; electricity access, and pricing; geospatial analysis; energy use and access; and management strategies, with emphasis on informal settlements in South Africa. The first part of the study reviewed energy pro-poor policies, relevant to improving energy access and energy-use efficiency in energy-poor households in South Africa. The study also investigated electricity access (access rates), connection costs (access costs), and electricity tariffs to understand historical precedents and forecast scenarios, and the relationships to gaining complete electricity access by 2030 in the City of Cape Town. The third part mapped and monitored informal areas to understand landscape processes and poverty with energy poverty propagations by Land Cover (LC) and Land-Cover Change (LCC) in the City of Cape Town. The fourth part of the research investigated energy-use patterns and other energy-related matters in a selected informal settlement - a typical case study of an energy-poor community in South Africa and sub-Saharan Africa. The last part proposed and designed a novel System Reinforcing Model (SRM), an Energy Access Sustainability (EAS) management scheme, applicable to mitigating energy poverty in any energy-poor community.

The study review validated government efforts in improving energy access in energy-poor households through commissioned energy pro-poor policies but not without drawbacks and proposed recommendations to support future policy reforms. The research also revealed increasing patterns in historical trends of access rates, costs, and tariffs, and relationships between parameters within the assessment period (from 2010 to 2018). The forecast analyses (from 2019 to 2030) demonstrated that total electricity access could not be reached by 2030 without a shift in Business-As-Usual (BAU) patterns in the City of Cape Town. The LC conversions of informal areas revealed poverty with energy poverty propagations through landscape degradation processes - *Persistence* and *Intensification* - in the City of Cape Town. The research study further revealed poor energy use patterns and behaviour in the target Settlement. Informal households in the settlement mainly adopted local energy fuels and appliances in satisfying household energy needs.

The novel part of the research study described the application of a systems approach - Systems engineering (SE) and Systems Thinking (SsT) - into energy poverty and access processes to developing the new SRM. SE and SsT concept analyses were employed in identifying and integrating four operating system interfaces in these processes into the new SRM. The new SRM simulated complex systems and elements within the interfaces and categorized them as design decisions and system designs. These systems and elements were grounded in energy-use patterns and behaviour, energy access, and EAS, as well as socio-economic, cultural, technical, and environmental features. Arrays of feedback loops in reinforcing patterns in the new SRM modelled the interactions between, and within, design decisions and system designs, for future energy access rebranding, based on significant sustainability outcomes of favourably coalesced system interfaces. SRM was applied in the target settlement, where the model's significance was validated. Based on its multi-criteria decision approach, among its many features, SRM revealed system parts instigating energy poverty situations and limiting EAS in the target settlement. SRM tailored energy access solutions, whilst integrating significant outcomes of the whole research study, to advancing energy poverty mitigation and EAS in the target settlement.

Keywords: Energy Poverty, Energy Poverty Mitigation, Energy-Use Patterns and Behaviour, Energy Access, Energy Access Sustainability, Informal Settlements, Energy White Paper, Energy Pro-Poor Policies, Electricity Access, and Pricing, Electricity Forecasting, Land-Cover Classification, Land-Cover Change Detection, Land-Cover Conversion, Spatial Analysis, Geographical Information System, Systems Approaches, Systems Engineering, Systems Thinking, System Modelling, System Reinforcing Model.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

Ab	Abandonment
AEL	Atmospheric Emission License
ANC	African National Congress
BAU	Business-As-Usual
BEST	Biomass Energy Strategy
CD: NGI	Chief Directorate: National Geospatial Information
CDM	Clean Development Mechanism
CGA	Centre of Geographical Analysis
CNs	Cognitive Norms
CO^2	Carbon dioxide
CoGTA	Cooperative Governance and Traditional Affairs
CSP	Concentrating Solar Power
CVM	Contingent Valuation Method
D1	Reference 2011 LC
D2	Edited 2011_2010 LC
D3	Derived 2016 LC
DD4	Change analysis between D1 and D3
DD5	Change analysis between D2 and D3
DHS	Department of Human Settlements
DME	Department of Minerals and Energy
DoE	Department of Energy
EAS	Energy Access Sustainability
EBSST	Electricity Basic Support Services Tariff
EC	Energy Cultures
EDI	Energy Development Index
EISD	Energy Indicators For Sustainable Development
EMS	Electromagnetic Spectrum
EO	Earth Observation
EPRAP	Energy for Poverty Reduction Action Plan
EPs	Energy Practices

ESRI	Environmental Systems Research Institute
FBAE	Free Basic Alternative Energy
FBE	Free Basic Alternative Energy
GDP	Gross Domestic Product
GHG	Greenhouse Gases
HDA	Housing Development Agency
HDI	Human Development Index
HES	Household Electrification Strategy
IBT	Inclining Block Tariff
ICTs	Information and Communication Technologies
IDPs	Integrated Development Plans
IEA	International Energy Association
In	Intensification
INCOSE	International Council on Systems Engineering
INEP	Integrated National Electrification Programme
LC	Land Cover
LCC	Land-Cover Change
LGES	Local Government Equitable Share
LPG	Liquefied Petroleum Gas
MCs	Material Cultures
MDGs	Millennium Development Goals
MEPI	Multidimensional Energy Poverty Index
MLC	Maximum Likelihood Classifier
MODIS	Moderate Resolution Spectroradiometer
NEP	National Electrification Programme
NEP	National Energy Policy
NERSA	National Energy Regulator of South Africa
NES	National Electrification Scheme
NGO	Non-governmental Organization
NIR	Near-Infra-Red
NLC	National Land Cover
NSCs	Non-Subsidized Connection Costs

OBIA	Object-Based Image Analysis
OEP	Off-Grid Electrification Program
Pe	Persistence
PM	Particulate Matters
PPP	Purchasing Power Parity
PV	Photovoltaic
RD	RDP Development
RDi	RDP Development (Interspersed)
RDP	Reconstruction and Development Programme
REI4P	Renewable Energy Independent Power Producers Procurement Programmes
REP	Rural Electrification Program
RGB	Red, Green, Blue
SALGA	South Africa Local Government Association
SANSA	South African National Space Agency
SCs	Subsidized Connection Costs
SE	Systems Engineering
SEA	Sustainable Energy Africa
SEA	Sustainable Energy Access
SHEP	Self-Help Electrification Program
SHS	Solar Home System
SNEP	Strategic National Energy Plan
SoS	System of Systems
SRM	System Reinforcing Model
SSA	Sub-Saharan Africa
SsT	Systems Thinking
StatsSA	Statistics South Africa
SWHs	Solar Water Heaters
UD	Urban Development
UN	United Nations
WHO	World Health Organization

CHAPTER 1: INTRODUCTION AND BACKGROUND

Many energy poverty issues have been broadly advocated in literature and public policies (Sadath and Acharya, 2017); McCollum *et al*. 2017; van Vuuren *et al*. 2017; M. Balmer 2017). Typically, energy poverty is regarded as a socio-economic problem, mostly faced by poor households in rural and urban poor areas, particularly in developing countries. In its simplest form, energy poverty is normally described as a lack of access to clean energy sources and modern energy services. Energy poverty is beyond a lack of access to energy and income poverty. One of the factors promoting energy poverty mostly comes from socio-cultural environments, which are likely to shape energy-use patterns and behaviour in households. According to Mehlwana (1997), the situational analysis of energy-use patterns requires assessments of multi socio-cultural dimensions, compelling energy poverty situations among energy-poor groups. Consequently, energy poverty mitigation cannot employ only technical indexes, and algorithms but should consider extensively, socio-cultural circumstances defining energy-poor groups. According to literature, billions of people lack access to electricity and clean cooking facilities, in developing countries (Sokona, Mulugetta and Gujba, 2012). Supposedly, over 2.5 billion people are expected to lack access to clean energy sources for cooking by 2030 (United Nations 2014).

No consensus has been reached as to what entails energy access. The International Energy Association (IEA) describes energy access to include, firstly, satisfying basic human needs, improving productivity, and lastly, satisfying modern energy services (Vermaak, Kohler and Rhodes Bruce 2013). Energy access eradicates poverty by providing social services, employment, and promote economic growth and sustainable human development (Brew-Hammond 2010). Clean energy access also gratifies modern energy services and reduces Greenhouse Gas (GHG) emissions and health maladies, such as chronic respiratory illnesses, caused by poor energy use. Primarily, improving clean energy access requires decisions promoting environmentally-friendly energy technologies and energy affordability in the long run. Now and again, these decisions are beyond government efforts and policies but tied to complex processes surrounding energy access and consumption, and future management specifications.

Regardless, the South African government has been improving clean energy access through energy pro-poor policies, as far back as 1998, in energy-poor households (DME 1998). These policies include the Integrated National Electrification Programme (INEP) plan (DoE 2015); Free Basic Electricity (FBE) policy (DME 2003); Free Basic Alternative Energy (FBAE) policy (DME 2007); Non-grid policy (DoE 2012); Inclining Block Tariff (IBT) regulatory structure (SEA 2014); and the Reconstruction and Development Programme (RDP) – a pro-poor housing scheme (DME 1998). Policies have been implemented and progress on implementations well-recorded but nearly half the nation's population lack access to electricity and clean energy sources (SEA 2014). Some studies are seen to have reviewed energy pro-poor policies, separately or in groups, and have provided policy recommendations (Borchers and Dobbins 2007; and Mohlakoana 2014), and progress achieved, over time (Kelly and Geyer 2018). No study was found to have reviewed, collectively, these policies, expressed in the 1998 Energy White Paper (DME 1998). The **first part** of this research broadly reviews these identified policies to understand policy effectiveness, progress, drawbacks, and recommendations for future policy reforms in South Africa.

For long, electricity/energy forecasts are employed in modelling future energy access and scenarios to reduce risks of supply shortages as a result of socio-economic and political abstractions (IEA 2009). Both long- and short-term forecasts can provide useful empirical information on the need to develop energy technologies that equal energy consumption and improve energy-use efficiency. Forecasting electricity and energy-related matters identify problem areas of energy security that require institutional advancements and policy modifications. Studies have analyzed either long, or short-term forecasts of electricity prices (Neupane, Woon and Aung 2017; Bento *et al.* 2019), and electricity demand (He *et al.* 2017; Kankal and Uzlu 2017; Qiu *et al.* 2017). A particular study critiqued electricity demand projections by the utility parastatal - Eskom, in South Africa (Inglesi and Pouris 2010). At this point, no study has conducted electricity forecasts based on electricity access rates, and electricity costs and tariffs. The **second part** of this research study conducts historical assessments and short-term forecasts of these electricity-related matters to gaining total electricity access, within a specified period, at a regional scale; in this case, the City of Cape Town – acting as the secondary case study of the research.

South African cities are presently inundated with traditionally developed and low-density suburban regions, often referred to as informal settlements or areas. Mostly, urban poor are marginalized in these regions due to discriminatory legislature on land distribution in force during the Apartheid era. Theoretically, valuable information obtained through a temporal scaling of infrastructure support energy poverty mitigation (Kyprianou and Serghides 2018), mainly propagated in informal settlements that are rapidly expanding across the provinces in South Africa. According to ESRI (2009), the location-based information on infrastructure accelerates clean energy and promote environmental integrity to economic growth. Evidently, spatial data and regionalized resources provide valuable evidence, complying with future infrastructure and energy management (Cooper *et al.* 2014). These resources can be used to interpret relationships between multiple environmental spheres, spatially, and temporally. The public health sector has employed geospatial data and techniques, including the built environment, social, and economic indices, to monitor disease outbreaks (Oldfield 2011). A similar study used similar techniques in monitoring informal settlements, sprawling across provinces in South Africa, (DHS and SANSA 2011). No study has considered using an indicator-based detection approach in describing trends in informal areas. The closest to this adopted this approach in characterizing landscape gradients for grassland rehabilitation in the rural Eastern Cape in South Africa (Munch *et al*. 2017). The **third part** of this research maps and monitors informal areas and then employs this approach in describing land-cover conversions of informal areas at the regional level – the City of Cape Town.

Most informal households have electricity access – thanks to an extensive electrification programme since 1994 (DoE 2015), whereas others are without electricity access. Whether informal households have electricity access or not, local energy sources, such as paraffin, charcoal, are used in satisfying energy needs in these households. Also, these households practice multiple energy uses, such as using, concurrently paraffin, and electricity for space heating in winter, for example (Mdluli and Vogel 2010). According to Mehlwana (1997), household multiple energy uses are beyond some financial implications but may be due to some sociocultural inclinations. The World Health Organization (WHO) though considers energy access as a percentage of people using electricity whilst integrating other energy sources. Reporting on energy-use patterns in South Africa has always been all-inclusive of informal households across the provinces (Mdluli and Vogel 2010; SEA 2014; Mehlwana 1997; HDA 2012). A precise assessment can identify insignificant factors prompting certain energy-use patterns and behaviour, especially where future mitigation measures may be possible. The **fourth part** of this study embraces empirical studies to analyze energy-use patterns and behaviour and other energy-related matters in a selected energy-poor informal settlement. For this study, the target settlement acted as a primary case study of a typical energy-poor community in South Africa, which is also representative of similar communities in the sub-Saharan African region.

Sustainable Energy Africa (SEA) (2014) has reported on the intensity of energy poverty in informal settlements in South Africa. As reported by SEA (2014: 10), for a significant shift to take place in household energy access in the next 20 years, "*a deepened engagement with civil society and communities in energy-poverty matters and decision making is crucial and urgently needed at the local level". Also, there is a need to "develop an integrated energy poverty policy/framework for the country*" (SEA 2014: 10). These proposed recommendations (Sustainable Energy Africa (SEA) 2014) were considered in developing a management framework for energy poverty mitigation by employing a systems approach. Applying the concept of a systems approach (Buede and Miller 2016; Biahmou 2015) into energy poverty mitigation (Karásek and Pojar 2018; O'Sullivan and Howden-Chapman 2017) may seem impractical since these two ideas have dissimilar theories and operational needs. However, design principles have evolved, from product designs to systems of consumerism and production, and from strictly environmental matters to multiple mixes of socio-cultural, economic, and environmental concerns, particularly on sustainability schemes (Vezzoli *et al.* 2017).

Since maintaining a balance between the sustainability pillars - environmental, social, and economic, is essential for sustainability schemes (Tejeda and Ferreira 2014), designing an "Energy Access Sustainability" (EAS) scheme may produce a multi-criteria decision support system, critical to energy poverty mitigation. We understand that sustainable energy access averts the energy poverty impact that may compromise the needs of future generations. The United Nations reported on key sustainability elements, including environmental protection, economic, and social developments, as synergetic and mutually exclusive elements (Tejeda and Ferreira 2014). Energy poverty by itself has multiple elements influencing its persistence in households (Stephenson *et al.* 2010), so also the process of energy access improving EAS (Shrestha and Acharya 2015). Design syntheses of multiple and diverse elements in energy poverty and access processes using a systems approach, involving Systems Engineering (SE) with Systems Thinking (SsT) concepts, can provide a roadmap to energy poverty mitigation and promoting EAS.

The SE concept identifies and also describes complex system units within and outside an overarching system (Wasson 2015). SsT principles, on the other hand, provide justifications behind complex system behaviours and their interactions by decrypting mechanisms and projecting outputs (Arnold and Wade 2015). The key action in SE is to integrate system requirements and system functions into a design synthesis that is verifiable, analyzable, and controllable (Biahmou 2015). SE configures a system, iteratively by defining, synthesizing, analyzing, designing, testing, evaluating, and validating the operational needs into comprehensive performance parameters (Esa 2006). The purposefulness of SsT principles is integral in SE in enabling human thinking in analyzing complex engineering system designs (Bakshi and Fiksel 2003). For this, resolving sustainability concerns considers SE, from conceptualization to execution, while evoking SsT to comprehend any complex system behaviour (Williams *et al.* 2017). Accordingly, SE with SsT concept analyses found its usefulness in energy poverty mitigation. As much as the SE concept is applied to mitigating energy poverty, sustaining energy access requires an SsT rationale. Ultimately, providing a solution to energy poverty using SE, inherently summons SsT principles (Forlizzi, Sevaldson and Ryan 2017).

Several studies have applied SsT principles in various ways, from the conception of product designs to Information Technology (IT). This approach has been applied in the public health sector (Rusoja *et al*. 2018; Mutale *et al*. 2017; Homer and Hirsch 2006); wind energy sustainability (Tejeda and Ferreira 2014), technology transfer processes (Kalnins and Jarohnovich 2015), and renewable technologies (Brent and Kruger 2009). Two main lines of thought have also changed the conception of an SsT approach to action research and as a liberating praxis suggesting a wholeness through spiritual awareness (Flood 2010). A different study has suggested using this approach in teaching climate change as a system with interconnected variables, and dynamic patterns (Roychoudhury *et al.* 2017). Up till now, no study has considered a solution to energy poverty using SE and SsT. The closest was a study reviewed by Shrubsole *et al*. (2018) on the application of SsT principles in energy and environmental performance in buildings. The **fifth and last part** of this study introduces SE with SsT concepts (Roychoudhury *et al.* 2017) into engineering an Energy Access Sustainability (EAS) scheme by developing a new System Reinforcing Model (SRM). This part of the study contributed to the state of the art by (1) identifying key elements acting against, and within energy poverty and access processes; (2) applying SE in integrating these elements into mutualistic systems, and then the new SRM; (3) understanding model interrelationships to improving EAS using SsT principles; and (4) applying the new SRM in a typical energy-poor community.

To date, studies have reviewed policies and their effectiveness in improving energy access in households (Mohlakoana 2014; Azimoh *et al.* 2016; Masekameni *et al.* 2018; Ye, Koch and Zhang 2018). Again, forecasting electricity and parameters has been conducted in various capacities and dimensions (Inglesi and Pouris 2010; He *et al.* 2017; Kankal and Uzlu 2017; Neupane, Woon and Aung 2017; Qiu *et al.* 2017; Bento *et al.* 2019). Also, the suitability of determining energy poverty propagation through spatial analysis of informal areas has been established (ESRI 2009; DHS and SANSA 2011; Oldfield 2011). Studies have also analyzed energy poverty issues at global (Maxim *et al*. 2016; European Commission 2015; Sovacool 2012), and sub-Saharan African levels (Khennas 2012; Sokona, Mulugetta and Gujba 2012). Similar studies were conducted in rural (Kohler and Rhodes 2013; Vanhoren *et al*. 1993) and informal households (Mdluli and Vogel 2010; SEA 2014; Mehlwana 1997; HDA 2012) in South Africa. Although energy poverty has been defined (Day *et al*. 2016; European Commission 2015), these definitions are not accepted, universally (Sadath and Acharya 2017). Energy poverty has been variously measured (Thomson, Bouzarovski, and Snell 2017; Nussbaumer, Bazilian, and Modi 2012) using models (Day, Walker and Simcock 2016) and indexes (Olang, Esteban, and Gasparatos 2018; Sadath and Acharya 2017). The impact of energy poverty on social and environmental spheres have been extensively emphasized, as well (Sovacool and Drupady 2012). The consensus was reached (Pachauri 2011), policies made (European Commission 2015) and frameworks, developed (Shrestha and Acharya 2015) to, however, promote sustainable energy access. We know that a systems approach has been suggested (Roychoudhury *et al*. 2017; Richmond 1994; Arnold and Wade 2015) as an effective tool to strategic planning and management (Haines 2000; Hassmiller Lich *et al*. 2017), and in developing a multi-criteria decision support system (Bernardo, Gaspar, and Antunes 2017; Cherni *et al*. 2007). Yet, most of these studies were applied to address some parts of energy poverty problems, mainly bedevilling sub-Saharan economic developments.

This research study embraced multiple approaches in addressing energy poverty problems in sub-Saharan Africa, using representative secondary and primary case studies. Altogether, the study reviewed relevant energy pro-poor policies conveyed in the 1998 Energy White Paper (DME 1998) to assess policy effectiveness, as well as policy progress, in South Africa. Secondly, the study assessed paradigm shifts in electricity access rates and other electricity-related matters to predict plausible and future scenarios of energy access levels in the City of Cape Town. Thirdly, the study mapped and monitored informal areas to indirectly measure the poverty with energy poverty propagation in the City of Cape Town. Fourthly, the study investigated energy-use patterns and other energy-related matters in informal households in a case study settlement. Lastly, the study developed a proposed new SRM using SE with SsT concepts and demonstrated the model's utility in the selected case study area. Significant outcomes of whole research investigations were represented and modelled, using the newly designed SRM model.

1.1 DEFINING ENERGY CONSUMPTION BEHAVIOUR AND SUSTAINABILITY PATTERNS

An Energy Cultures framework (EC) developed by Stephenson *et al*. (2010) identifies key elements and systems surrounding energy consumption and prospects for change in behaviour (Figure 1.1). A similar framework addresses analyses of behaviour using similar elements (Lawson and Williams 2012), integral to individual performance (Ishak 2017). Exploring consumption behaviour, which defines EC, involves integrations of diverse but common elements that increase energy use and its efficiency (Shrubsole *et al.* 2018). Energy-use (or consumption) behaviour is determined from the interrelationships between the elements, distinctive in a given system but expected to follow a similar behaviour pattern, producing a common goal, purpose, or function (Stephenson *et al.* 2010). These elements examine outwardly system parts showing the most influential behaviors and adopt measures to gain a successful behaviour change.

As illustrated in Figure 1.1, energy poverty systems in an EC identify drivers of energy-use behaviour and the interrelationships between, and within them. The goal of *energy poverty assessment* has been to improve energy-use efficiency in energy-poor households. A slight behavioral change in energy use requires an improved understanding of key drivers of energy poverty and their interrelatedness (Denny no date; Hoicka and Parker 2017). The *energy poverty assessment* undoubtedly demands that the relationships between *material cultures*, *cognitive norms*, and *energy practices* do, in fact, promise to influence energy-use behaviour and efficiency in energy-poor households. Besides, an EC recognizes entrenched behaviour in a system as an alteration of one element reflects on whole system behaviour. The ability to categorize these elements within systems clarifies the complexity of consumer behaviour to developing suitable interventions, increasing energy-use efficiency in energy-poor households (Pelenur 2018).

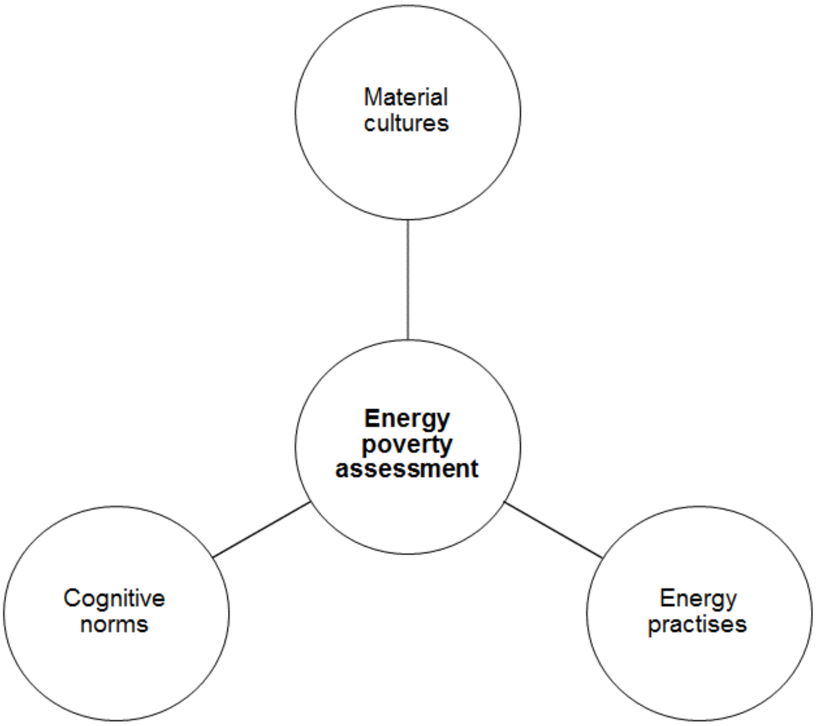


Figure 1.1 Energy Cultures Framework Comprising of Energy Poverty Systems Defining Energy-Use Patterns and Behaviour. (Source: Stephenson *et al*. 2010)

Alternatively, Shrestha and Acharya (2015) developed a Sustainable Energy Access (SEA) framework to assess energy poverty and improve energy access in households. As shown in Figure 1.2, the framework demands that energy access can be improved by *assessing energy poverty* in light of *energy demand, resource availability, access options, cost and benefits, sustainable technologies*, and *affordability*. The *assessment of energy poverty* determines additional and improved energy demand and supply options in energy-poor households and energy supply systems, correspondingly (van Gevelt *et al*. 2018; Gupta *et al*. 2018). The SEA framework considers the minimum basic energy needs; environmental-friendly energy technologies; the financial weight of energy supply; affordability of cleaner energy options; benefits of energy access options; and option sustainability. While considering improved energy access concerning social, economic, and environmental benefits, the SEA framework also assesses energy technologies in terms of economic, environmental, social, institutional, and technical sustainability pillars. These are single entities that are mutually interdependent in facilitating sustainable energy access in an energy-poor community.

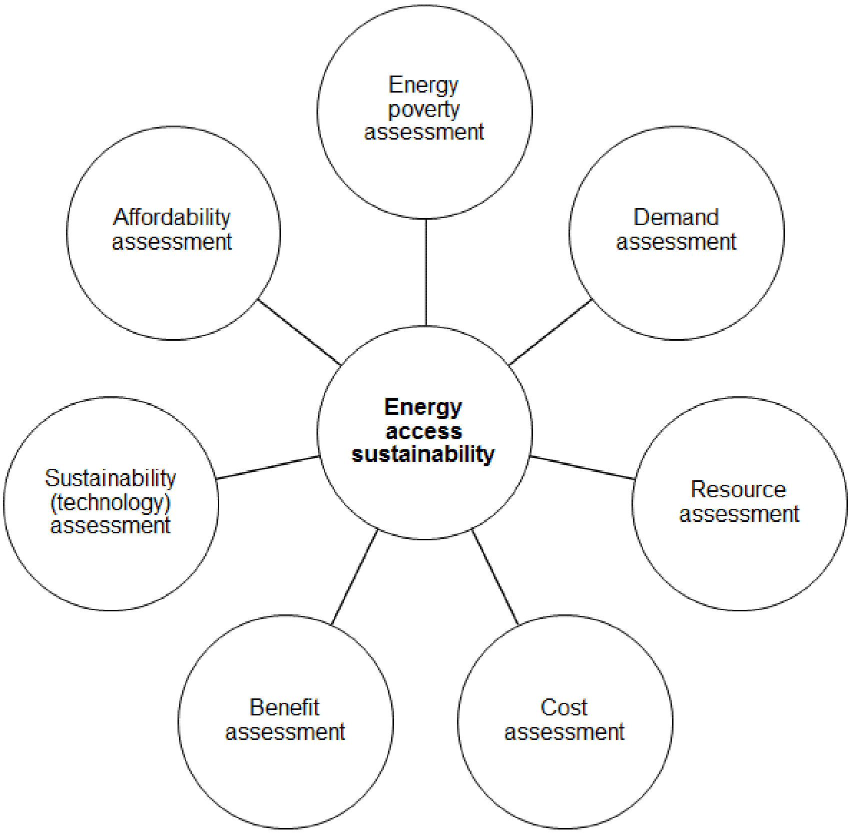


Figure 1.2 Sustainable Energy Access Framework Comprising of Systems of Energy Poverty and Energy Access. (Source: Shrestha and Acharya 2015)

In the course of this research, basic concepts of EC and SEA frameworks are adapted in identifying 'systems' and 'elements' and their 'interrelationships', with the 'common goal' of mitigating energy poverty and improving energy access. While EC reveals behavioral shifts in energy use, SEA mainly requires that the sustainability of social, economic, technical, and environmental systems balances out to lessen the energy poverty impact. These concepts are integrated into developing a proposed new SRM, using SE with SsT in identifying and integrating systems, elements, interrelationships, and purpose (common goal), as would be detailed in Chapter 3[1] of this thesis.

1.2 REAL-WORLD PROBLEM

A lack of clean energy access, particularly electricity has been an issue for some time now, especially in developing countries. Access to electricity contributes to socio-economic developments and the national economy. In particular, access to electricity in agriculture promotes agricultural practices and production, which, in turn, increases food circulation in society. Mostly in rural Africa, agriculture is one of the many sources of livelihood in

[1] CHAPTER 3: APPLYING A SYSTEMS APPROACH TO MITIGATING ENERGY POVERTY

households. But, only about 68% of rural Africa have access to electricity for agricultural practices (United Nations 2014). Agriculture sustains household livelihoods in sub-Saharan Africa as well but lack of electricity access mainly prevails in rural areas. We know that agriculture depends on electricity access for large-scale mechanization and production and without such access, food production will be reduced. Essentially, electricity is used for irrigation, running pipe wells, and transportation of harvested products, among others, in agriculture. Without electricity access, farmers manually carry out these farming activities, limiting the quality and quantity of agricultural production. This further restricts the use of cutting-edge agricultural practices for large-scale food production.

Expanding electricity to farmlands for efficient farming mechanization contributes to the national economy, particularly in sub-Saharan Africa. A solution therefore may require decentralized electricity options through local connections and regional strategies, building energy infrastructure in rural sub-Saharan Africa (Khennas 2012). Other options such as renewable energy technologies can be explored in situations and areas where electricity infrastructure is costly or underdeveloped. It has been previously established that growth in agricultural production in sub-Saharan Africa essentially drives wealth restructuring (United Nations 2014) in dissolving the infrastructural dichotomy between the urban and rural areas (Mcewan 2017). Moreover, electricity access in agriculture will lead to an upsurge in the economy, as well as sustaining socio-economic, and human developments (United Nations 2014). This study though has not explored the expansion of electrification networks for agriculture.

Modern industrialization requires that industries run efficiently without shortages or interruptions in electricity supply. In many sub-Saharan African countries, the electricity supply is occasionally, or regularly interrupted in all demand sectors - industrial, commercial, and residential. Many factors are identified to encourage supply shortages, which mainly revolve around poor developments in electricity infrastructure. South Africa, for example, is presently burdened with occasional incidences of ‘rolling out electricity blackout’ events, popularly referred to as ‘load shedding’ events, mainly caused by poor maintenance of generating electricity plants and shortages in coal production, along with some other financial and institutional constraints (United Nations 2014). These events distress national and local economies and limit energy productivity and consumption in demand sectors. Currently, the energy sector is exploring options to limit load shedding in an effort to maintain a reliable electricity supply in South Africa. This study considered these events as one of the many problems restricting the expansion of electricity access in energy-poor households in South Africa.

Since 2014, about 2.6 billion people use biomass fuels for cooking (United Nations 2014), particularly in rural and urban poor households in developing countries. Despite the fact that biomass use is arduous, it also affects health and the environment. Among the major ecological threats of using biomass is Greenhouse gas (GHG) emissions that speed up events of climate change, such as global warming and severe weather events. Deforestation (also known as woodcutting) is another direct cause of biomass use. In addition to resource depletion and air pollution resulting from biomass burning, woodcutting for biomass use also exposes earth surfaces, causes soil erosion, and reduces tourist attractions and landscapes. Biomass use is a common practice in energy-poor households in South Africa. The UN has been trying to eradicate biomass use through its Millennium Development Goals (MDGs) but its efforts are occasionally repressed (Vermaak, Kohler and Rhodes Bruce, 2013). Providing cleaner energy technologies, such as electricity, goes a long way to support the ongoing UN’s efforts in mitigating energy poverty in developing countries. Improving affordability encourages electricity use, which eventually eradicates biomass use. In contribution to the ongoing UN’s efforts, this research attempts to determine factors influencing poor energy use in a typical energy-poor community and develop multidimensional strategies to influence energy-use behaviour in households in South Africa.

As already established, electricity is the most reliable access option that effectively satisfies modern energy services. For now, the World Summit has integrated modern energy access options such as electricity as part of the MDGs to safeguard health, and the environment (Vermaak, Kohler and Rhodes Bruce, 2013). Without access to electricity, modern energy services are limited, along with income-generating opportunities, and energy productivity (United Nations 2014). Alternatively, poor households, at most times, are unable to afford electricity use due to high electricity costs, and as a result, adopt poor energy sources and multiple energy use practices. Poverty and energy poverty are at that point continuously entangled in prolonging poor energy-use patterns and behaviour in energy-poor households. Some practical tools and interventions can salvage energy poverty and improve sustainable energy access, globally (Ammer, 2017; Collier, 2017; Kılkış 2017). As a solution, this study adopts SE and SsT concepts into a proposed new SRM development, with the capacity to improve energy access. With its novelty, the model can reduce poor energy practices and improve the use of modern energy services in energy-poor households.

1.3 RESEARCH AIM AND OBJECTIVES

The United Nations (2014) proposes energy poverty mitigation as one of the Millennium Development Goals (MDGs) to be achieved by 2030. The aim of this research was to '*investigate poverty and energy poverty by evaluating multidisciplinary energy-related matters and methodologies using a novel systems approach'*. In addressing the research aim, the study focused on addressing the research objectives below:

1. Examining energy pro-poor policies and programmes put in place to reduce poverty and energy poverty in South Africa.

2. Assessing trends in electricity access and related matters, and predict future scenarios supporting total electricity access by 2030 at a regional level, using the City of Cape Town as a case

3. Land Cover (LC) Mapping and Land-Cover Change (LCC) monitoring of informal settlements on a spatiotemporal scale to indirectly measure rates of poverty with energy poverty propagation in the City of Cape Town as a case.

4. Investigating energy-use patterns and other energy-related matters at the household level in a selected informal settlement called the Sofia settlement, used as a primary representative case study of an energy-poor community.

5. Developing a proposed new SRM, a model that prioritizes best strategies and options in improving energy access, useful in addressing energy poverty at a community level. Significant outcomes of Research Objectives 1 to 4 are incorporated into the new model to facilitate Energy Access Sustainability (EAS) in the primary case study area – a typical energy-poor community.

1.4 RESEARCH QUESTIONS

Addressing the research objectives, the following key questions below, postulated for each research objective were answered:

1. Are existing energy pro-poor policies adequate to mitigate energy poverty in energy-poor households in South Africa?

2. What is the trend in electricity access over a historical 8-year period? Will assessing electricity access and related matters in such a period, be suitable to predict future progress in achieving total electricity access by 2030 at a regional scale?

3. Will mapping and monitoring informal areas define the state of (energy) poverty and LCC processes over time, at a regional scale?

4. What are the present energy-use patterns and behaviour in informal households in a typical informal settlement?

5. Will the proposed model serve as a suitable framework to support modelling of key drivers of energy-use patterns and behaviour and EAS, as well as external factors affecting processes in an energy-poor community? Can the new SRM help to mitigate energy poverty and improve energy access in such a community?

1.5 SIGNIFICANCE AND RATIONALE

There have been constant regimes of poor energy-use for space heating in energy-poor households such as informal households in South Africa. (Stats SA 2016). Most informal households struggle to lessen the energy burden on household income, as a result, practice multiple energy uses. Over the years, the South African government has been attempting to address these energy poverty situations through policies and subsidies, and thus far, has demonstrated laudable efforts. These policies are mainly pro-poor, commissioned to improve lives, energy access and consumption, and socio-economic development in energy-poor households. The main policy objectives are to provide clean access options and develop cost-effective strategies to increase energy use. Policies have been implemented yet informal households use local traditional energy sources. Moreover, there are, undoubtedly, unequal distributions of policy benefits in informal households, made worse by these households constantly increasing in space, and time. Most households in overly populated informal settlements, for example, in the Gauteng and Western Cape provinces, are not even aware of most of these policies to be able to benefit from them.

The South Africa government has been promoting national electrification through the INEP programme (DoE 2015), aiming to achieve total electricity access by 2030 while targeting mainly energy-poor households. Even though most informal households are grid-connected, majorities are grid-connected through illegal connections or electricity theft (SEA 2014). As previously indicated, most informal households lack electricity access and this is largely dependent on various limiting factors of the electrification process within authorized energy providers. Also, there could be drawbacks in policies and subsidies in promoting grid-connections in informal households (DoE 2015). Regardless, grid-connected informal households consume local energy sources, which perhaps are due to expensive and rising electricity tariffs (SEA 2014), or socio-cultural influences defining a particular region (Mehlwana 1997).

The rationale of this research was to assess related energy poverty topics, such as energy policies; rates of electricity access and related matters; land-cover and land-cover change processes; and energy-use patterns and behaviour, to understand situations of poverty with energy poverty in South Africa. The significance of the research is in the designing and application of a proposed new SRM, an EAS management framework, implementable to mitigating energy poverty in energy-poor communities. Given the resourcefulness of a systems approach, a proposed new SRM contains complex sets of systems and dimensions, addressing energy poverty and providing access solutions, whilst considering other external factors influencing model behaviour.

1.6 DESCRIPTION OF CASE STUDY AREAS

There are two selected case study areas for this research – primary and secondary case study areas. The primary case study area is a selected community in South Africa, largely representative of a typical energy-poor community, commonly seen, for example, in most countries in sub-Saharan African regions and Asia. The selected primary case study area, referred to as the Sofia settlement, is also largely representative of a typical energy-poor community in South Africa. The study focused on investigating study concepts of Research Objectives 4 and 5[2] in a typical energy-poor community such as the selected Sofia Settlement. The City of Cape Town Metropolitan is selected as the secondary case study area and the regional area, characteristic of the primary case study area. The study focused on investigating Research Objectives 2 and 3[2], which centred on electricity access rates and spatial analyses, within the scope of the secondary case study area. For Research Objective 1[2], the study

[2] Section 1.3: RESEARCH AIM AND OBJECTIVES

investigated study concepts whilst focusing on energy pro-poor policies and energy-poor households within the scope of South Africa, as a whole.

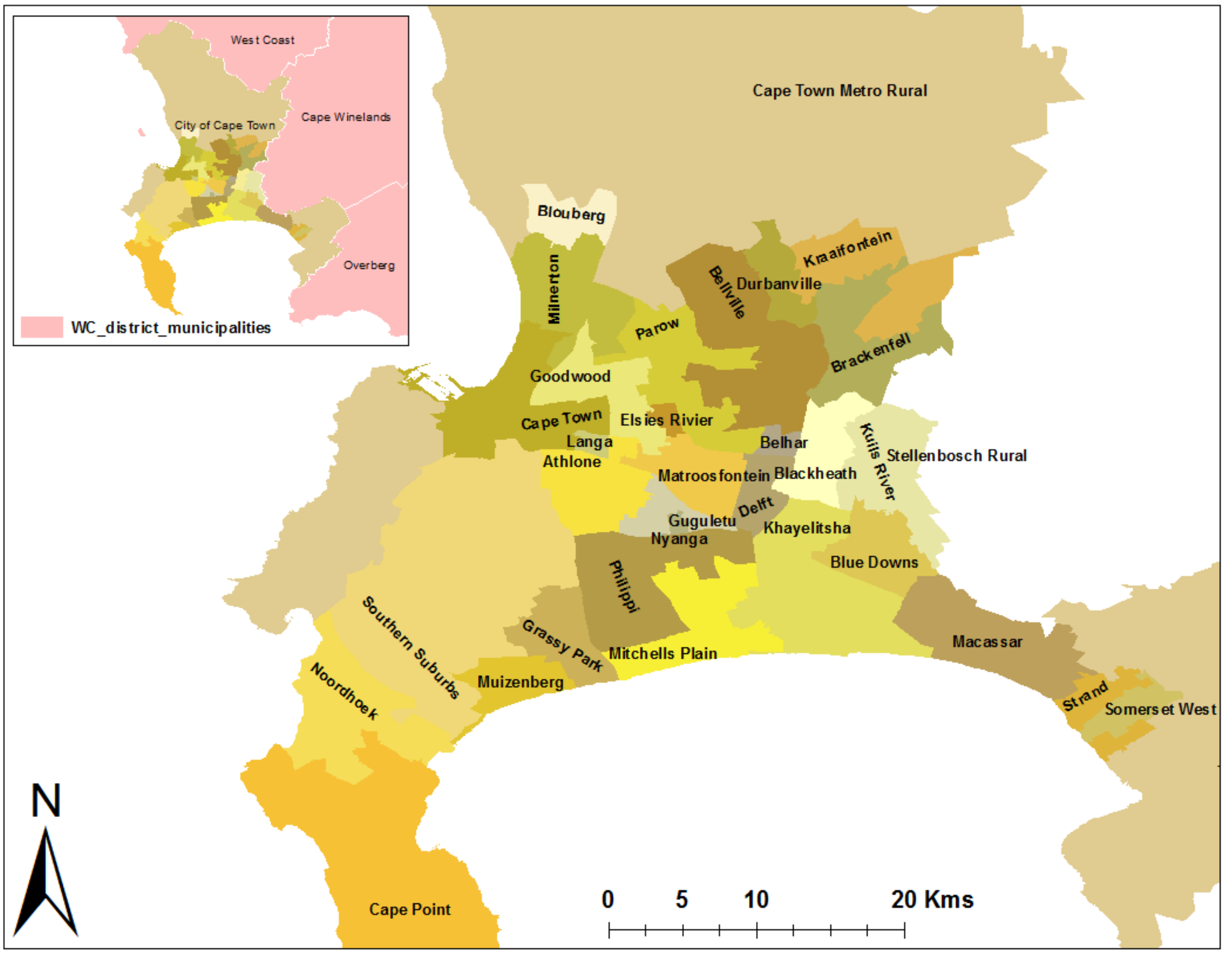


Figure 1.3 Map Showing major Suburbs in the City Of Cape Town Metropolitan.

The City of Cape Town is situated at the south-western tip of Africa, in the Cape Floristic Region of South Africa, with a landmass of 2 446km². The City is the provincial and legislative capitals of the Western Cape Province, and South Africa, respectively. The climate is the temperate Mediterranean with warm dry summers and cool wet winters at a latitude of 34° (Wilkinson 2000). The City is the second-most populated in South Africa with a culturally diverse population of 4 004 793. The City comprises of various races, including Coloured (mixed race), African, and White races, in that hierarchical order (Stats SA 2016). It has administrative areas in the Cape Flats and northern coastal plain and some agricultural landscapes to the northeast. It is also recognized for its histrionic natural scenery in the Cape Floral Kingdom, and biodiversity. Major economic sectors as regards to output levels include manufacturing, trade, catering services, finance, and real estate (Wilkinson 2000). The City comprises of 43 suburbs but the major suburbs, serviced with basic social utilities and infrastructure, such as on-site water and electricity, are represented in Figure 1.3

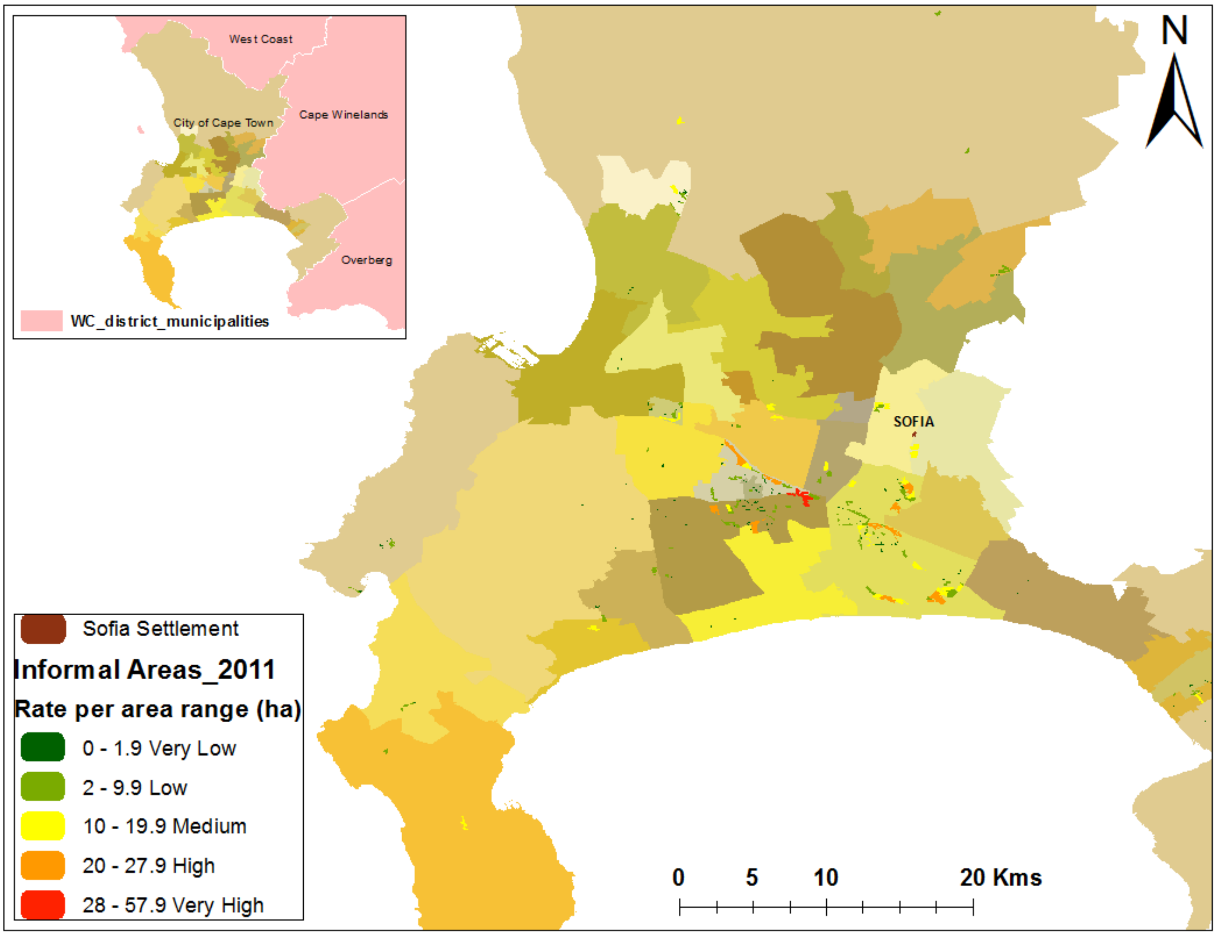


Figure 1.4 Map Showing Metros And Distribution of Informal Settlements in the City Of Cape Town, also indicating the Location of the Primary Case Study Area - The Sofia Settlement.

Like most sub-Saharan cities, and South Africa, in particular, the City of Cape Town has informal settlements, sprawling across the suburbs (Figure 1.4). The distribution of informal settlements ranges from very low to very high in landmass and largely predominant in major suburbs. The highest informal settlements in area size are in Khayelitsha, Gugulethu, and Nyanga (Figure 1.3; Figure 1.4). Both medium, low, and very low area-sized informal settlements are also well-distributed along the periphery of all suburbs. Medium area-sized informal settlements are more prevalent across suburbs (Figure 1.4). Very low area-sized informal settlements, including the Sofia settlement, are not too densely distributed across suburbs, except in Khayelitsha, Gugulethu, and Nyanga (Figure 1.3; Figure 1.4)

As shown in Figure 1.5, the Sofia settlement is a small area–sized, inconspicuous informal settlement, located at Sunbird Park, Blackheath in the City of Cape Town. The settlement comprises of about 250 to 300 informal households[3], mostly shack-clustered[4], not in the backyard[5], and typical of most informal settlements in South Africa. The environment is unsanitary, with a repugnant atmosphere and single tap water shared amongst households. The Sofia settlement is mostly characterized by unemployed[6], low-income households, and of the black race, having very poor socioeconomic environments, also typical of most informal settlements in South Africa. The Sofia settlement has no electricity access, even though it is located close to the grid. As a result, informal households in the Sofia settlement consume mainly local energy sources, such as paraffin and charcoal, to meet their energy needs.

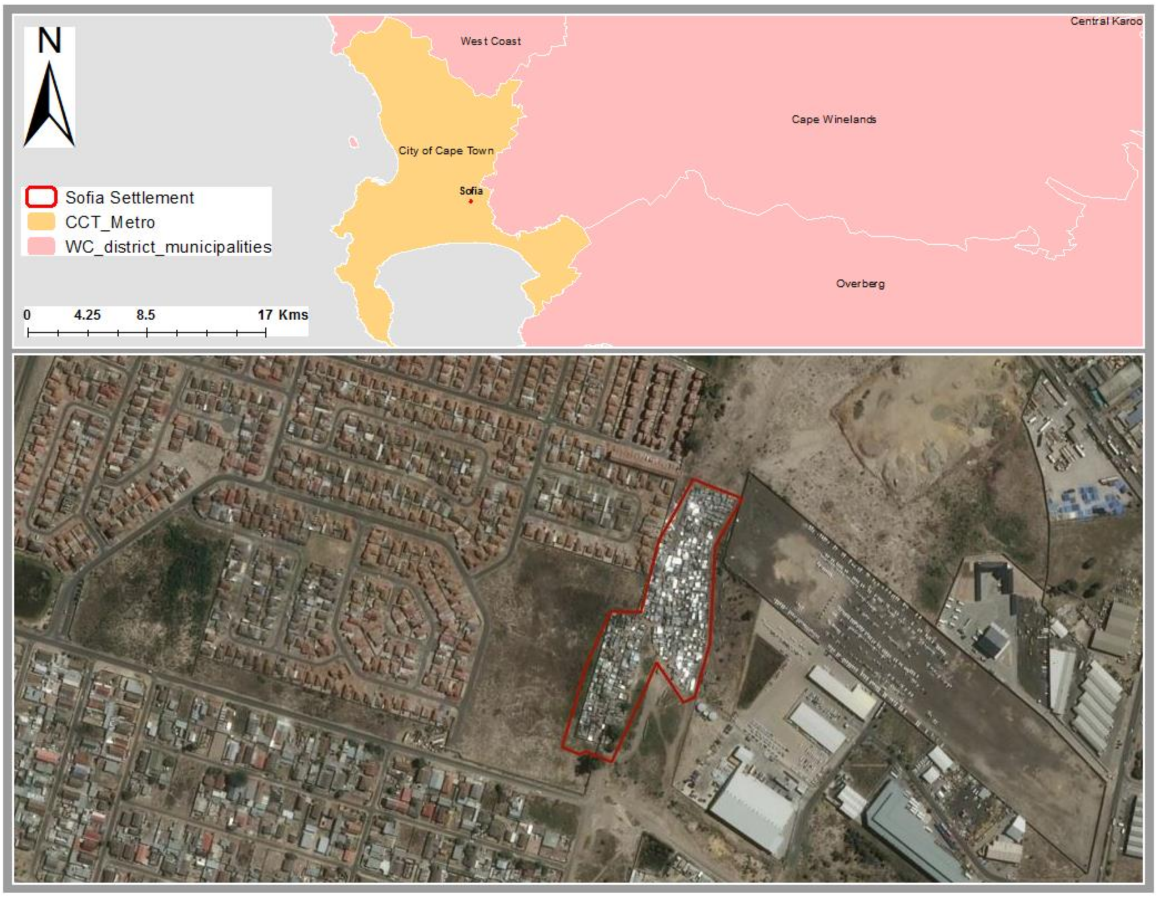


Figure 1.5 Map and Bing Aerial (2019) (Open Layers Plugin in QGIS) Showing Aerial Photograph of the Primary Case Study Area - the Sofia Settlement.

[3] Household population count is given by community committees (focus group) in the case study area.
[4] A Shack is an informal dwelling, roughly constructed and poorly insulated dwelling, constructed using corrugated iron sheets
[5] Shacks not in the backyard are shacks developed on erstwhile vacant land that is not behind formal/residential dwellings. On the other hand, shacks in the backyard are those developed on erstwhile vacant land behind formal/residential dwellings
[6] During the field survey in the settlement, the focus group informed that more than half the population are unemployed and depend on government grants.

1.7 RESEARCH METHODOLOGY AND DESIGN

This research adopted various methodologies, from empirical to non-empirical and desktop studies, along with inferential and analytical purposes. The study approaches included social, empirical, model building, applied, and qualitative and quantitative data. Two types of data collections were used – primary and secondary data collection. Primary data collection was carried out by using householder questionnaires, and semi-structured short interviews. The sampling technique was random, and sample sizes were considered representative for all purposes and intents of the research. Secondary data, including household surveys and census data, policy implementation data and records, and data on electricity access and prices, was obtained from the City of Cape Town Metropolitan municipality and other energy service providers.

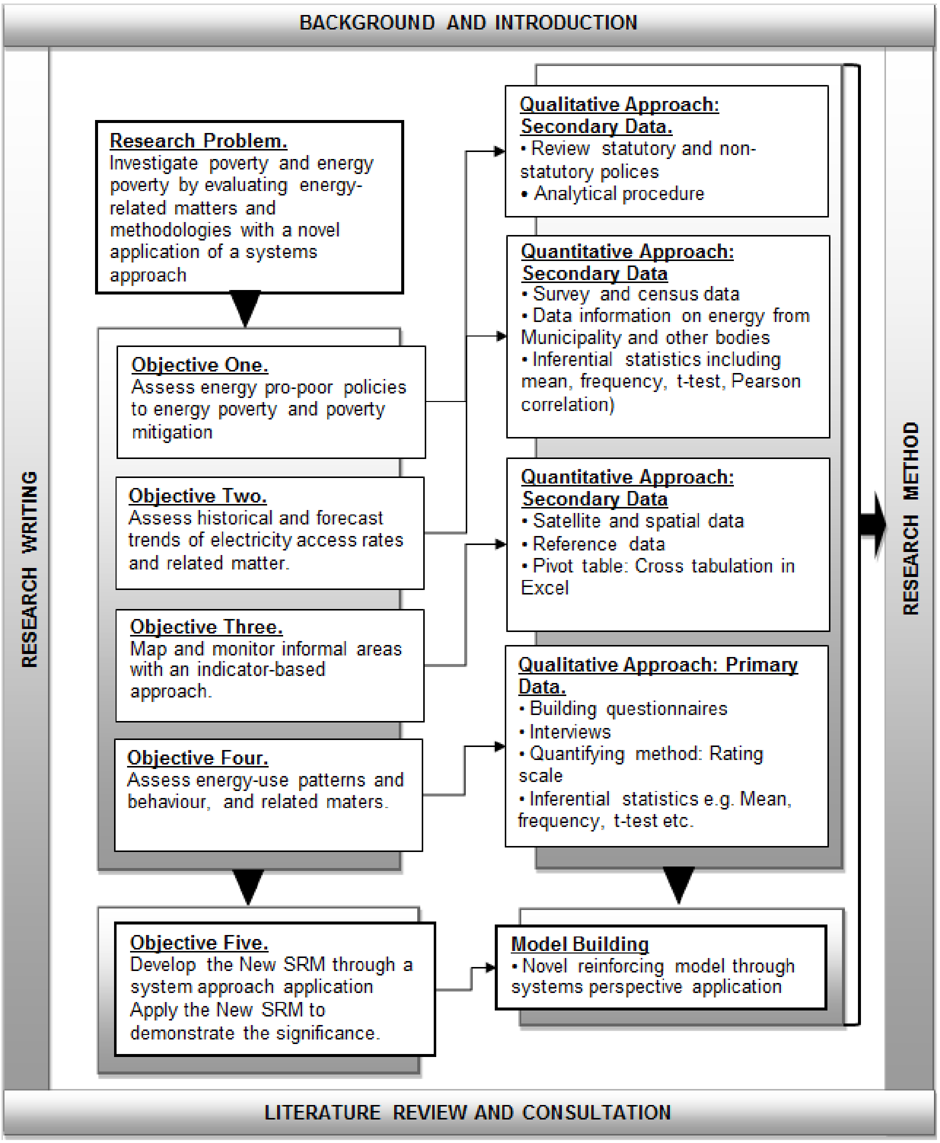


Figure 1.6 Flow chart of Methodologies Adopted for Research Objectives.

The research design, describing study methodologies and salient steps to be undertaken in addressing research objectives, is presented in Figure 1.6. To address Research Objective 5, a model building approach, with other adopted methodological approaches and their logical applications, was employed and would be detailed in Chapter 3. Methodologies employed in addressing Research Objectives 1 to 4 are summarized in Figure 1.6 and fully detailed in individual subsections below.

1.7.1 Policy Review: Energy Pro-Poor Policies

As shown in Figure 1.6 and in addressing Research Objective 1, the methodology adopted followed qualitative and quantitative approaches and embraced both desktop and empirical studies, agreeing with Davidson *et al*. (2006) and Asumadu-Sarkodie and Owusu (2016). In the 1998 Energy White Paper document (DME 1998), six main energy pro-poor policies were identified as relevant in improving energy access and energy-use efficiency in energy-poor households, as shown in Table 1.1. Each policy was reviewed based on the availability and accessibility of data, using either quantitative (empirical) or qualitative (desktop studies) evidence or both, in analyzing them. An empirical investigation for all the policies was not feasible due to a lack of proper data documentation and records within authorized service providers.

Table 1.1 Energy Pro-poor Policies in the 1998 Energy White Paper and Years of Commissioning

Energy Pro-poor Policies	**Year of Commissioning**
Reconstruction Development programme (RDP) (DME, 1998)	1994
Integrated National Electrification Programme (INEP) (DoE 2015)	2001
Non-Grid (Mini-Grid) Electrification Policy (DoE 2012)	2002
Free Basic Energy (FBE) Policy (DME 2003)	2003
Free Basic Alternative Energy Policy (FBAE) (DME, 2007)	2007
Inclining Block Tariff (IBT) (SEA, 2014)	2010

For the review, the focus was centred on a broad-spectrum of quantitative and qualitative occurrences since 1994 – this date was selected as this was roughly when energy pro-poor policies were first addressed (Table 1.1). Empirical studies employed secondary data from project databases of National Electricity Statistics - Department of Energy (DoE) (DoE 2015) and Statistics South Africa (StatsSA) (Stats SA 2016). Desktop studies covered conference/working papers, scientific papers, scientific reports, and publications from governments/NGO reports, Sustainable Energy Africa (SEA), and South Africa Local Government Association (SALGA). The search was broadened to include energy policies in Ghana and Botswana by reviewing scientific papers, government reports, and various publications from energy institutions in these countries. Ghana and Botswana were selected because they have almost the same populations of people without electricity access, just like South Africa, in the sub-Saharan Africa region[7]. Comparisons were made between similar policies in these countries, benchmarking policies listed in Table 1.1, such that deduced information is descriptive to the degree of policy effectiveness in South Africa.

1.7.2 Historical Trends and Forecasts: Electricity Access Rates, Access Costs, and Tariffs

In addressing Research Objective 2, the study adopted a quantitative approach and secondary data analysis (Figure 1.6). The methodology adopted, used time-series analysis of historical precedents of data in forecasting trends, agreeing with Melikoglu (2018) and Winkler *et al*. (2017). This study employed secondary data such as electricity data records on meter installations (Appendix 1) (EGD 2018a *pers. com*)[8]; connection costs (Appendix 2); and electricity tariffs (Appendix 3) (EGD 2018b *pers. com*)[9], obtained from the Electricity Generation and Distribution (EGD), EGD Head Quarters in the City of Cape Town. This secondary data was employed to assess the historical precedents (2010 - 2018) of meter installations (access rates), connection costs (access costs), and electricity tariffs. Only the historical records of meter installations and connection costs were employed in the forecast analyses (2019 - 2030). The end year, 2030, was benchmarked because the United Nations (2014), as part of the MDGs, is set to reduce energy poverty by 2030.

All data manipulation and calculation were done in Excel using the statistical tools, such as Forecast Exponential Triple Smoothing (ETS) algorithm, Forecast (ETS) Confidence, Correlation Coefficient (r), and Chi-Square (X^2) test, in analyzing data (Excel 2013). The Forecast ETS algorithm returns forecasted values for a specific future target date using the

[7] To be discussed in Section 2.2: POVERTY AND ENERGY POVERTY IN SUB-SAHARAN AFRICA; and presented in African countries. Table 2.3 Rates of Electricity Access and Biomass Use (2014) in Some Selected Countries in Sub-Saharan Africa (elect. = electrification)

[8] (a) Data Source: Hammer, M. (Maurisha.Hammer@capetown.gov.za) 2018. Electricity connection (meter installation) per annum for about10 years. 2nd Floor, Electricity Generation & Distribution (EGD), EGD Head Quarters. http://www.capetown.gov.za/. Email to: P. Okoye (pokoye04@gmail.com) (12 August).

[9] (b) Data Source: Ross GM 2018 (GaryMichael.Ross@capetown.gov.za). Connection fees (both subsidized and normal residential) as well as the residential consumption tariffs for the period 2009/10 to 2018/19. 2nd Floor, Electricity Generation & Distribution (EGD), EGD Head Quarters. http://www.capetown.gov.za/. Email to: P. Okoye (pokoye04@gmail.com) (26 July)

exponential smoothing method (Excel 2013). This algorithm was employed to predict future events in meter installations (access rates) and connection costs (access costs) by estimating future trends based on historical values (Karmaker 2017). The Forecast ETS Confidence tool returns a confidence interval for forecasted values at a specified target date (Excel 2013). The ETS Confidence was used to reveal the confidence level (95%) and compute upper and lower bound limits of the forecasted events (Dhakre, Sarkar and Manna, 2016). The correlation coefficient (r) tool returns the Pearson correlation coefficient between the two datasets (Excel 2013). The Chi-Square (X^2) test returns the test for independence and an appropriate degree of freedom (Excel 2013). These methods were employed to analyze the relationships (linear) between, and within, access rates and access costs (Turner *et al.* 2015). The univariate analysis, such as Mean and Standard Deviation, was used to analyze the geometry within groups.

1.7.3 Mapping and Monitoring Informal Areas

In addressing Research Objective 3, the study employed a quantitative and secondary data approach in mapping and monitoring informal areas in the City of Cape Town (Figure 1.6). Various methodologies were employed in LC mapping and LC change detection of informal areas[10]. Supervised (manual digitization) methods (Campbell and Wynne 2011; Mather and Koch 2011) were selected for the LC classification. LC detection techniques, such as a comparative post-data classification method (Okoye 2016), computer-based change modelling (ESRI, 2009), and an indicator-based detection approach (Munch *et al*. 2017) were selected and merged for LC change analysis of informal areas. Since selected methods were supervised, informal areas, including in backyards and not in backyards, were considered in the classification. It is important to note that this research study did not intend to count informal households residing in informal areas in the City of Cape Town or assess their population densities.

As shown in Table 1.2, the secondary data employed is a single-date (2011) National Land Cover (NLC) (also termed reference 2011 LC) of informal areas in South Africa, used as a reference dataset (1) for this study. The dataset was obtained from the Centre of Geographical Analysis (CGA), originally from the Department of Human Settlements (DHS and SANSA 2011). From the reference 2011 LC data, the City of Cape Town's boundary was extracted. Other reference data used include aerial photographs of 2010 and 2016 [reference set (2)]

[10] To be detailed in Section 2.5: EARTH OBSERVATION OF INFORMAL

obtained from National Geospatial Information (NGI). Ancillary datasets, such as roads, rivers, and cadastral, were also employed to identify informal areas with access, or close, to basic utilities and infrastructure.

Table 1.2 Short Descriptions of Secondary Data Used in LC Classifications and LCC Analysis of Informal Areas and Other Generated Datasets.

Data Types	Secondary Data	Given Name	Year	Data Source
Reference Set (1)	National Land Cover (NLC) data (Reference 2011 LC)	D1	2011	Department of Human Settlements (DHS and SANSA, 2011) c/o Centre of Geographical Analysis (CGA)
Reference Set (2)	Aerial Photographs, Google Earth Map (Street view)		2010 2016	National Geospatial Information (NGI)
Ancillary data	Roads, River, Cadastral			Public Domain
	Generated Datasets			
Generated data: Post LC classification	Edited 2011_2010 LC	D2		
	Derived 2016	D3		
Generated data: Post LCC detection	Reference 2011 LC (D1) vs Derived 2016 (D3)	DD4		
	Edited 2011_2010 LC (D2) vs Derived 2016 (D3)	DD5		

1.7.3.1 Data processing: Land-cover (LC) mapping of informal areas

Data processing was done in ArcMap (ESRI 2009), using software tools in analyzing LC classification and change detection. The acquired reference 2011 LC is inherent with discrepancies and errors in LC classifications of informal areas in South Africa (DHS and SANSA 2011), which may have resulted from the mapping scales used or the large-area coverage. These discrepancies include uncaptured and inaccurately captured boundaries of informal areas. To improve data validity, the reference 2011 LC was reworked using the reference set (2) - 2010 aerial photographs (CD: NGI) (Table 1.2). The main reason for reworking the reference 2011 LC data was to improve data accuracy (1) by capturing new polygons or boundaries of informal areas, not captured (2) to finely define mapped informal areas' boundaries, and (3) to ultimately, produce valid results for the benefits of policymakers and future researches.

The flow chart, describing key procedures and steps followed in LC classification and LCC analyses of informal areas, is presented in Figure 1.7. As previously indicated, the reference 2011 LC data (henceforth, D1 dataset) was reworked using 2010 aerial photographs as base maps. New polygons of informal areas were mapped (manually digitized) based on visual investigations of the reference set (2) - 2010 aerial photographs and Google Earth Map street-view. Thereafter, a new dataset was generated from D1, termed 'Edited 2011_2010 LC' (hereafter, D2). Generating LC data at a different period, other than 2010, is important to generate the two-time step analysis of LCC detection. Then again, D2 was edited using the reference set (2) - 2016 aerial photographs as base maps, hence producing 2016 classified informal areas' LC. This resultant LC dataset is labelled 'Derived 2016 LC' (henceforth, D3).

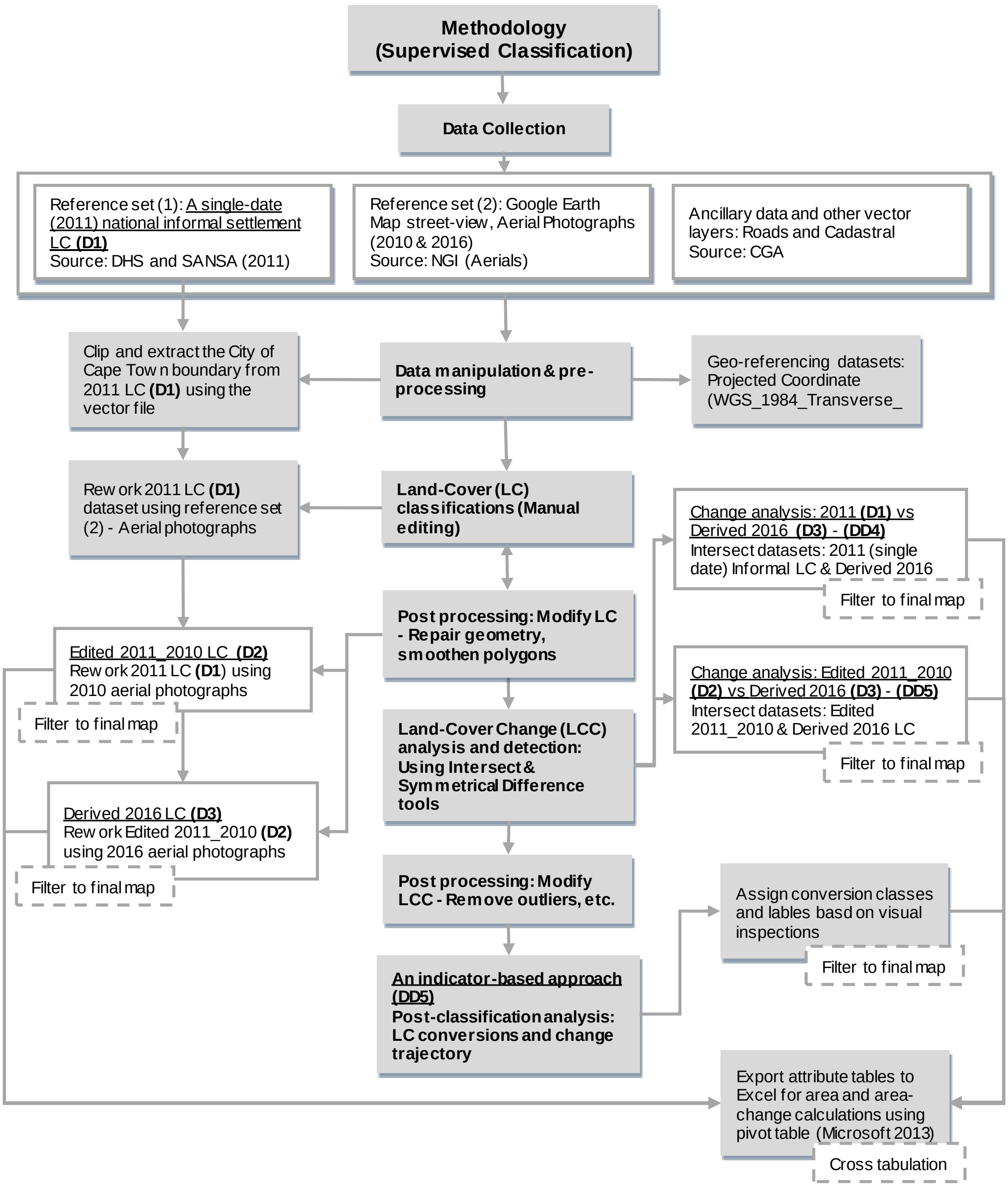


Figure 1.7 Flow Chart of Procedures for Land-Cover (LC) Classification and Land-Cover Change (LCC) processing of Informal Areas in the City of Cape Town, Showing the Key Steps in the Central Column.

1.7.3.2 Data Processing: Land-Cover Change (LCC) detection (or monitoring) and conversion dynamics of informal areas

Before LC change analysis, further pre-processing was done on reference (D1) and newly generated datasets (D2 and D3) using Software tools such as Repair Geometry and Smooth Polygon, as shown in Figure 1.7. These tools were employed to smoothen and repair newly generated polygons and geometry of informal areas. At this point, D2 and D3 now have higher data accuracies in representing actual LC of informal areas due to supervised manual classifications adopted. Subsequently, a computer-based change modelling (ESRI 2009) was done by using 'Intersect' and 'Symmetrical Difference' tools in ArcMap (ESRI 2009) in monitoring LCC between datasets (or layers) (D1 and D3; and D2 and D3). The 'Intersect' tool was used to extract overlapping features or portions between layers by combining two pairs based on geometry. The 'Symmetrical Difference' tool was used to extract features or portions that do not overlap between layers.

As shown in Figure 1.7, the derived LCC datasets from LCC analysis between D1 and D3 (hereafter, DD4), and D2 and D3 (hereafter, DD5) were further edited to eliminate outliers. While DD4 has polygons and attributes of both 'reference 2011 LC' and 'Derived 2016 LC' datasets, DD5 contains those of 'Edited 2011_2010 LC' and 'Derived 2016 LC'. The derived LCC datasets were then assessed using a comparative post-data classification method (Okoye 2016). As a result, and due to higher accuracies of underlying D2 and D3 datasets, DD5 was employed to assess LC conversions (Munch *et al*. 2017) of informal areas. Area calculations were carried out for all sampled datasets, and attribute tables were exported to Excel (Excel 2013) for data manipulation using cross-tabulation in a pivot system. Statistics on gains and losses in LC datasets, and percentage area change in LCC and LC conversion datasets were computed (Munch *et al*. 2017).

Based on a concept from Munch *et al*. (2017), an indicator-based detection approach was employed to assess LC conversions in DD5, concerning landscape processes such as environmental degradation, development, and sustainability, as shown in Figure 1.7. LC conversions are used to understand the trend in LC change in a target area within a specified period. Conversion classes or labels are assigned to LC conversions in describing patterns and trajectories, qualitatively and quantitatively, and can be thematically represented in maps (Munch *et al*. 2017). The LC conversion analysis was done, and conversion classes and labels were then assigned in DD5 based on visual investigations of the reference set (2), defining differences in target features between the two-time assessment period (2010 – 2016). The conceptual schema of LC conversions and conversion labels in the DD5 dataset are presented in Table 1.3.

Table 1.3 LC Conversions and Change Trajectories of Informal Areas to Other Land Covers From 2010 To 2016 and Conversion Labels Used. Adapted from: (Munch *et al.*, 2017)

		2016					
2011_2010	Land Cover Class	Bare Soil	Expanded Informal Areas	Informal Areas	RDP Houses	RDP and Shacks	Houses and Built-up
	Informal areas	Ab					
			In				
				Pe			
					RD		
						RDi	
							UD

Table 1.4 Descriptions of Conversion Classes (and Labels), Concerning Change Trajectories And Patterns In Informal Areas Adapted from: (Munch *et al.*, 2017).

Informal Areas Conversion Class	Description
Ab - Abandonment	Areas where shacks are converted to bare soil
In - Intensification	Areas where shacks substitute bare soil
Pe - Persistence	Areas with no change in informal areas
RD - RDP Development	Areas where shacks are replaced with RDP houses
RDi - RDP Development (Interspersed)	Areas intertwist with RDP houses and shacks
UD - Urban Development	Areas converted to urban houses and built-up structures

As presented in Table 1.4, there are conversion classes (labels), describing LC conversions in DD5. With no change in the informal areas' boundaries, the conversion class is labelled *Persistence*. Of particular importance are informal areas where shacks have expanded (*Intensification*), removed (*Abandonment*), or replaced (*RDP Development*). The conversion class termed *RDP Development (interspersed)* was classified due to difficulties in finely delineating most RDP houses within informal areas. Informal areas converted to urban houses and other built-up structures are labelled *Urban Development.*

1.7.4 Energy Use and Related Data, Patterns, and Relationships

In addressing Research Objective 4, the methodology used was a primary data survey (Figure 1.6) and concurs with Africa *et al*., (no date). Two sets of surveys - householder questionnaire (Appendix 4), and short interviews (Appendix 5) for local suppliers (or area vendors) were employed for the primary data collection in the selected primary case study area – the Sofia settlement. The householder questionnaire (consisted of 42 closed-end questions) was used to investigate energy-use sources, modern energy access, and energy-use patterns and behaviour. Local supplier interviews involved short semi-structured interviews for the area vendors, peddling energy products in the case study area, concerning product prices, affordability, scarcity, procurement, barriers, and sustainability of energy products.

Out of 130 informal households surveyed, 120 questionnaires (see Appendix 6) were filtered using content analysis, based on data compliance between responses. The filter was done to reduce data irregularity that occurred from households being thrifty with the truth to gain empathy. Participants were not compelled to respond to questions they perceived as uncomfortable, or personal. Respondents to specific questions were only considered in addressing them. All 120 filtered questionnaires were recorded, electronically using Google forms (Google online). These electronic forms were exported in an Excel format for data manipulation and processing in Excel Software using the PivotChart system (Excel 2013). Responses were transcribed into quantitative data and relative weights were assigned to both grouped and ungrouped parameters Statistical analyses, such as mode (frequency) and Chi-square test (X^2), were used in analyzing data and significance of relationships between, and within, groups of parameters. A qualitative method was employed in analyzing the local suppliers' survey.

1.8 THESIS LAYOUT

Chapter 1 focuses on the preliminary aspects by introducing study concepts and providing detailed insights for research objectives. First, EC and SEA frameworks contextual to developing a proposed new SRM are discussed. The chapter discusses real-world problems and the significance and rationale of the research study. Research aim, objectives, and questions, and descriptions of selected case study areas and research design are also covered. Study methodologies to be employed, addressing research objectives, are also discussed. The key features of this chapter, reflecting key study concepts, include energy poverty, energy-use patterns and behaviour; electricity access rates, electricity costs, and tariffs, and trends; LC classification, monitoring, and spatial analysis; policy review on energy pro-poor; systems approach - SE with SsT concepts; and a proposed new SRM.

Chapter 2 reviews the literature on the topics of energy poverty, energy poverty indicators, thresholds, and impacts, particularly at the sub-Saharan level. The chapter narrows down discussions on energy distribution and supply challenges in the South African energy sector. Profiling informal settlements and inequality in energy distribution in South Africa are also discussed. Then, the chapter reviews the literature on earth observation resources, spatial analysis, LC classification methodologies, and finally, LCC detection procedures, and techniques. The chapter also discusses trends in energy-use patterns and related matters in informal households at the regional level. Ways of controlling energy poverty and systems underpinning EAS are also discussed. The chapter goes further to discuss basic concepts of a systems approach, providing literature on SE with SsT and its logical consideration and application into energy poverty and access processes.

Chapter 3 focuses on the application of a systems approach through SE with SsT concept analyses into energy poverty and access processes, thence building on the methodology to addressing Research Objective 5. In this chapter, a proposed new SRM is developed and presented, and logical procedures taken in developing the model are also discussed. Other methodologies and techniques, adaptable in addressing systems in the new SRM are also reviewed.

Chapter 4 centres on reviewing energy pro-poor policies in the 1998 Energy White Paper document (DME, 1998), addressing Research Objective 1. The chapter goes further to benchmark these policies against such similar policies in selected countries in sub-Saharan Africa to ascertain the degree of policy effectiveness in mitigating energy poverty in South Africa. The chapter also discusses various drawbacks in policy implementations and most importantly, provides clear-cut policy recommendations and interventions for future policy reforms, with more emphasis on improving energy access in energy-poor households in South Africa.

Chapter 5 logically presents the results and outcomes, followed by discussions of results for Research Objectives 2, 3, 4, and 5. First, the chapter analyzes study results on historical and forecast trends in access rates (electricity access) and access costs (connection costs), and historical trends in electricity tariffs in the City of Cape Town, followed by the discussions, addressing Research Objective 2. Secondly, the chapter analyzes study results on LC mapping and LC change detection in the City of Cape Town, followed by the discussions, addressing Research Objective 3. Thirdly, the chapter analyzes study results on energy-use patterns and behaviour, and related matters in the primary case study area, followed by the discussions, addressing Research Objective 4. The final part of the chapter demonstrates the logical application of a proposed new SRM in the primary case study area, then the discussions, addressing Research Objective 5. By integrating relevant study outcomes, a tailored SRM framework is developed and presented in this chapter, for managing energy poverty and increasing energy access in the case study area. Since a proposed new SRM design and its application is the highpoint of this research study, this chapter, in addition, discusses its importance and benefits to policymakers.

Chapter 6 provides final discussions and recommendations by discussing important study outcomes and concepts to encourage EAS in South Africa, at large.

Lastly, Chapter 7 concludes the thesis with relevant concluding remarks, summarizing limitations, and recommendations for each part of the research study.

CHAPTER 2: LITERATURE REVIEW ON MATTERS OF ENERGY POVERTY

This chapter provides an overview of the literature on the topics of energy poverty, energy poverty impact, energy poverty mitigation, and energy access. The chapter considers relevant literature to understand the important aspects of these matters in addressing the research questions in Chapter 1. The review considers scholarly works with methodologies that have important relevance to this research.

Energy poverty is particularly prevalent in developing countries, and as a result, situations of poverty and energy poverty in Sub-Saharan Africa (SSA) are first discussed. The chapter narrows the review within the South African context, where energy distribution and its challenges and inequality especially in informal settlements, followed by spatial analyses of informal areas, and lastly, energy-use patterns and behaviour in informal households, are discussed. Generally, the discourses on energy poverty impact, ways of controlling energy poverty, and systems underpinning energy access sustainability, are broadly covered. The chapter narrows the literature review on systems thinking underpinning the frameworks of energy access sustainability. Finally, the conclusion. To enhance clarity, the chapter is subdivided into the following sections below:

- Energy Poverty, Indicators and Thresholds
- Poverty and Energy Poverty in Sub-Saharan Africa
- Energy Distribution and Challenges particular to South Africa
- Inequality in Energy Distribution: Profiling Informal Settlements
- Earth Observation of Informal Settlement
- Post Classification and Land-Cover Change detection
- Trends in Energy-Use Pattern and Related Matters in informal settlements in the City of Cape Town
- Impact of Energy Poverty
- Controlling Energy Poverty
- Underpinning Sustainable Energy Access
- Systems Thinking - Underpinning Energy Access Sustainability
- Concluding Remarks

2.1 ENERGY POVERTY: INDICATORS AND THRESHOLDS

Energy poverty can be described as a lack of access to electricity, particularly in developing countries. Also, fuel poverty can be described as a lack of heating fuels in households in developed countries. Within the study context, these two phrases attempt to describe a lack of access to cleaner energy, particularly in the domestic sector. In a somewhat wider sense, Vermaak *et al*. (2013) describe energy poverty as a lack of access to all energy forms and modern energy services, from electricity to heating or cooking fuels. This research study embraces the definition by the International Energy Association (IEA), which views energy poverty as a lack of access to clean and affordable (modern) energy services, including smart electricity and other clean cooking (energy access) facilities, in households (United Nations 2014).

Table 2.1 Modern Energy Services Contributing to Achieving Millennium Development Goals (MDGs) (Source: Practical Action 2010)

MDGs	Lighting	Cooking and water heating	Space heating	Cooling	ICTs	Earning a living
End poverty and hunger	Increases productivity Reduces money spent on low-quality lighting	Reduce time lost gathering wood Increase productivity Food can be cooked safely	Reduces time lost gathering wood Increases productivity	Reduces food waste and increase income for producers	IT enables better market prices for producers ICTs support economic growth	New and Improved income earning
Universal Education	Children are allowed to study at night Rural schools and colleges attract teachers	Less time spent collecting wood means more time for education	Less time spent collecting wood means more time for education	–	Access to educational software and information from global sources	Children are released from earning while learning
Gender Equality	Women's domestic burden reduces by improving lighting services	Reduce the burden on women to obtain cooking fuels	Reduces the burden on women to obtain heating fuels	–	Equal access to information, including information on government programs	Broader income-generation opportunities for women Reduce the importance of physical strength
Child Health	Reduces death and injury from unsafe lighting Less lung damage from sooty flames	Reduce smoke inhalation and related diseases among young children	Reduces child death due to cold-related illnesses	Vaccine refrigeration enables inoculation	Information about child healthcare to become more available	Higher-income linked with improved health
Maternal Health	Improves lighting for clinics, essential for safe night births and treatments	Increase the birthweight of children without smoke Hot water available, essential for childbirth	Improves comfort and health of the mother in pregnancy and childbirth	–	Information about healthcare options become more available	Higher-income linked with improved health
Combat HIV/AIDS	Improved lighting essential for clinics	Needles can be sterilized	–	Liquid anti-retroviral drugs can be refrigerated	Information about protection and healthcare options become more available	–

Environmental Sustainability	Lighting is an ideal end-user for renewable electricity	Improved practices reduce deforestation and emissions	Improved practices reduce deforestation and emissions	–	Monitoring and communication of environmental impact is possible	–
Global Partnership	–	–	–	–	Communication enables dialogue, information exchange, and partnership	–

As presented in Table 2.1, modern energy services and associated benefits are in sync to achieving Millennium Development Goals (MDGs). Access to modern energy services contributes to socio-economic development and promotes environmental sustainability and global partnerships. All households are to meet the basic modern energy services, such as lighting, cooking, and heating, which also help to assess their levels of energy access and consumption to achieving MDGs. With improved access to these services, health, the environment, and social wellbeing, among many, can be improved. In the same way, energy poverty, poverty, and health illnesses can be reduced, particularly in mothers and children. Households are anticipated to satisfy modern energy services using, at best, cleaner access options, if not, households are considered energy poor. Using these access options, such as Liquid Petroleum Gas (LPG), seemingly saves time, increases productivity, and has fewer impacts on health, and the environment (Puzzolo *et al.* 2019). Relevantly, the connections between access to modern energy services and achieving UN MDGs require addressing challenges and prospects influencing energy service provisions, particularly in energy-poor households (Brew-Hammond 2010).

According to the Energy Ladder Theory, the cost and quality of energy use ascend from traditional solid fuels to liquid fuels, such as LPG and paraffin, and lastly, to electricity. Theoretically, the energy ladder describes the relationships between energy-use patterns, household income, and transitional shift (Bahadur Rahut *et al.* 2017). The theory assumes that energy use in households immediately shifts from lower traditional energy forms to cleaner energy sources, such as liquid fuels, and finally, smart electricity, once household income increases. As per the theory, as household wealth grows, the scale of energy cleanliness is expected to climb up the energy ladder. The concept behind the energy ladder theory is fundamentally describing modern energy services and its improved and associated energy benefits.

Figure 2.1 describes the three-step ascending energy ladder to electricity use, from deficiency to evolution stage, as developed by the IEA (Day, Walker and Simcock 2016).

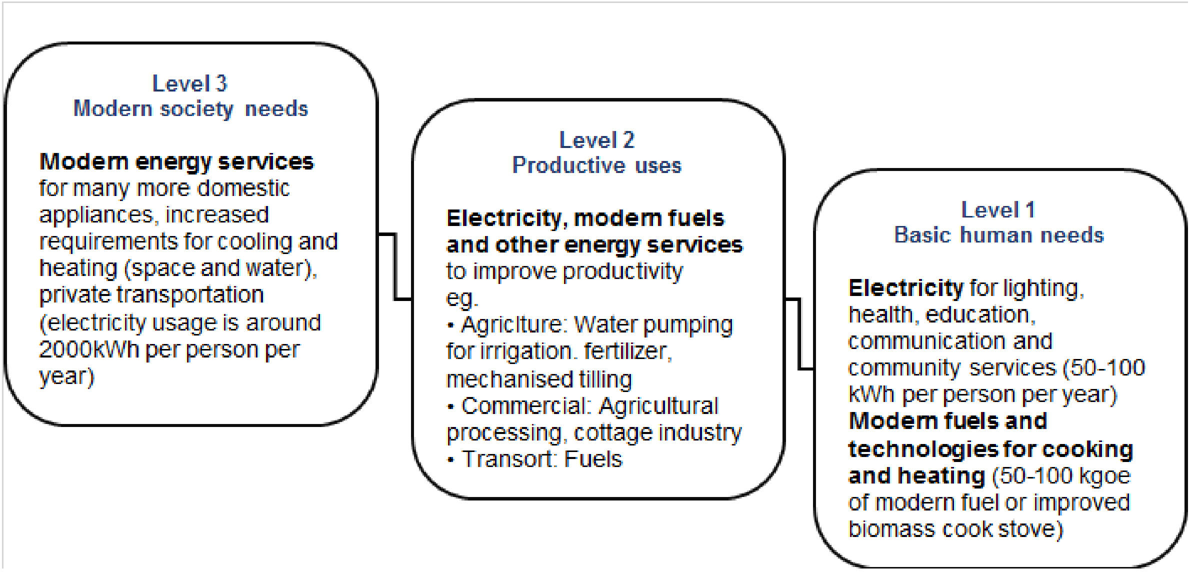


Figure 2.1 Energy Ladder, showing the Progression in Energy Use (Source: Bazilian *et al*. 2010)

Energy poverty has been determined using approaches (Nayan Yadava and Sinha 2019; UN AGECC 2010; Nussbaumer *et al*. 2012), indicators, and threshold levels in defining access to modern energy services (Ntaintasis, Mirasgedis and Tourkolias 2019; Okushima 2019; Papada and Kaliampakos 2019). Indicators of energy poverty are equally as important as predefined thresholds. Studies have evaluated various threshold levels useful in estimating total energy consumed in households on a routine basis (see Bazilian *et al*. 2012; Mirza and Szirmai 2010). Likewise, energy consumption per capita provides a different scope in determining energy poverty levels (Wu *et al.* 2019). The United Nations suggested an early target of 1 200 kWh consumption, about 100 kilograms of oil equivalent (kgoe) of modern fuels, and 100 kWh of electricity (Pachauri 2011) per person per annum (UN AGECC 2010). Day *et al*. (2016) suggested a threshold of about 8 140 kWh consumption per capita per annum. The Indian government declared a minimum lifeline threshold of 365 kWh per household, annually, as acceptable (Pachauri 2011). In a different way, the South African government identified a lifeline rate of 600 kWh per household in a year. Other studies went further to evaluate total energy use by defining the minimum acceptable thresholds against the actual energy use based on predefined indicators of modern energy services (Practical Action 2010). According to Practical Action (2010), the minimum acceptable energy needs must include lighting, cooking, and heating.

Energy poverty is known to occur when energy technologies are not substantially secured to meet modern energy services (Sokona, Mulugetta and Gujba 2012). Presently, more than one billion people, globally, are without access to smart electricity and affordable modern energy services, particularly in sub-Saharan Africa (Thomson *et al.* 2018). Many energy-poor households in rural and urban poor areas in the sub-Saharan Africa region, consume large quantities of solid fuels such as biomass (Sokona, Mulugetta and Gujba 2012; Bohlmann and Inglesi-Lotz 2018).

The next section reviews poverty and energy poverty, typifying different scenarios of energy poverty in the global south. For this research, the global south is also referred to as the sub-Saharan African region.

2.2 POVERTY AND ENERGY POVERTY IN SUB-SAHARAN AFRICA

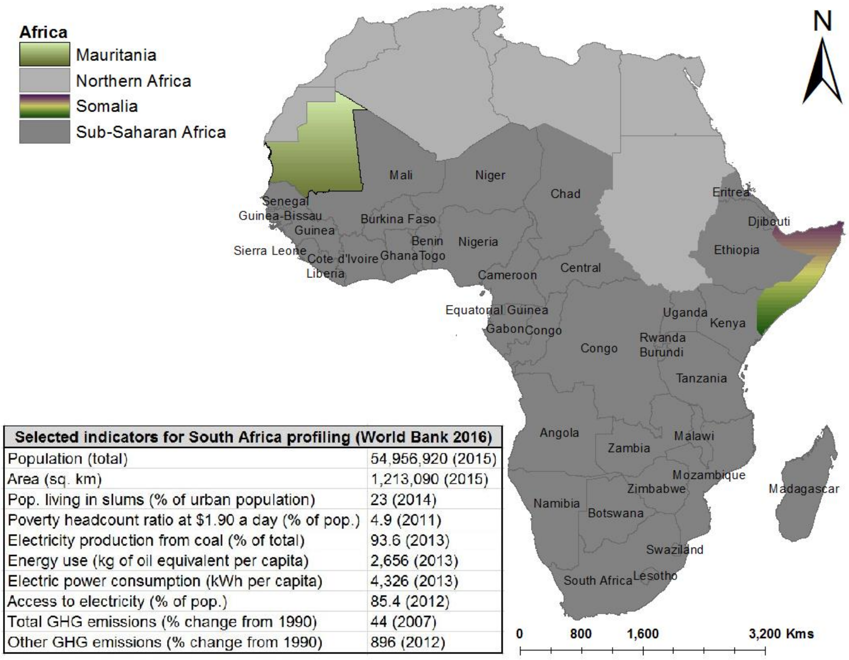
The global south is known to have higher intensities of poverty and energy poverty levels in most rural and urban poor areas (Thomson *et al.* 2018; World Bank 2016). In addition, high poverty levels have been established to retard socio-economic development in sub-Saharan Africa (World Bank 2016). The population of sub-Saharan Africa was estimated at more than 922 million in 2012, with a 40% increase from 1993, as shown in Table 2.2. In the same year, the World Bank reported that about 27% of the population lives below the poverty line, depending on an average income of US$1.90 per day. By 2012, the population living below two dollars a day has increased, significantly. Compared to North Africa, levels of national income are markedly lower in sub-Saharan Africa (World Bank 2016). Excluding South Africa, the Gross National Product (GNP) per capita in sub-Saharan Africa drops from US$ 492 to US$ 306, far below the per capita income in developed countries (Karekezi 2002). As a result, high poverty levels are particularly apparent in rural areas, accounting for about 64% of the total population in sub-Saharan Africa. Based on national poverty references, poverty intensities in rural sub-Saharan Africa range from 50% to 77% (Karekezi 2002a).

As indicated in Table 2.2, energy sectors are chiefly dominated by coal sources for energy production in Sub-Saharan Africa. Energy resources such as energy renewables, hydroelectric, and oil and gas are used in significantly small quantities. Most oil-producing countries within sub-Saharan Africa and North Africa mostly depend on oil and gas resources for electricity generation. Alternatively, South Africa largely depends on coal sources for its electricity generation, producing over 93% of electricity output in 2013 (Figure 2.2). Currently, North Africa and South Africa account for more than 50% of the total energy production in Africa (Walwyn and Brent 2015). South Africa by itself dominates the sub-Saharan African power sector, contributing half the total electricity generation in the continent (Walwyn and Brent

2015). In comparison, Ghana's electricity production is mainly from fossil fuel combustion and small quantities of renewable resources such as hydropower and solar. Ghana's energy sector was shown to generate a total of 12 870GWh of electricity in 2013 (Asumadu-Sarkodie and Owusu 2016). In another comparison, Botswana has large coal reserves as the major energy resource base and also exploits traditional and commercial energy forms. Petroleum products constitute about 30% of the primary energy in Botswana. These raw energy products are refined in South Africa before redistribution in the demand sector in Botswana (Mzezewa 2009). As electricity supply in Botswana is enormously dependent on South Africa, electricity distribution is occasionally repressed due to supply shortages, as is the case in many developed countries. Besides, sub-Saharan African energy sectors contribute, significantly to global GHG emissions, such as carbon dioxide (CO_2), among others. These emissions, for example, other GHG emissions in Table 2.2, were observed to be in deficit in 1993 from the 1990 level, which prominently intensified with a 62% annual increase in 2012.

Table 2.2 Some Selected Socioeconomic and Demographic Indicators of Poverty and Energy Poverty in Sub-Saharan Africa (Adapted from World Bank 2016).

Indicator Name	**1993**	**2012**
Sub-Saharan population (% of the total population)		
Urban population	28.30	36.23
Rural population	71.70	63.77
Population growth per annum	2.8	2.77
Poverty headcount ratio at $1.90 a day (2011 PPP)	27.07	42.6
Total population	552,842,678	922,855,109
CO_2 emission (% of total fuel combustion)		
CO_2 emissions from electricity and heat production	54.96	54.41
GHG emission rates (% change from 1990)		
Total greenhouse gas emissions	-15.04	35.53
Other greenhouse gas emissions	-19.54	62.20
Energy use (% of total energy)		
Combustible renewables and waste	57.54	58.26
Fossil fuel energy consumption	40.56	39.24
Renewable energy consumption	73.28	69.93
Energy use (kg of oil equivalent per capita)	674.08	676.027
Electric power consumption (kWh per capita)	503.39	496.39
Electricity production (% of total)		
Renewable electricity output	18.95	22.00
Electricity production from hydroelectric sources	16.10	20.14
Electricity production from oil, gas, and coal sources	70.89	66.08
Electricity production from coal sources	65.77	55.09
Access to electricity (% of the population)	**2000**	
Urban population	60.28	71.41
Rural population	9.73	14.03
Total population	70.01	85.44



Selected indicators for South Africa profiling (World Bank 2016)	
Population (total)	54,956,920 (2015)
Area (sq. km)	1,213,090 (2015)
Pop. living in slums (% of urban population)	23 (2014)
Poverty headcount ratio at $1.90 a day (% of pop.)	4.9 (2011)
Electricity production from coal (% of total)	93.6 (2013)
Energy use (kg of oil equivalent per capita)	2,656 (2013)
Electric power consumption (kWh per capita)	4,326 (2013)
Access to electricity (% of pop.)	85.4 (2012)
Total GHG emissions (% change from 1990)	44 (2007)
Other GHG emissions (% change from 1990)	896 (2012)

Figure 2.2 Map of Africa indicating the Sub-Saharan African Region (Dark Grey), Profiling Some Selected Indicators in South Africa. (Source: IEA, World Energy Outlook 2016)

The literature has vastly determined high energy poverty levels in the global south through electricity access level and poor energy consumption (Sokona, Mulugetta and Gujba 2012; (Thomson *et al.* 2018). As specified in Table 2.2, the rate of electricity access is rather slow compared to the rapid population growth in sub-Saharan Africa. The urban population in 2012 almost doubled the total population in 1993, guaranteeing that future demands for modern energy services are to skyrocket, proportionally. Electricity access is more improved in commercial and industrial divisions, and high-income households, than in low-income households in sub-Saharan Africa. Mostly rural and urban poor households are without electricity access as deduced from 14% electricity access in rural areas in 2012. The general electricity access in sub-Saharan Africa is about 85% and the rest depend on biomass for domestic use (World Bank 2016). For total electricity access to be gained by 2030, the World Bank (2016) proposes investment costs of roughly $11 million per annum to achieve 100% of electricity access in sub-Saharan Africa.

Energy poverty is equally reflected in total energy consumption in sub-Saharan Africa. As shown in Table 2.2, the total energy use has been minimal and almost stagnant from 1993 to 2012, slightly dropping from 674 kg of oil equivalent (kgoe) to 673 kgoe. Even before 2012, modern energy consumption has been on the decline, slightly reducing from 1990 to 1997 (Karekezi 2002a). Rather than increasing, the electricity consumption also dropped, but only slightly, from 503 kWh to 493 kWh per capita. Generally, electricity consumption is very low in sub-Saharan Africa except in a few countries, such as South Africa, Ghana, and Botswana. Ghana gained 72% of national electrification, while South Africa gained about 86% in 2014, as presented in Table 2.3. In the same year, Botswana gained more than 50% electricity access, with the least population of people without electricity access, when compared to other sub-Saharan African countries.

Table 2.3 Rates of Electricity Access and Biomass Use (2014) in Some Sub-Saharan Africa Countries (elect. = electrification) (Source: IEA, World Energy Outlook 2016)

Region	Pop. without electricity (millions)	National elect. (%)	Urban elect. (%)	Rural elect. (%)	Population relying on biomass (millions)	Population relying on biomass (%)
Sub-Saharan Africa	**632**	**82**	**63**	**19**	**792**	**81**
Angola	16	33	69	6	13	52
Botswana	1	53	69	32	1	36
Burkina Faso	14	18	58	1	17	95
Burundi	10	5	28	2	11	98
Chad	13	4	13	1	13	95
Dem. Rep. of Congo	62	18	42	0	71	95
Ethiopia	73	25	85	10	92	95
Ghana	8	72	91	50	22	82
Kenya	36	20	60	7	38	85
Madagascar	21	13	22	8	23	98
Malawi	15	12	46	5	16	97
Mali	13	26	53	9	17	98
Mozambique	16	40	67	27	26	96
Niger	16	15	62	4	18	97
Nigeria	98	45	55	36	134	76
South Africa	8	86	87	85	5	10
South Sudan	12	1	4	0	12	98
Sudan	24	40	67	26	27	69
Tanzania	36	30	57	18	50	96
Uganda	31	19	52	12	37	98
Zambia	11	28	62	5	13	82

The use of biomass energy is particularly high in sub-Saharan Africa, with about 2.7 billion people using it for mainly cooking (Karekezi 2002). Biomass energy, such as charcoal and firewood, is one of the primary energy use for cooking and heating in Ghana (about 71%) (Asumadu-Sarkodie and Owusu 2016). In the early 21st century, biogas and LPG were introduced in Ghana, which dropped biomass use to 60% in households (Asumadu-Sarkodie and Owusu 2016). Botswana, on the other hand, adopted a much wider mix of energy sources, including paraffin, fuelwood, coal, LPG, and small quantities of renewables, for domestic use. Energy choice in Botswana is fairly dependent on household income, where high-income earners consume electricity and low-income households depend mostly on biomass. In Kenya, energy sources are mainly firewood, charcoal, agricultural wastes, with petroleum products not consumed that commonly. While rural areas in Kenya use biomass, commercial and industrial sectors use petroleum products. Tanzania consumes biomass energy and petroleum products, with coal and electricity consumed the least, similar to Senegal. Despite being one of the oil-rich producing countries in sub-Saharan Africa, Nigeria consumes about 76% of the biomass, as shown in Table 2.3, of which more than 90% of fuelwood is used to meet household energy needs (World Bank 2016). South Africa, on the contrary, has only a smaller population depending on biomass energy for domestic energy needs, compared to other countries in sub-Saharan Africa.

It is important to understand factors influencing biomass use in households and occasional supply shortages in the South African energy sector (United Nations 2014). The section below discusses energy production, distribution, and challenges in the South African energy system. The subsequent section discusses factors and situations promoting poor energy use in households.

2.3 ENERGY DISTRIBUTION AND CHALLENGES PARTICULAR TO SOUTH AFRICA

The energy system plays a huge role in the national economy, particularly in the industrial development of South Africa. This is, similarly, reflected in most countries in sub-Saharan Africa except that South Africa happens to be one of the largest coal consumers, contributing about 70% of energy production in the continent (Karekezi 2002a; Walwyn and Brent 2015). With coal production of roughly 94% in 2013 in Africa, South Africa equally recorded the highest figures of coal produced in sub-Saharan Africa (World Bank 2016). Eskom, the key government-owned electricity utility, controls the South African energy sector (Mcewan 2017). Out of the total coal production in South Africa, Eskom utilizes 50% of coal produced for electricity generation, and exports around 33% to boost the economy (Davidson *et al.* 2006). Less than a quarter of coal production is consumed in domestic and commercial sectors, with more than a quarter channelled into petroleum production. Together with coal resources, petroleum (38%) and gas products (1%) are also used, contributing only two percent of electricity generation in South Africa.

Electricity is considered as the primary energy use in South Africa since electricity access accounts for about 85% and consumption per capita stands at about 4 000 kWh, as shown in Table 2.4. The key parastatal, Eskom, operates several power stations in South Africa with a total generating capacity of 38 000 MW, mainly situated in coalfields in the Mpumalanga

Highveld. Eskom has invested huge amounts into national electrification and can effectively supply surplus electricity in domestic and commercial sectors. At present, Eskom generates about 95% of electricity output in South Africa (Kelly and Geyer 2018) and about 50% of the total demand in Africa (Walwyn and Brent 2015). Private organizations contribute only two percent of the total electricity production (Pegels 2010), amounting to about US$3 million in total investments by 2015. The industrial sector consumes more than 60% of the generated electricity (Spalding-Fecher and Matibe 2003). The remaining 40% purchased by electricity-distributing municipalities are redistributed in residential areas, and small-scale businesses (Kelly and Geyer 2018).

Table 2.4 Profiling Energy System, Energy Supply Sector, and Other Energy-related Indicators in South Africa. (Adapted from World Bank 2016).

No	Indicator Name	Year	Proportions and Figures
1	Electricity production from coal sources (% of total)	2013	93.67
2	Access to electricity (% of the population)	2012	85.4
3	Electric power consumption (kWh per capita)	2013	4,326
4	Electricity production from oil, gas, and coal sources (% of total)	2013	93.7
5	An energy intensity level of primary energy (MJ/$2011 PPP GDP)	2012	9
6	Energy use (kg of oil equivalent per capita)	2013	2,656
7	Fossil fuel energy consumption (% of total)	2013	86.7
8	GDP per unit of energy use (constant 2011 PPP $ per kgoe)	2014	4.6
9	Investment in energy with private participation (current US$)	2015	3,973,250
10	Other greenhouse gas emissions (% change from 1990)	2012	895
11	Population living in slums, (% of urban pop.)	2014	23
12	Poverty headcount ratio at $1.90 a day (2011 PPP) (% of pop.)	2011	4.9
13	Renewable energy consumption (% of total final energy consumption)	2012	16.93
14	Total greenhouse gas emissions (% change from 1990)	2007	44
15	Urban poverty headcount ratio at national poverty lines (% of urban pop.)	2010	39.2

The initial challenge in the South African energy sector commenced with coal shortages for electricity production, followed by unexpected breakdowns of generation plants. As a result, intermittent blackouts, which began in the first quarter of 2008 and also referred to as load shedding, was initiated in South Africa. When the system capacity is outpaced by high energy demands, these occasional blackouts are set in motion to circumvent the breakdown of generation plants. The diurnal peak system load is mainly from industrial and commercial sectors. The domestic sector uses less than 15% of the total generated electricity but also contributes to the diurnal peak load. As electricity access increases in households, Eskom experiences under-capacity to meet high energy demands from different sectors, leading to a 30% additional demand load. The peak system demand load is typical in winter because of increased energy consumption for thermal needs in the demand sectors, both domestic and commercial sectors.

The spiralling cost of installing new generation plants forced Eskom to use low-cost system management approaches in managing peak system energy demand loads. As a result, these rotational load shedding events cutting off 1 000 MW and above from the standard system load demand, was put in place to circumvent the total collapse of the power supply system (United Nations 2014). Another demand-side management option is the tariff adjustment method, which is using prepayment meters to control the time of use to ease peak system demand load. There are no economic benefits to save energy in the industrial and commercial sectors. Poor households are more compliant to save energy because of the energy burden on household income. Thus, Eskom offers low (subsidized) tariffs, and efficient and cheaper appliances as part of the connection contract to ease off energy burden in households and electricity peak demand profile in the supply sector (Kelly and Geyer 2018).

It can be postulated that challenges in the energy supply sector occur due to little or no competition resulting from the vertically-integrated monopolistic Eskom. The Botswana government, on the other hand, restructured its energy industry by encouraging competition through privatization, at the wholesale level. As a result, electricity access increased favourably, and about 23% of electricity access was added to rural areas in 2012 (Consumption and Resources 2016). This illustrates that electricity privatization can be a practical tool to stimulate competition in the South African energy sector to maintain a constant and guaranteed energy supply. As stated by Letladi (2006), electricity privatization expands electricity supply whilst generating more revenues for the government. Privatization may be a lengthy and rigorous process but has presented to be a potential solution to supply shortages in the South Africa energy sector. At present, South Africa has privatized only two percent of its total electricity production (Pegels 2010). If this percentage is increased, electricity privatization may resolve supply shortages and other emerging electrification challenges in the South African energy system.

The South African energy system has shown a remarkable trend in national electrification through policies and strategies, to date (DME 1998). The energy sector constantly ensures cost-effective tariffs and also promotes energy-use efficiency through energy planning schemes (Spalding-Fecher and Matibe 2003). Unfortunately, despite huge investments to promote national electrification since 1994 (DoE 2015), energy poverty continues to proliferate in both rural and urban poor areas. Most remote rural areas are entirely off-grid and cannot be easily grid-connected, in the earliest. Most urban poor areas are close to the grid and are still not electrified. These urban poor areas, also commonly known as informal settlements, or shack-clustered areas, are sprawling and very well-distributed across the South African provinces. Regardless of the obvious challenges limiting electricity supply in the energy sector, there are equally other multitudes of factors sustaining the lack of electricity access in informal settlements; this would be discussed in the section below.

2.4 INEQUALITY IN ENERGY DISTRIBUTION: PROFILING INFORMAL SETTLEMENTS

Typically, there are three dwelling types - formal, informal, and traditional (and other or unknown) dwellings in sub-Saharan Africa, including South Africa (Stats SA 2016). Formal dwellings are usually built on surveyed and announced residential land, whereas traditional dwellings mainly comprise of mud/straws huts, as well as other (or unknown) dwellings. According to SEA (2014), informal dwellings, also known as shacks, are makeshift dwelling structures not constructed according to approved architectural plans. This particular dwelling type is mostly occupied by the urban poor living in urban-poor areas such as informal settlements (also referred to as squatter settlements).

Traditionally, informal settlements developed when inequality in the political economy translated, directly into inequality in energy distribution and land segregation during the apartheid regime (Mcewan 2017). The relatively wealthy was settled in clean, and scenic suburbs, away from industries and pollution. The poor, comprising of mostly blacks, were marginalized in the city periphery, close to coal dumps and large petrochemical plants, with restricted access to social services. The apartheid legislature, not only confined the poor to unsustainable urban areas but also subjected them to the deleterious impacts of over-industrialization (Chidhindi *et al.* 2019). A series of forces creating unequal access to basic services are then magnified because of infrastructural dichotomy caused by land segregation. Before the 1980s, informal settlements were well laid out and planned, with access to infrastructure and social services. Now, informal settlements are isolated with limited access to basic services. Worse still, the dwellings are developed by the urban poor themselves, mostly poorly built and non-insulated with no support of energy-use efficiency (HDA 2012; Stats SA 2016).

Generally, informal households are low-income households in South Africa because large majorities live below the poverty line (World Bank 2016). Sources of income are mainly from salaries and wages (68%), pension (12%), remittances (7%), other means (11%), and 'no income' (2%) (HDA 2012). The highest (monthly) income earned in informal households stretches from < R3 500 to > R7 500 (R = South African Rand, approximately US$1 = R16 at the time of writing), making up about 10% of the population (HDA 2012). Others (17%), earn between R850 - R3 500 and the rest earn below R850 (HDA 2012). Household expenditures are mainly on foods and beverages (31%), with 8% allocated to housing, water, fuels, and electricity (HDA 2012). While some households (26%) have piped water within proximity, most households (74%) obtain piped water (communal taps) within walking distance or have no water access, at all (HDA 2012). Most informal dwellings (73%) have no toilet facilities, others use modern (flush) toilets (19%), and the reminder use latrine types such as pit, bucket, and chemical (HDA 2012).

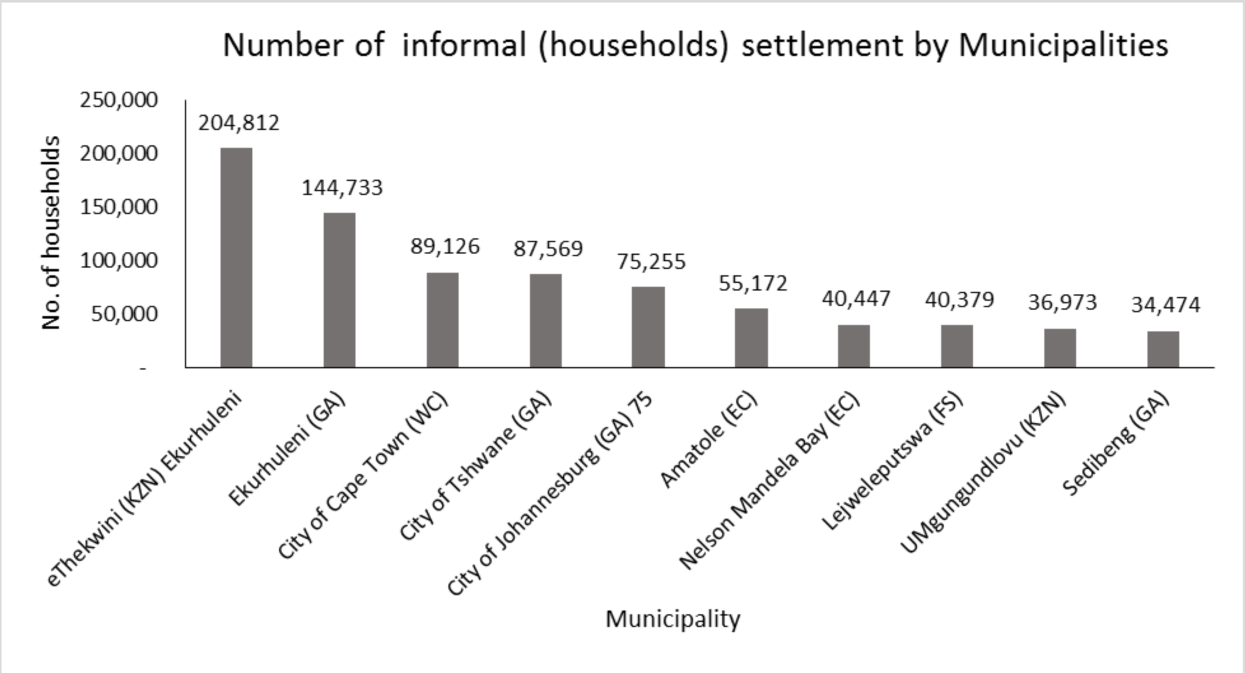


Figure 2.3 Distribution of Informal Households in Some Municipalities (Census 2001) in South Africa (Source: HDA 2012)

Eskom estimates that over 3.5 million informal households are without electricity access (Vermaak, Kohler and Rhodes Bruce, 2013). A more recent study opposed Eskom estimates and reported only about 871 000 informal households with no electricity access in South Africa (Stats SA 2016). There are significantly large populations of informal households within municipalities that may require electrifications, for example, about 25% in the eThekwini Municipality and 11% in the City of Cape Town (Figure 2.3). In general, informal households (about 70%) depend wholly, or partially on, electricity, paraffin, charcoal, candles, batteries, LPG, and fuelwood, etc. for energy needs. In Soweto, about 80% of informal households use both coal stoves and electric hotplates, concurrently, for space heating in winter (Vermaak, Kohler and Rhodes Bruce, 2013). Besides, energy preferences in households are highly dependent on cultural and socio-economic regional dispositions of an informal settlement (Mehlwana 1997). For instance, informal households close to coal mines commonly use coal, whereas paraffin use is preferred in southern and south-western metropolises in South Africa (Mehlwana 1997).

Many factors are restricting grid-connections of informal households by local electricity-distributing authorities. Local authorities in urban poor dominated areas, are mostly underequipped with the necessary paraphernalia to manage electricity networks, connection services, and new connection demands. Development funds for expanding access and maintaining operations in these authorities are often boycotted due to poor technical and managerial capacities. As a result, these local authorities are often financially constrained to manage both old and new connection services and demands at affordable rates. Other factors limiting operations in local authorities include, but are not limited to, poor personnel staffing, and skills, as well as inefficient operational processes. Further details on other challenges restricting electricity access in informal households will be discussed[11] in the course of this research study.

[11] To be discussed in CHAPTER 4: POLICY REVIEW: ENERGY PRO-POOR POLICIES; Particularly in Section 4.3: DRAWBACKS IN POLICY IMPLEMENTATIONs

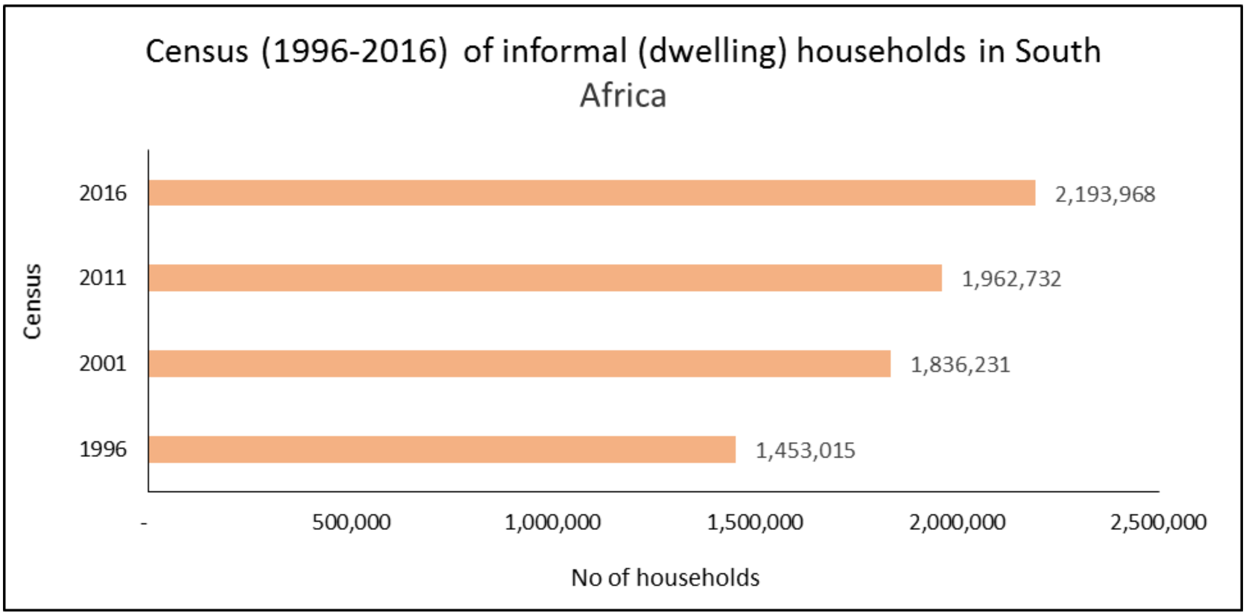


Figure 2.4 Distribution of Informal Households from the 1996 Census to 2016 in South Africa. (Source: Stats SA 2016)

Since 1996, there has been an increasing trend in the number of informal households (Figure 2.4), particularly in the Gauteng and Western Cape provinces (Stats SA 2016). Municipal Estimates reported that a total of 2 754 informal settlements are distributed across the municipalities in South Africa. Conversely, Eskom spatial data estimated a total of 1 016 boundaries (or polygons) of informal settlements, nationwide (HDA 2012). Spatial data on infrastructure monitors informal areas' distributions and can assess, indirectly poverty cum energy poverty levels in informal settlements (ESRI 2009). It is imperative to engage geographical intelligence in reporting, accurately, the distribution of informal settlements at a given time and space (ESRI 2009; Oldfield 2011).

The next section discusses the Land-Cover (LC) classification, Land-Cover Change (LCC), techniques, and methodologies, employable in spatial data analyses of informal areas.

2.5 EARTH OBSERVATION OF INFORMAL AREAS

As already established, informal settlements (or areas) are one of the key areas with large numbers of energy (urban) poor households in South Africa. As they expand in land use, more poverty with energy poverty persists. Informal areas in South Africa are rapidly formed and periodically changed, which most often affects the database records (HDA 2012). Monitoring land use and urban energy play a huge part in shaping energy distribution, and carbon footprints into the future. By monitoring land use novel strategies can be developed and directed to mitigating energy poverty and increasing energy access. Many geographical techniques are employed in navigating obstacles in earth observation (EO) of informal areas. Earth Observation (EO) systems are useful tools for assessing LCC at a temporal stretch. EO systems likewise monitor mortality, natural and anthropogenic property loss, and environmental-related issues (ESRI 2009). The EO data, alternatively, delivers large feature areas of the earth's surface in near real-time.

Remote sensing is a technique used for siphoning information of earth features using satellite imagery captured with electromagnetic sensors (Zhu *et al.* 2017). Various satellites such as MODIS, Landsat 8, and Spot provide satellite imagery at periodic intervals. The historical archive of satellite imagery provides a multi-temporal monitoring capability, appropriately compatible with generating LC and LCC datasets of a target area (Kabisch *et al.* 2019). The common problem of satellite imagery often lies in its mapping capacity, defined by spatial resolution in image pixel sizes, often coarser than target features (Zhang *et al.* 2018). Satellite imagery is appropriate for mapping informal areas but may be limited in finely defining boundaries due to the low resolution of some imagery. The most common classification errors originate from a low spatial resolution that limits object details during LC classification.

<u>Hyperspectral data</u>

Using finer spatial resolution data on small and complex target objects can amplify small features for image identification in LC classifications (Boyd and Foody 2011). Hyperspectral data have a high spatial resolution that enhances spectral properties by examining narrow and adjoining wavelengths (of <10 nanometres) throughout the Electromagnetic Spectrum (EMS) (Thenkabail *et al.* 2004; Mansour, Mutanga and Everson 2012). Using the remotely sensed hyperspectral data for classifying informal areas is challenging, majorly due to the cost of acquiring multiple datasets (HDA 2012; Mansour *et al*. 2012; Metternicht *et al*. 2010).

<u>Multispectral data</u>

A multispectral sensor is another optical data that has EMS with electromagnetic spectral subdivisions in constant wavelengths, permitting a series of image capture that can be integrated into multiple ways (Lillesand, Kiefer and Chipman 2014). Multispectral data has been extensively used, for example, in the LC classification of National Land Cover (NLC) 2000 in South Africa (Fairbanks *et al.* 2000; Stuckenberg, Münch and van Niekerk 2013). Multispectral data require less pre-processing time, easy classification techniques, and affordable. The multispectral data performance depends on the capacity of variously chosen EMS bands to elucidate brightness and contrast of features for image identification (Keith *et al.*, 2009;

Lillesand, Kiefer and Chipman, 2014). Common-used EMS combinations include Near-Infra-Red (NIR) and Red, and Green, Blue (RGB) bands. Applying combined bands of brightness, RGB, and NIR on land-cover features to enhance image reflection and structural patterns, are also commonly used.

Land-Cover (LC) classifications

LC classifications mainly include supervised and unsupervised classifications. Supervised classification such as decision trees and expert systems are pixel-based classifications, commonly used for image classification and analyses. Supervised classification considers a priori information of actual classes in identifying unknown image objects (Sathya and Baby Deepa 2017). The actual data are also referred to as training data, which contain statistical inferences and spectral properties of each class used in training classifiers for classification (Campbell and Wynne 2011; Mather and Koch 2011). The commonly used classifier (or classification algorithms) is the Maximum Likelihood Classifier (MLC) (Kamal, Muhammad and Mahardhika 2020; Rajani and Varadarajan 2020). In the geometric sphere, the classifier statistically compares attributes of each pixel, both known and unknown pixels, and collates pixels into a class based on comparisons. Manual digitization (or vectorization) is one of the supervised techniques for image classification (Dunshee 2016). Although time-consuming, supervised classification produces satisfactory accuracy, largely dependent on the cautious preparation of the training data. Alternatively, unsupervised classification automatically collates pixels into user-specified classes based on similar spectral characteristics. This method is valuable where classification structures or study area lacks a priori information to aid classification. The unsupervised method is, usually, less used due to better techniques in supervised methods, such as manual digitization (Dunshee 2016), expert systems, and decision trees (Pal and Mather 2003).

Contrary to pixel-based classifications, Object-Based Image Analysis (OBIA) is another classification technique employed in delineating and cohesively classifying useful spatial fragments by applying spatial concepts (Lang 2008). In OBIA, each image object is characterized based on spatial, spectral, structural, and hierarchical properties. Spectral information of image objects reflects additional mean, median, maximum and minimum, and variance values. Compared to pixel-based, this information finely delineates classification in OBIA, reduces spectral discrepancy, and removes the “salt-and-pepper” effect (Liu and Xia 2010). OBIA is an iterative process with a multiscale purpose and employs several classifiers and rule-based expert systems. These expert systems apply a complex network of human knowledge to understand image information based on image perception as an aggregate of objects. Studies have broadly reported the effectiveness of applying expert systems in OBIA (Whiteside and Ahmad 2005; Chen *et al.* 2009). The decision tree in OBIA equally classify based on image object recognition using pixel contexts, and spatial interrelatedness with other pixels (Steele *et al.* 2013).

Post-classification editing and Land-Cover Change (LCC) detection

After the LC classification, post-classification editing is employed to reduce discrepancies between classes and other classification errors (Okoye 2016). Derived land-cover maps are susceptible to uncertainties that originate from data acquisition, processing, conversion, assessment, and final presentation (Bogaert, Waldner and Defourny 2017; Chen *et al.* 2018). Moreover, restricted access to data resources and satellite sensor's sensitivity reduces the accuracy of derived maps. Using reference data including aerial photographs and Ground Control Points (GCPs) in post-classification editing improves the accuracy of derived data. Post-classification editing includes, and is not limited to, re-digitization, vector merging, data conversion, and correlation of legends.

Following the post-classification editing is the LCC detection process. The LCC detection process is used to analyze the trend in change in a target area through spatial techniques (Japelaghi, Gholamalifard and Shayesteh, 2019), such as image enhancement (Raj and Gurugnanam 2018), multi-date (Chamundeeswari 2013), and post-data classification methods Okoye (2016). These techniques adopt change modelling i.e. collating change and abstracting details of change density between classes and periods (Munch *et al*. 2017). A computer-based change modelling collates a series of changes and then, extracts differing details among classes using software tools, for example, in ArcMap (ESRI 2009). The Intersect or Combine Tool in ArcMap, for instance, runs the change interception and pixel comparisons between two combined raster or vector outputs. Cross-tabulation using a pivot table in Excel (Excel 2013) also generates temporal change detection in tables from successfully overlaid derived maps (Alphan, Doygun, and Unlukaplan 2009). According to Okoye (2016), a comparative approach of post-data LC classifications, independently generated, also produces higher accuracy in derived LCC data. Mas (1999) used this approach combined, with image enhancement techniques, to reduce detection errors and recorded higher accuracy in derived LCC data. Conversely, Munch *et al*. (2017) used an indicator-based detection approach by generating LC conversions in derived LCC data, assigned conversion labels to them, and thematically represented them in maps.

Post-classification approach

Another post-classification approach includes accuracy validation/assessment. After the image processing, accuracy validation is employed to assess the quality of derived datasets using reference data or field validation methods (Saralioglu and Gungor 2019). Traditionally, data referencing with higher accuracy or finer resolution data, such as Ground Control Points (GCPs) and aerial photographs, produce high data accuracy in derived land-cover maps (Puliti *et al.* 2017). The cross-tabulation between the derived and reference data using error or confusion matrix identifies misclassifications and measures accuracy rates of derived data or remotely-sensed mapped data (Foody 2002). Aerial photographs are reliable reference data, although errors may occur from the user’s interpretation or image vagueness. Field validation methods, such as GCPs, when combined with aerial photographs, and expert consultations, on a target area, give accurate validations of derived data. Combining reference data exposes areas, not captured by satellite imagery, or not accessible, during field surveys (Congalton and Green 2008). Another accuracy assessment technique that can be employed is a random sampling scheme. The commonly used scheme is 50 reference plots per class, as a rule of thumb (Lillesand, Kiefer and Chipman 2014). Generally, accuracy validation is costly and demands proper considerations of the study area, sensors to be used, and the cloud (climate) cover in satellite imagery limiting statistical validations. Visual interpretation is another valuable technique for image identification and can be employed to improve supervised classifications and accuracy validation (Guimarães, Barbosa and Otávio Coaracy Brasil 2019)

Assessing trends in LC change requires an understanding of global-scale observation and regional surveys that facilitate logical measures to lessening driving factors. Whether local or global modelling of environmental situations and changes using spatial analysis, this provides scientific models and decisions, valuable in policy that can be directed to environmental and social management. Global modelling surveys a large area from a single unit analysis, while local modelling surveys a small area from a unit analysis (Munch *et al.* 2017). Local modelling of informal areas may require merging different techniques during image processing, LC classification, LC change analysis, data referencing, and accuracy assessments. Aerial photographs are high-resolution images (Ojha *et al.* 2016) that produce higher accuracy in mapping informal areas since its physiognomy is at variance with the rest of the built environment. Generally, selecting classification techniques and sampling schemes depends on imagery to be used and a range of questions to be addressed in a study. To this point, geographical intelligence has been established as a tool to filter information on land use and urban energy and ultimately, on rates of poverty and energy poverty in informal settlements (ESRI 2009; Munch *et al*. 2017).

Alternatively, an empirical assessment provides definite information on energy poverty, regarding energy-use patterns and related matters in informal households, as discussed in the section below.

2.6 TRENDS IN ENERGY-USE PATTERNS AND RELATED MATTERS IN INFORMAL HOUSEHOLDS IN THE CITY OF CAPE TOWN

Surveys on energy-use patterns in informal households have similar outcomes across the provinces in South Africa (Mdluli and Vogel 2010; SEA 2014). In this section, energy-related matters are reviewed at the regional level, which in this case, the City of Cape Town. The literature review embraces an analytical procedure and is undertaken to gauge data dimensionality and compliance with the primary data survey in the course of this study. Secondary data used, was obtained from StatsSA (2011)[12]. Out of 43 suburbs in the City, the focus of this review is placed on suburbs, with higher populations of informal households (Figure 2.5). For some parts of the review, informal households, including in backyards and not in backyards, caravans, and tents, are grouped. Parameters, including household population; population group; household size; education level; household income; employment status; and access to electricity and other energy sources, are employed to analyze trends in energy-use patterns and matters, as discussed in individual paragraphs below.

[12] Secondary data obtained from SuperCROSS and SuperWEB, Statistics South Africa (StatsSA). The SuperCROSS was collected from the StatsSA office in Cape Town in the form of Discs. The SuperWEB was accessed on http://superweb.statssa.gov.za

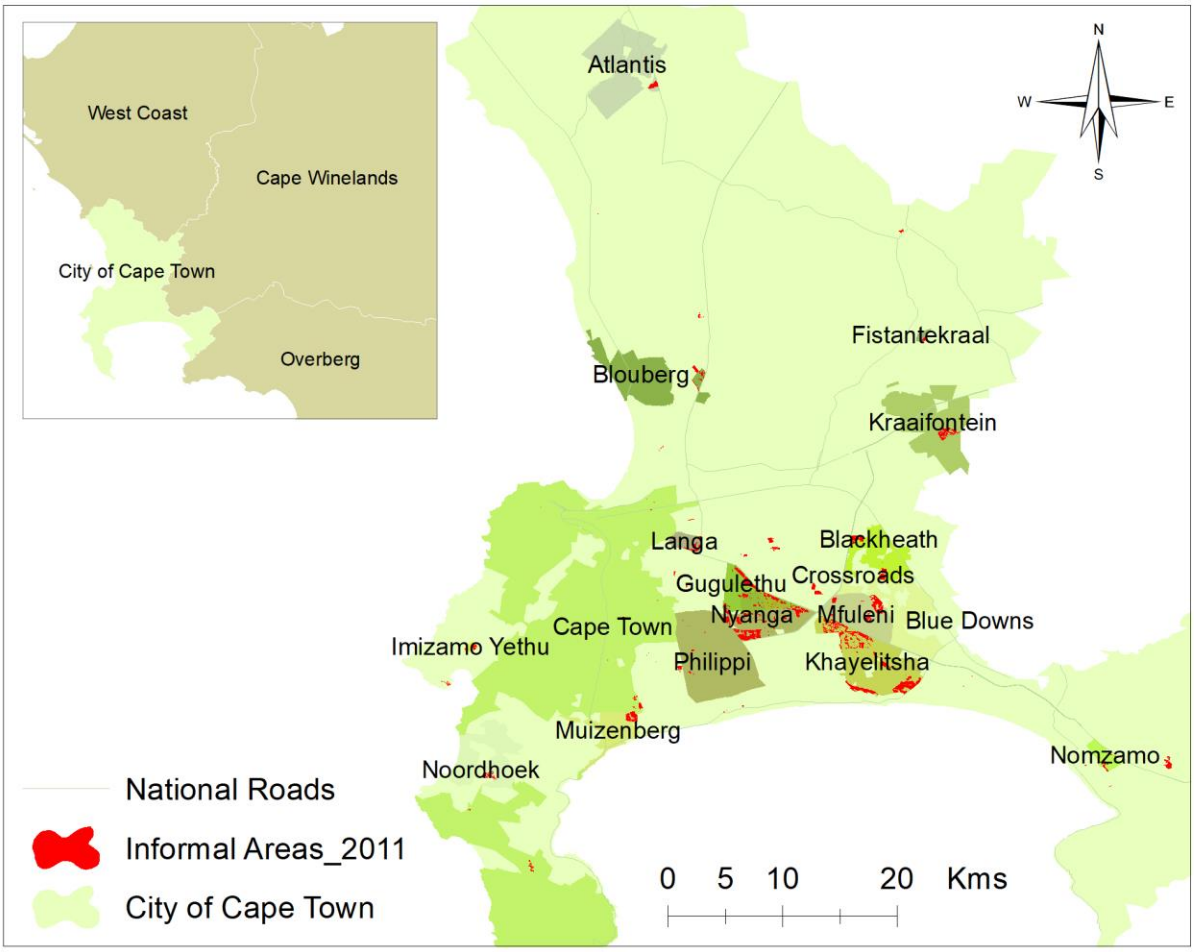


Figure 2.5 Map of some suburbs (selected) with higher proportions of informal households within, showing its distribution of informal areas in the City of Cape Town

<u>Household population</u>

The household population is used to assess the number of informal households residing in a particular area, at a given period. In the City of Cape Town, the population of informal households increased over time, with more than a 13% increase from 1996 to 2001 (StatsSA 2011). The population increased by about 53% from 2001 to 2011 (219 780), amounting to a total of 560 809 informal households in 2016 (Stats SA 2016). The highest populations of informal households not living in the backyard (n = 143 823) (StatsSA 2011) are found in Khayelitsha (38%), Philippi (15%), and Gugulethu (8%) (Figure 2.6). Small populations of households live in Blouberg, Langa, and Blue Downs, accounting for about 10% of the total households in selected suburbs. Small proportions are also found in Blackheath (nearly one percent), Mfuleni, and Delft (about three percent, respectively) (Figure 2.6).

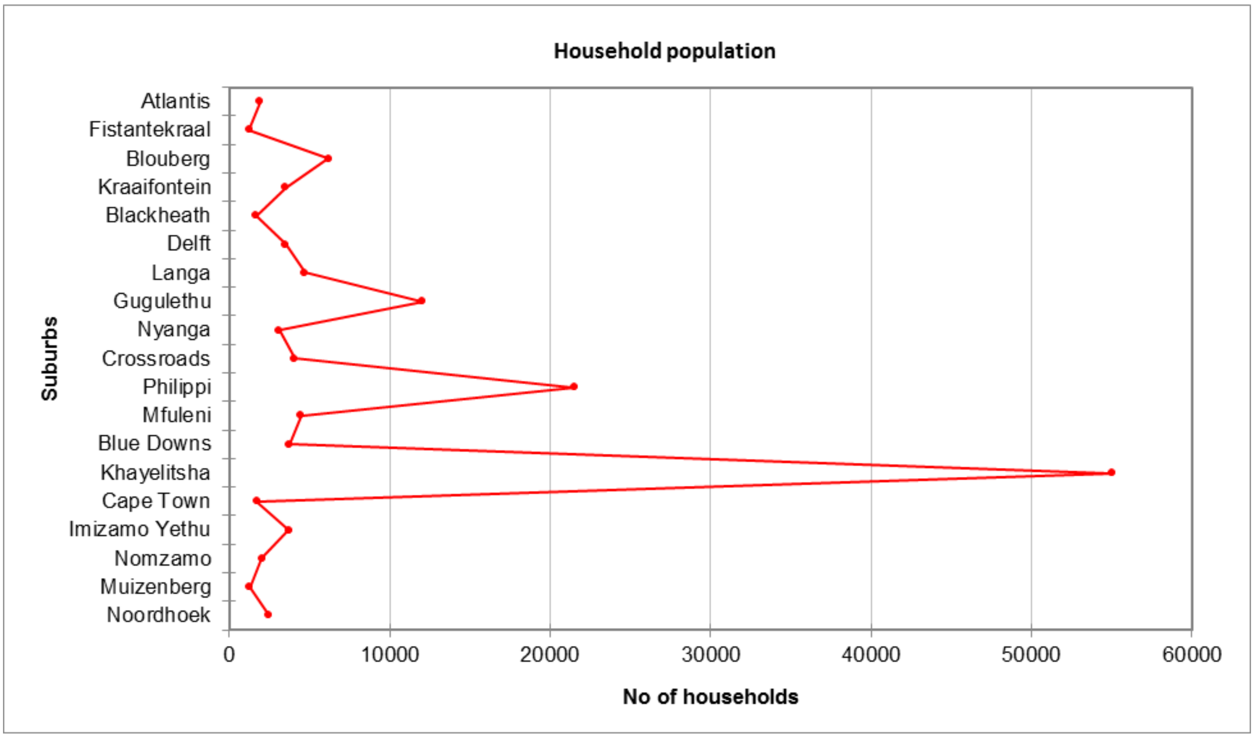


Figure 2.6 2011 Survey showing the Population Distribution of Informal Households Across Some selected Suburbs in the City of Cape Town. (Source: StatsSA 2011).

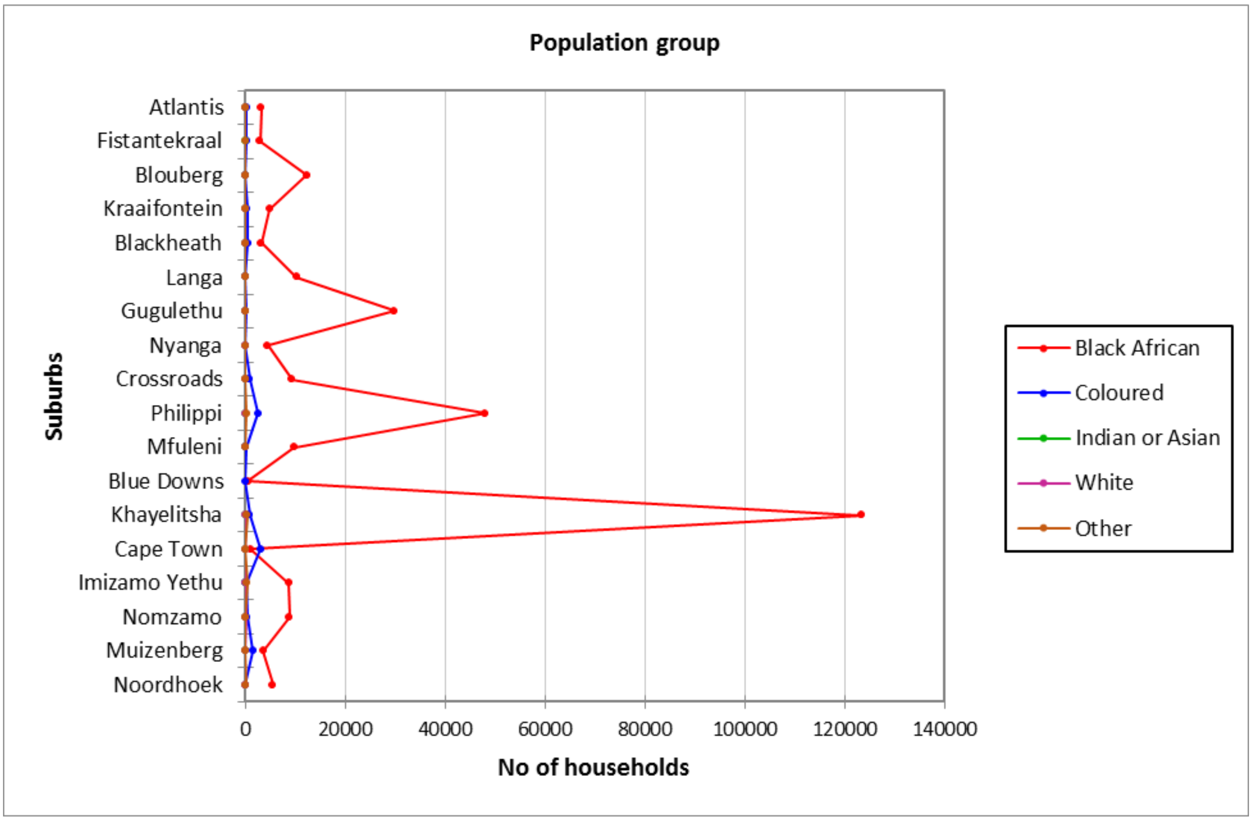


Figure 2.7 2011 Survey showing Population Distributions and Groups of Informal Households Across Some selected Suburbs in the City of Cape Town. (Source: StatsSA 2011).

Population group

Population group is used to describe the category of people or races characterizing informal households in a particular area. The common race, making up the majority of informal households in the City of Cape Town, are Black Africans (Figure 2.7). In Blackheath, households are mostly Black Africans [3 207 (n = 3 771)], and a small population of the coloured (mixed) race (517) (Figure 2.7). Smaller populations of Indians, Asians, White, and other groups also characterize informal households in most suburbs (Figure 2.7).

Household size

Household size is used to assess the size of households i.e. the number of people living in households in a particular area. In the City of Cape Town, household sizes range from a household size of one to a household size of ten (Figure 2.8). There have been population increases in the household size of one to that of five, having over a 50% increase in the household size of one, over time (Figure 2.8). Household sizes of six to ten increased and decreased, simultaneously, within the period (Figure 2.8). Among the household sizes, the population of the household size of one was higher in Blouberg (48%), Langa (42%), and Khayelitsha (35%) (Figure 2.9). Households of one (40%) were also highest in Gugulethu, followed by households of two (20%), and then, three (15%) (Figure 2.9). Household sizes (n = 1 661) of one (28%) and two (24%) account for the most parts in Blackheath.

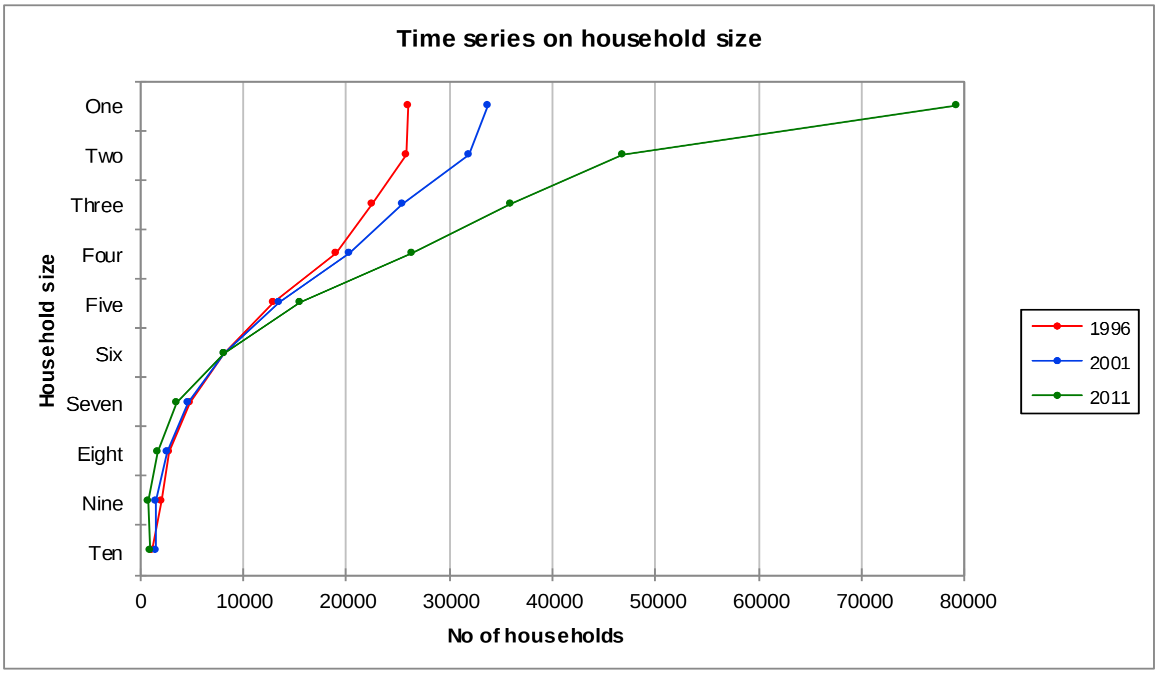


Figure 2.8 Distributions of Household Sizes At A Temporal Stretch In Informal Households (Grouped) By Census Years in the City of Cape Town. (Source: StatsSA 2011)

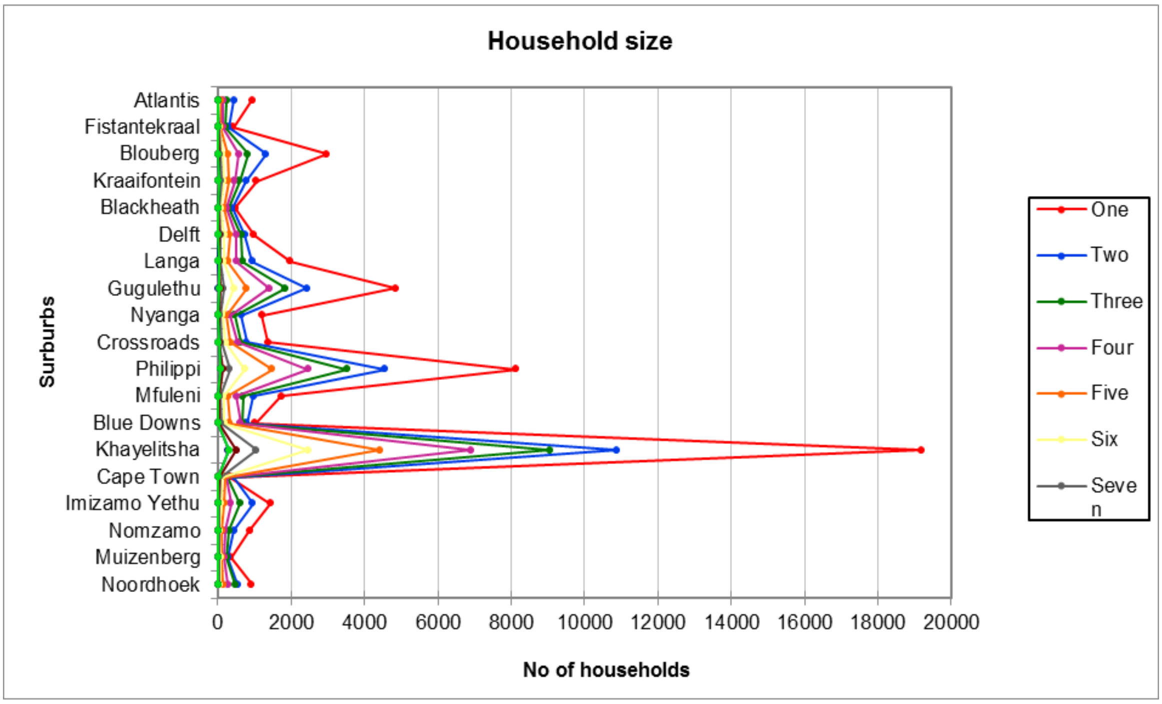


Figure 2.9 2011 Survey Showing Distributions of Household Sizes in some selected Suburbs in the City of Cape Town. (Source: StatsSA 2011)

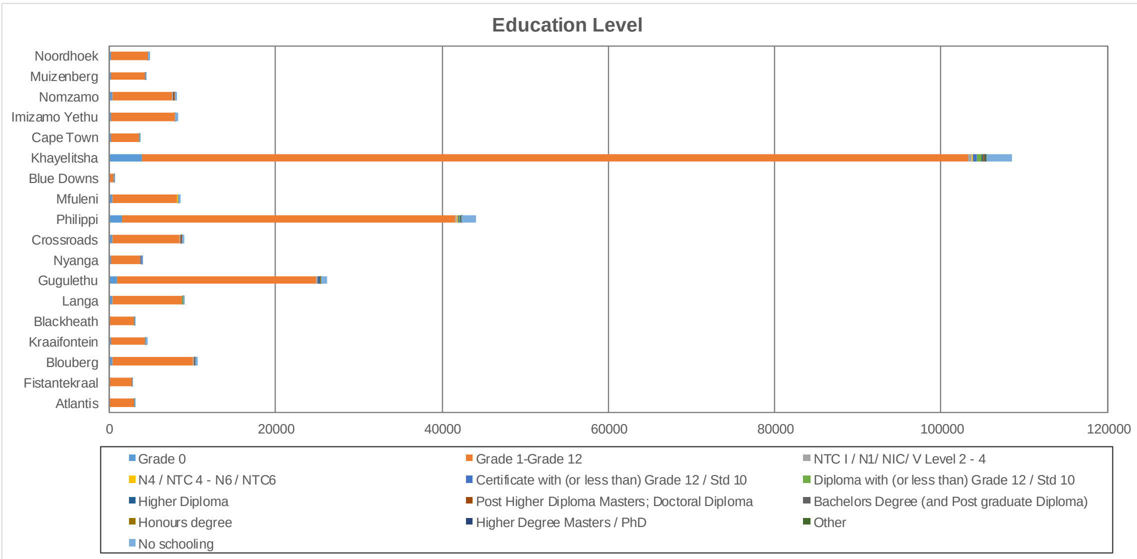


Figure 2.10 2011 Survey Showing Household Populations of Education Levels of in some selected Suburbs in the City of Cape Town. (Source: StatsSA 2011)

Education level

Education level is used to assess the level of educational degrees and certificates, informal households have acquired, over time. This parameter also assesses employable household members and expected awareness of poor energy-use practices, as well as cleaner energy-use benefits, in households. Education levels are mainly Grade 1 to 12 (95%) across the suburbs (Figure 2.10). In Blackheath, households mainly gained Grade 1 to 12 certifications (about 2

900, n = ~ 3000) and about seven percent of 'grade 0' and 'no schooling' categories (Figure 2.10). Higher educational levels were less than one percent in all suburbs, except 'Certificate with (or less than) Grade 12 / Std 10' and 'Higher Diploma' in Nyanga (2.20%), and Blue Downs (1.13%), correspondingly (Figure 2.10).

Figure 2.11 Temporal Stretch of Household Monthly Income in Informal Households (Grouped) by Census Years in the City Of Cape Town. (Source: StatsSA 2011).

<u>Household income</u>

Household income (monthly) assesses the level of household income per month. This is also used to determine the affordability level of energy products as well as the energy burden on household income. Most informal households earn between 'R1 601-R3 200' and 'no income source'. Others earn between 'R401-R800', 'R801-R1 600', and 'R3 201-R6 400' but income earners between 'R401-R800' declined, over time (Figure 2.11). There are more informal households with 'no income' (about 50%) across suburbs except in Gugulethu (44%), Khayelitsha (46%), and Hout Bay (43%) (Figure 2.12a). This category earns below \$1.90 per day, modelled as the base level poverty indicator in the global south (World Bank 2016). Informal households in this category are currently supported through government grants and poverty alleviation schemes in South Africa. In Blackheath, highest income earners are 'no income' (n = 1 390) and 'R1 601 - R3 200' (n = 469). Income earners of 'R1-R400' reside mostly in Blouberg, Matroosfontein, Gugulethu, and Khayelitsha. Households earning R3 201 and above decreased, over time across suburbs, except in Hout Bay.

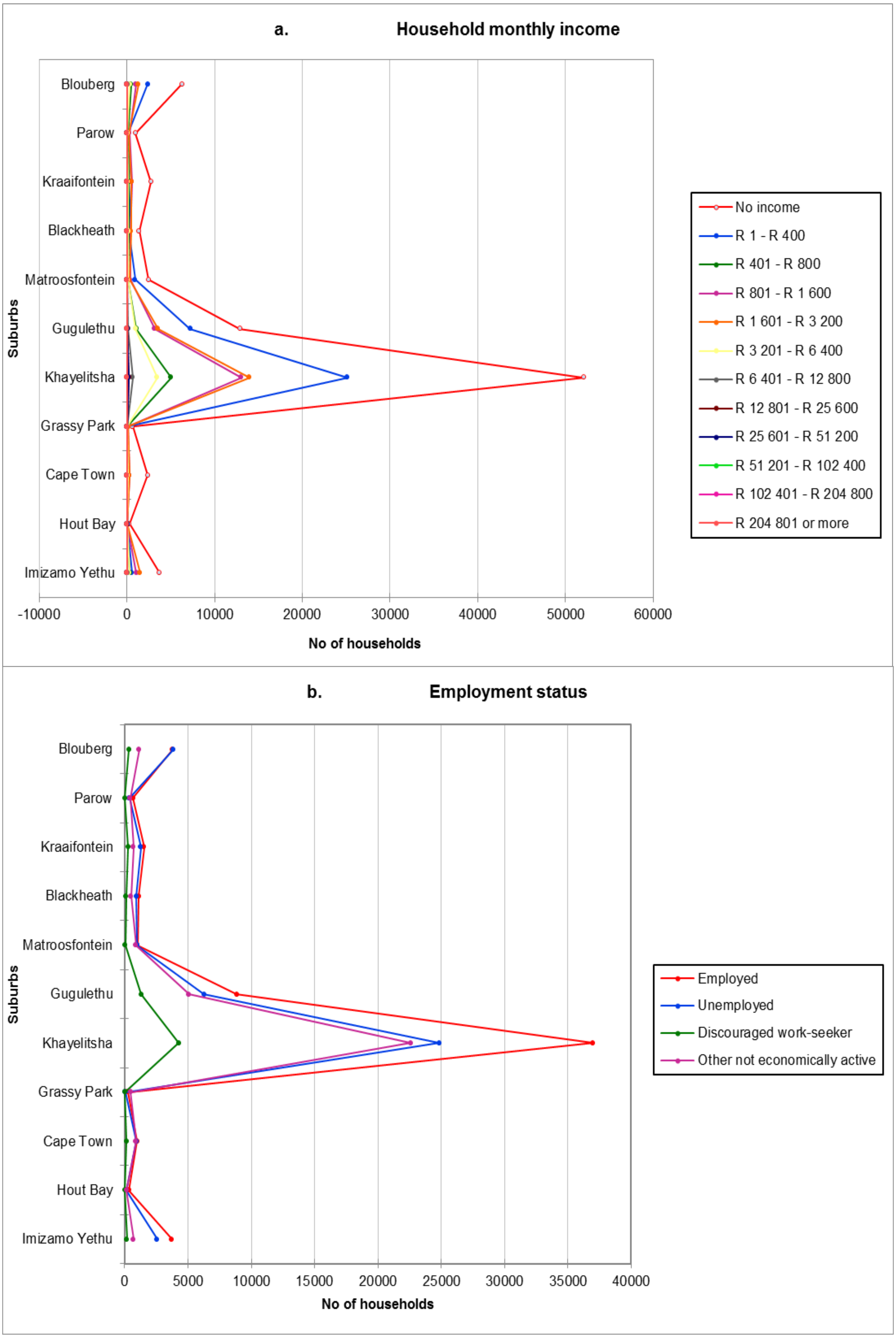


Figure 2.12 A 2011 Survey showing Distributions of Informal Households According to Household Monthly Income and Employment Status in Some Selected Suburbs in the City Of Cape Town. (Source: StatsSA 2011)

Employment status

Having employment contributes to household income. Majorities of informal households are gainfully employed, accounting for over 40% across suburbs, except in Grassy Park (32%), and Cape Town (33%) (Figure 2.12b). Employed informal households are mostly located in Khayelitsha and Gugulethu. Unemployed is about 30% in most suburbs, except in Grassy Park (five percent) and Hout Bay (18%) (Figure 2.12b). 'Not economically active' are higher than 'discouraged work-seekers' across suburbs but exceed employed households in Grassy Park (about 58% total) (Figure 2.12b). The total (over 55%) of 'unemployed', 'discouraged work-seekers', and 'not economically active' exceeds the number of employed households in each suburb except in Hout Bay and Imizamo Yethu (Figure 2.12b).

Table 2.5 Trends in Household Proportions (%) showing Available Energy Sources Used for Lighting, Cooking, and Heating in the City of Cape Town. (Source: StatsSA 2011)

Energy services	Lighting			Cooking			Heating		
Year	**1996**	**2001**	**2011**	**1996**	**2001**	**2011**	**1996**	**2001**	**2011**
Electricity	42.98	55.39	75.46	20.93	32.07	72.15	15.27	25.88	43.74
Gas	0.93	0.79	0.60	10.65	4.99	9.83	2.38	1.58	3.44
Paraffin	44.67	36.05	17.12	67.24	60.00	16.90	70.28	64.17	49.40
Candles	11.42	7.67	6.60	-	-	-	-	-	-
Wood	-	-	-	1.13	0.91	0.74	11.65	7.17	2.74
Coal	-	-	-	0.04	0.72	0.13	0.41	0.56	0.37
Animal dung	-	-	-	0.02	1.01	0.08	0.02	0.46	0.10
Solar	0.00	0.10	0.22	0.00	0.29	0.17	0.00	0.18	0.22

Energy-use patterns

Energy-use patterns are used to describe the energy poverty level and other factors influencing energy-use behaviour. Assessing energy-use patterns also identifies available energy-use sources, patterns, and appliances for household energy needs. Energy needs including lighting, cooking, and heating, have been accepted as the minimum basic energy needs (Practical Action 2010) for this research. Households using electricity for lighting (43%), cooking (21%), and heating (15%) were fairly small in 1996 but increased, over time (Table 2.5). Other energy sources, such as gas, paraffin, candles, wood, coal, animal dungs, and solar, decreased across periods for energy needs, except for gas and solar, which were mainly used for cooking and heating, and lighting and heating, respectively (Table 2.5).

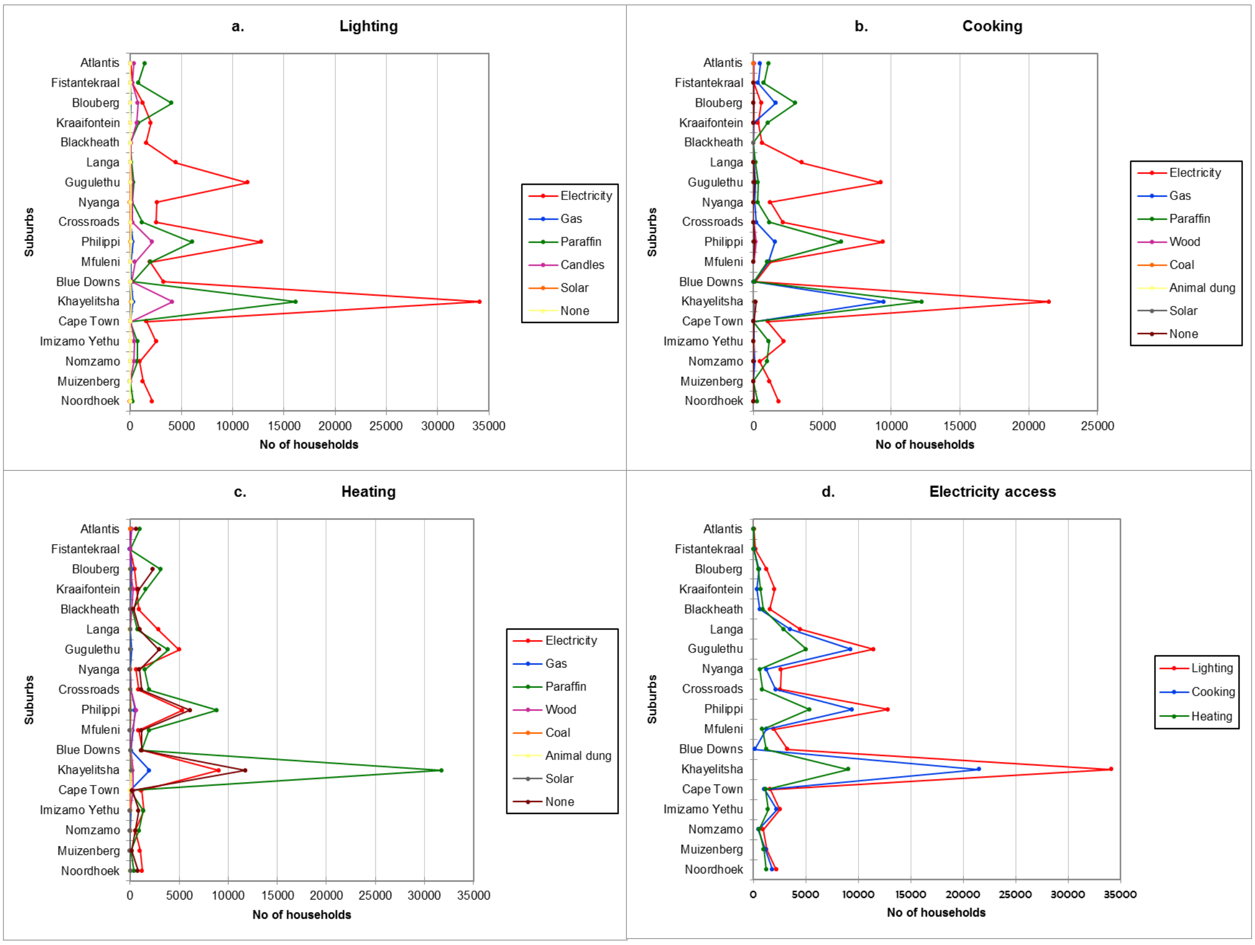


Figure 2.13 Distributions of Informal Households Showing Available Energy Resources Including Electricity Access for Lighting, Cooking, Heating in 2011. (Source: StatsSA (2011)).

In all the suburbs, the hierarchy is electricity, paraffin, and candle, except in Atlantis, Fistantekraal, and Blouberg, where paraffin is mainly adopted for lighting, followed by paraffin and gas for cooking (Figure 2.13a). In Blackheath, using electricity (about 94%) for lighting exceeds other energy sources, followed by candle use [circa 5% (n = 1 656)] (Figure 2.13a). Paraffin use for cooking is common in Kraaifontein and Nomzamo. Instead, Mfuleni shows multiple energy uses (n = 3 308) of electricity (37%), gas (32%), and paraffin (30%) for cooking (Figure 2.13b). For space heating, paraffin is mainly used in most suburbs, followed by electricity (Figure 2.13c). Gas, wood fuel, and solar are also used for space heating in households. In Atlantis, there is no electricity, as a result, paraffin is largely adopted to meet energy needs (Figure 2.13d).

According to the literature, energy-use patterns comprise mainly of poor energy sources and practices in informal households. The literature has also revealed the impact of using poor energy sources on health, and the environment (Aiken and Dubey 2017; Crandall *et al*. 2017; Li *et al*. 2017; Weldu *et al*. 2017). Energy production in the supply sector has been fraught with challenges, such as supply shortages and loading shedding, which also result in using poor energy sources in households.

The next section discusses the impact of energy poverty in both demand and energy supply sectors.

2.7 IMPACT OF ENERGY POVERTY

Between the 19th and 20th centuries, somatic energy schemes in energy production were replaced with exosomatic schemes through fossil fuel combustion, typically in developed countries (Rupf *et al.* 2017). These generated many opportunities for improved labour productivity, value-added goods, widened market networks, movements, global peace, and global distribution of wealth and power, but at a great expense. With increased fossil fuel combustion, came increased disputes and pollution that threatened energy security, people's health, and the environment (Baer and Singer 2016; Al-Maamary, Kazem and Chaichan 2017). GHG emissions e.g. carbon dioxide (CO_2), also increased, so did global earth temperatures, triggering climate change (Oliver-Smith 2012; Calvin *et al*. 2016). Annual CO_2 emissions increased by one-third from the emission level of 1990, contributing to over 30 billion metric tons worldwide, but declined (from 2008 to 2009) during the global economic recession (Oldfield 2011). The IEA expects a 65% increase in global GHG emissions by 2020 (Oldfield 2011). The recent COVID 19 (Corona Virus) pandemic halted most economic and industrial activities to allow such a percentage increase. The events of climate change are, otherwise, periodic and influence the global economy and the environment, both natural and built, through extreme weather events and conservative energy supply processes. In Canada, for example, a total cost of US$12 billion per annum is being accumulated from health issues, caused by air pollution (Oldfield 2011).

There are many alternatives in choosing energy technologies and restructuring strategies but recognizing associated impacts is important. Ecological footprints also come from coal combustion for energy production in South Africa (World Bank 2016). South Africa exports high-grade coal but burns low-quality coal grade containing 28% ash content (particulate matters) and other pollutants such as nitrogen dioxide and sulphur dioxide for electricity generation. These pollutants damage the environment and cause health problems such as respiratory illness, and early death. As it is, South African air quality is relatively poor (Vanhoren *et al*. 1993). But, Spalding-Fecher and Matibe (2003) recorded a 45% emission reduction in Particulate Matters (PM) by Eskom power stations in 1999. Instead, Sahu *et al*. (2018) reported PM exceedances to be significantly higher than the standard Atmospheric Emission License (AEL) limit values in many Eskom power stations in 2018. Another major ecological setback in the South Africa energy sector is large GHG emissions. As shown in Figure 2.14 and Figure 2.15, from the 1990 level, total GHG emissions increased by 44% in 2007, while relative GHG emissions increased by 1 178% in 2005. There was an upsurge of relative GHG emissions in 1998 (Figure 2.15) even with reductions in coal combustion from 1993 (96%) to 1998 (93%) (World Bank 2016). But again, Eskom has obtained over 50% reduction of relative GHG emissions by equipping new plants with bag filters, efficiency upgrading of existing electricity generation plants, and installing high smokestacks for wide dispersals of emissions.

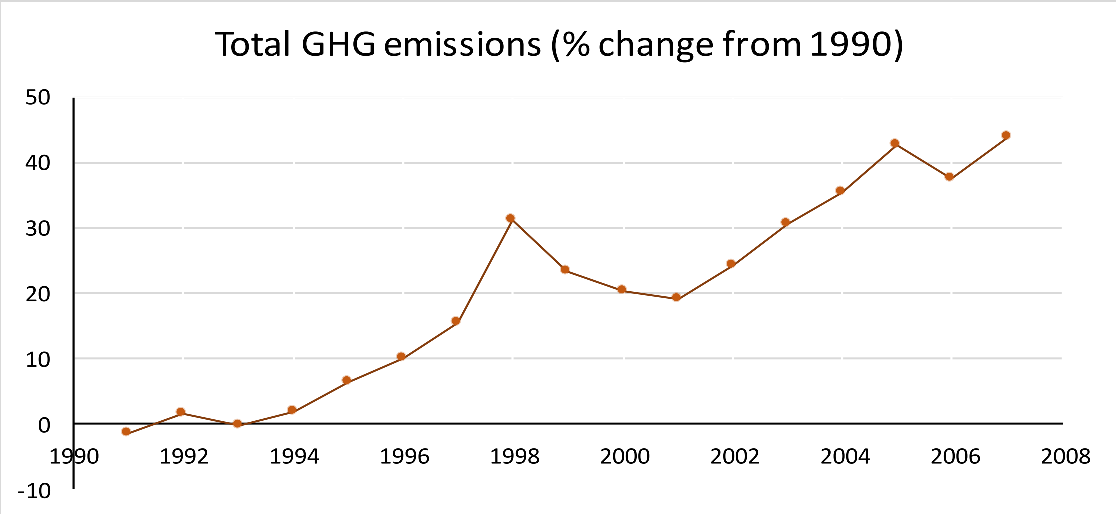


Figure 2.14 Percentage Increase in Total Greenhouse Gas Emissions since 1990 in South Africa. (Source: World Bank 2016).

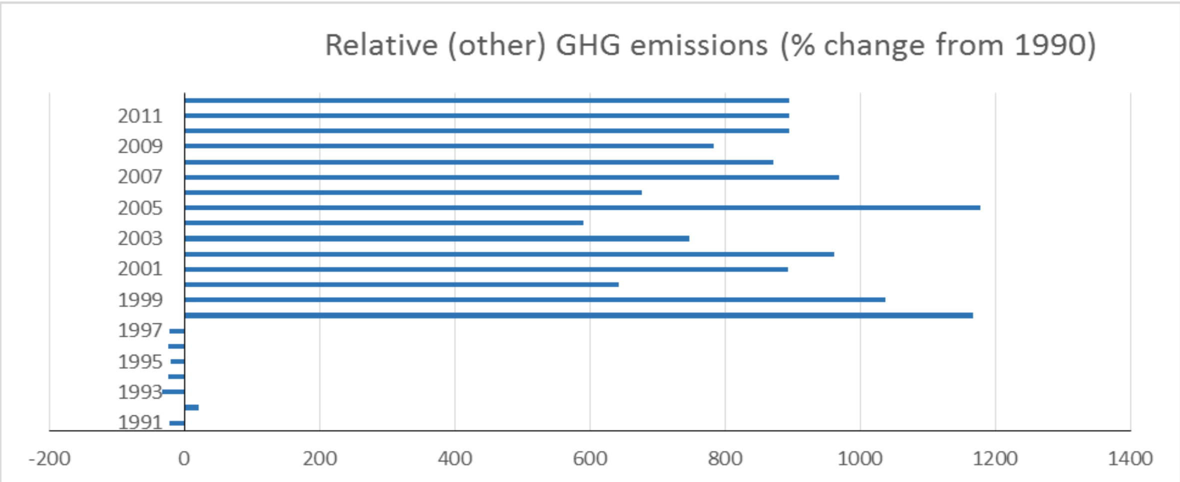


Figure 2.15 Percentage increase in relative (other) greenhouse gas emissions in South Africa since 1990. (Source: World Bank 2016)

Studies have established the impact of using less clean energy fuels or burning biomass in households (Shupler *et al.* 2018; Pillarisetti *et al.* 2019; Van Vliet *et al.* 2019). Recent studies reported respiratory symptoms, mostly in women relying solely on biomass for cooking, and heating (Shupler *et al.* 2018; Pillarisetti *et al.* 2019; Van Vliet *et al.* 2019). The United Nations (2014) reported many premature deaths in households caused by indoor air pollution from biomass burning in the global south. Up to this time, unvented biofuel stoves are used for cooking in many sub-Saharan African highlands. In South Africa, low-quality coal is mainly consumed for space heating, causing acute respiratory infections, particularly in households without chimneys or proper ventilation. The impact level, from burning low-quality coal containing impurities such as PM, on health, is contingent on the mode of dispersion, the duration of exposure, and the dose intake. Households largely depending on biomass have greater rates of exposure to these impurities (Vanhoren *et al*. 1993). According to the World Bank (2016), 99.71% of people were exposed to PM in 2010 and 99.87% in 2015 in South Africa. Energy poverty also breeds gender inequality, against women and female children carrying out most domestic duties, particularly in rural households. Deforestation is another impact of biomass burning, which results in woodland depletion, particularly in Kenya. Generally, impacts of biomass burning mainly include health maladies, consume time and energy spent in fetching firewood, deforestation, low energy productivity when carrying out domestic and economic activities, and gender inequality and a lack of education, especially against women and female children (Day, Walker and Simcock 2016).

Global GHG emissions are mainly generated by developed economies (Morales-Lage, Bengochea-Morancho and Martínez-Zarzoso 2016) while developing countries contributing the least fractions are impacted the most (Calvin *et al.* 2016). Thus far, the United Nations has directed efforts to reduce global emissions of GHG through global alleviation schemes (Ogujiuba and Jumare 2012). More so, global warming is sinkable when emissions from developed countries reduce by some fractions, below the emission level of 1990, by 2050 (Oldfield 2011). In the same way, a decline in global warming is within reach by reducing emissions through cleaner energy production, and distribution. Also, the IEA has been addressing global emissions through a range of policies, and functional strategies (IEA 2017). The IEA, later on, redirected its attention to key challenges in rapid-changing global energy markets and transformation to cleaner energy systems (IEA 2017). Similarly, South Africa concentrated efforts to improve energy production schemes and cleaner energy access in households (Tomaschek *et al.* 2012). Literature and public policies also advocated many strategies for controlling energy poverty rates in both energy supply and demand sectors (Ammer, 2017; Collier, 2017; Kılkış 2017), as discussed in the section below.

2.8 CONTROLLING ENERGY POVERTY AND IMPROVING ENERGY ACCESS

The key to controlling energy poverty is that of energy transformation to a smarter and more efficient energy-value chain (Ammer, 2017; Collier, 2017; Kılkış 2017). Smart energy technologies, from energy production, distribution to consumption, improve economic performance whilst concurrently reducing cost burdens of chronic respiratory illnesses and climate change events. Smart energy technologies by way of a smarter energy-value chain can meet global energy demands, which can be augmented through the use of geographic intelligence. Technically, most developing and underdeveloped countries have low national economies and lack national capacities to efficiently transform into smart production, distribution, and consumption chains. Since there is a global inequality in resources between countries, the government with advanced energy distribution systems needs to expand accessibility and affordability of energy technologies. Through global collaboration and industrialization, carbonization and energy poverty can be controlled within national borders. Industries and businesses can then run effectively, on less energy-intensive and in environmentally-friendly conditions. Plus, improved energy access can result in global GHG emission reduction, saves energy per cost, and sinks excessive investments in energy supply sectors.

As a way of improving energy access, the IEA has been empowering developing countries through initiatives and programmes. Some of these initiatives are geared toward facilitating sound energy policies in energy supply sectors (Energy Commission 2006). The IEA also emphasizes the importance of finding solutions to challenges, concerning energy security, through frequent engagement and dialogue. Most developing countries are signatories to international conventions as a means to develop their energy resource bases (Davidson *et al.* 2006). Countries are to adopt precautionary principles, mitigation, and adaptation measures according to their domestic dispositions (Cáceres 2017). With this in perspective, global emissions can be reduced within national boundaries and set objectives of some of the UN MDGs will be realized.

Moreover, renewable energy technologies are one of the many smart options for controlling energy poverty by creating cleaner energy use. Along with smart grid networks, diversified investments in energy renewables will support a sustainable environment and the creation of ‘green’ jobs (Zubi *et al.* 2019). Efforts are underway in developing renewable energy technologies and institutional capacities in energy distribution in developing countries (IEA 2009). Only 20% of the generating hydropower capacity has been exploited in sub-Saharan Africa, the lowest worldwide figure so far (World Bank 2016). Biomass is another energy renewable that up to now, has been harnessed to producing some kilowatts of electricity in Eastern, and Southern Africa (Deepchand 2001). Today, most agricultural practices use solar renewables through traditional methods in sub-Saharan Africa. The energy sector in Ghana, for example, adopts renewable energy technologies to diversify energy supply and sustain future energy security. In this case, the Ghana government projected a 10% expansion of installed generation capacity by 2020 and facilitated the Bui hydropower project in the country (Fritsch and Poudineh 2016)

Recently, a mandate was passed to increase energy renewables’ share due to ecological footprints from coal combustions in South Africa (Baruah and Enweremadu 2019). Biofuels from energy crops and solar energy renewables are increasingly exploited in South Africa (Tomaschek *et al.* 2012). Solar irradiation is well generated and distributed in South Africa (Figure 2.16), with two major solar-producing energy technologies adopted, including Concentrating Solar Power (CSP) and Solar Photovoltaic (PV) (Figure 2.17). While CSP uses a mirror effect in concentrating and transferring thermal energy, solar PV entrenches silicon in converting solar energy into electricity. Baruah and Enweremadu (2019) have shown that the decentralized generation of solar PV along with biogas can support electrical loads in non-electrified homes in South Africa. The Renewable Energy Independent Power Producers Procurement Programme (REI4P) promises to generate 17.8GW electricity capacity from renewables between 2012 and 2030 in South Africa (Walwyn and Brent 2015). Coupled with political, and development barriers (McEwan 2017), there are also obstacles in natural, social, and economic systems, limiting the integration of energy renewables in the energy sector in South African. Eskom does not have the necessary facilities to promote renewable energy technologies and, as a result, exclude the initiative from its strategies. For now, advancing renewable energy technologies depends on risks and market cost dynamics, technology advancement, reputational and legislation change, high costs of lending, and market capitalization in South Africa (Pegels 2010).

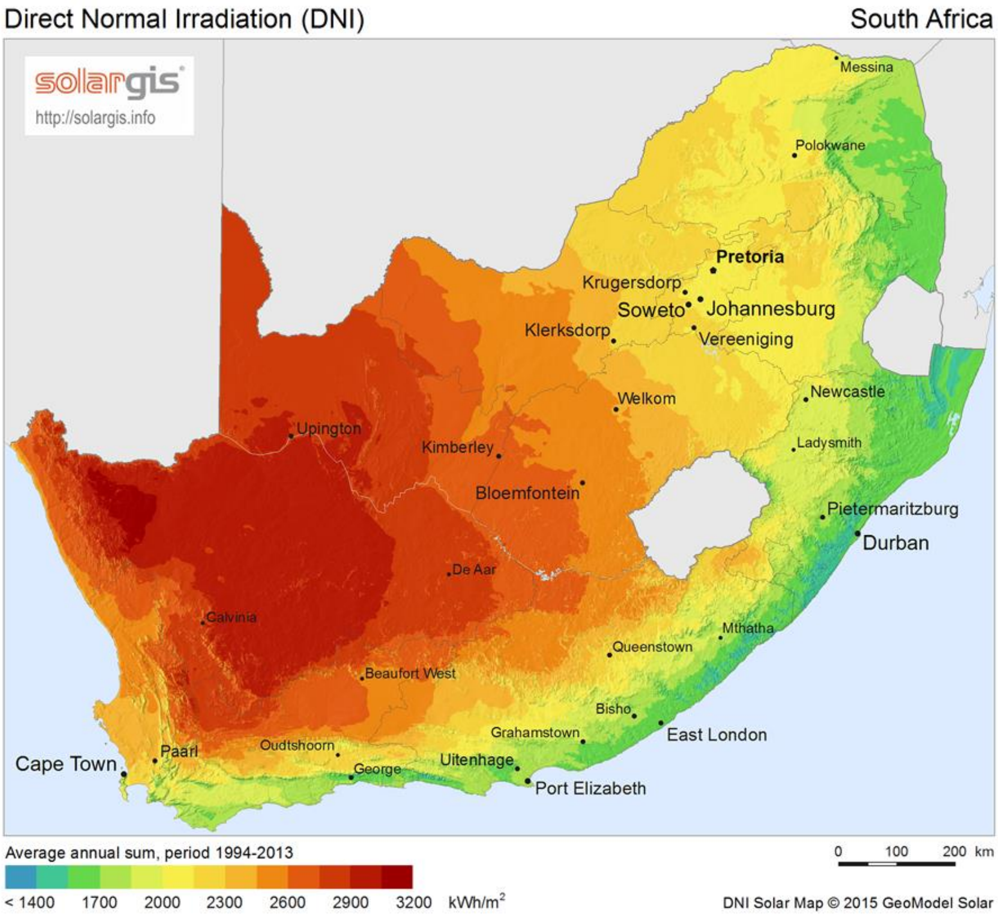
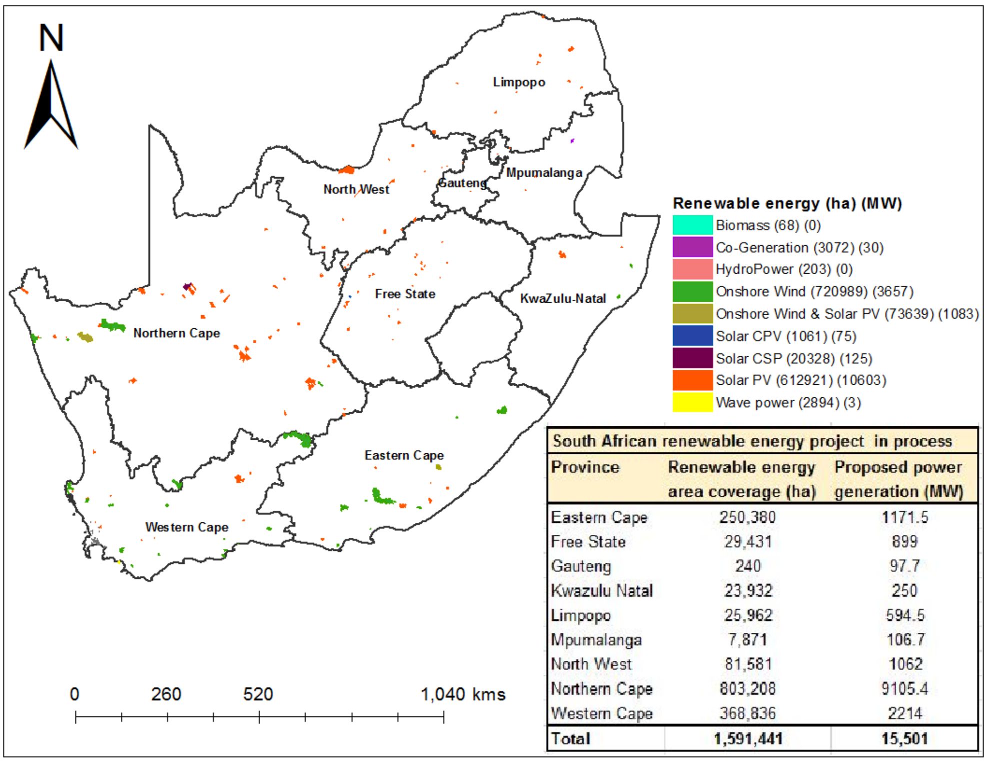


Figure 2.16 Distributions of Solar Radiation across Provinces in South Africa. (Source: DNI Solar Map © 2016 Solargis)



South African renewable energy project in process

Province	Renewable energy area coverage (ha)	Proposed power generation (MW)
Eastern Cape	250,380	1171.5
Free State	29,431	899
Gauteng	240	97.7
Kwazulu Natal	23,932	250
Limpopo	25,962	594.5
Mpumalanga	7,871	106.7
North West	81,581	1062
Northern Cape	803,208	9105.4
Western Cape	368,836	2214
Total	**1,591,441**	**15,501**

Figure 2.17 Map of South Africa showing Ongoing Renewable Energy Projects, Generation Capacity, and Area Coverage of Each Project Across Provinces. (Data Source: DEA 2017)

The IEA has placed emphasis on promoting sustainable energy policies, favouring economic growth, and environmental protection on a global scale. Applying timely strategies while recognizing trends in the energy-value chain promotes policies and legislation integral in organizational capacity building and high budgetary schemes. These timely strategies can develop energy policies that disprove energy imports and approve local economies by subscribing to community-adapted energy systems and smart grids. Since poor energy use in households is improved through sustainable energy policies in the supply sector, relevant policies are also required, addressing poor behaviour arising from the socio-cultural environment. Energy poverty mitigation has been a challenge, particularly in energy-poor households in South Africa, and may demand stakeholders' involvement in solving energy poverty issues. To date, energy policies have shown to improve energy access in these households, as well as increased energy efficiency, community sustainability, job creation, health, life, and air quality, and reduced ecological footprints in South Africa (DME 1998). As is, energy poverty mitigation strongly recommends access to modern, cleaner, and affordable modern energy services in these households, which is also critical to realizing the UN MDGs[13] (WHO 2010).

The literature has advocated energy policies promoting cleaner energy technologies and sustainable development in the supply sector (Davidson *et al.* 2006), and in both supply and demand sectors (Scharfetter and Van Dijk 2017; Winkler *et al*. 2017; Curnier, B; Lane, J; Wahnich, C; Walley, L; Szewczuk 2017; Adam 2010). The UN MDGs have also been recognized as a valuable reference to eradicating poverty and energy poverty in households (Waage *et al.* 2010). There are, consequentially, prevailing relationships between energy systems, energy services, socio-economic systems, and quality of life, that needs to be considered in mitigating energy poverty. Again, there are systems in energy access that are required to coalesce, favourably to promote EAS in a particular region.

The next section discusses these systems, capable of sustaining energy access within national boundaries.

[13] Table 2.1 Modern Energy Services Contributing to Achieving Millennium Development Goals (MDGs)

2.9 UNDERPINNING SUSTAINABLE ENERGY ACCESS

The literature has broadened the discourse on energy access, modern energy services, and benefits, over the past decades (Sokona, Mulugetta and Gujba 2012). Most public policies argued on energy access issues and most policy agendas debated on improving energy access using practical actions. Developing sustainable access to energy has been to restrict many challenges such as poverty and climate change. In the end, energy access has only been examined by its strong correlation with Gross Domestic Product (GDP), which sometimes, contravenes many quantitative definitions of energy access and related contents of energy poverty (Khennas 2012). Using the GDP as a benchmark in assessing energy access seems logical but it often ignores capital asset depreciation and compensation. South Africa, for example, has a higher GDP in terms of energy access but there is inequality in energy distribution between urban, urban poor, and rural areas. Energy access metrics should accordingly consider all possibilities - quantitative and qualitative, in determining a level of energy access at a given place and time.

Although there are no technical concerns of energy access, issues such as lack of good governance, competent parastatals, legal and regulatory structures, occasionally limit energy access in a nation. Systems operating in the energy access process can be conflicting in sustaining energy access. These systems include energy potentials (or prospect), energy planning, and political economy, which are expected to interact to promote EAS. Energy potentials are referred to as available natural wells or energy resources, which ensure energy security through its continuous yield and supply resilience (Okoye, Taylan and Baker, 2016). This operating system in the energy access process is only an asset within the scope of good governance that can lead to infrastructural developments and sustainable growth. With such developments, such as energy supply structures, comes improved access to social services, and most importantly, to modern energy services. If expanded to other economic sectors and not limited to energy sectors, infrastructural developments then become the pillar, sustaining the national economy. Energy potential only augments the energy access process but not, mandatorily the core driver of energy access. For instance, an oil-rich producing sub-Saharan African country, such as Nigeria, has the energy resource capacity to gain 100% electricity access but this is greatly compromised due to poor developments in supply structures and infrastructure, coupled with a lack of good governance (Khennas 2012). Contrary, North Africa achieved almost 100% of electricity access in their rural areas as a result of well-developed infrastructure and competent parastatals.

It can readily be deduced from the literature that energy planning needs to transcend national borders, especially for developing countries. With the energy planning system, factors acting within and against energy access are identified and addressed. On a national scale, developing energy access programmes results in designing energy planning schemes, operative at the domestic level. Hence, domestic energy planning is required to consider, extensively energy policies and investment decisions gratifying supply and demand-side options to sustainable development (Bazilian *et al.* 2012). Flawed energy planning, as a result of poor policies and decisions, can lead to a lack of energy access at different locations (Bazilian *et al.* 2012). Strategies and policies central to subsidy reformations and incorporated within the scope of energy planning can further advance the energy access process to reaching the UN MDGs (Rehman *et al.* 2012).

The political economy interprets the relationships between politics and economy and stresses the significance of historical developments, operational forces, and institutions in influencing economic outcomes (Vogt-Schilb and Hallegatte 2017). It is another operating system that determines the role of good governance towards infrastructural developments (Moe 2010). Within the context of energy access, the political economy establishes political roles in developing and widening energy access infrastructure (Moe 2010). The political economy of energy access is beyond just natural wells but also recognizes existing structures and development patterns. Major concerns of political economy on enabling energy access are integral to lack of grid networks, irregularity in electricity supply, political nepotism, and misdirected subsidizations. Energy access broadens when key drivers, highlighting areas of concern, are considered within the system of political economy (Rehman *et al.* 2012). This system thrives gallantly on infrastructural sustainability and energy supply services, when in conformity with social goals. With the operating system of the political economy, the energy access index presented in Table 2.6, can effectively determine energy access levels, and progress. The integration of these two concepts allows gainful insights and prospects for improving energy access, whilst considering acceptable energy consumption thresholds, particularly at the household level.

Table 2.6 Energy Access Index Measuring Quality And Level Of Capacity Output For Energy Sources. (Source: Practical Action 2010)

Energy supply	Quality level of supply (descending from high to low)
Household fuels	• Using a modern, clean-burning fuel and stove combination • Buying charcoal and using an improved stove • Buying wood and using an improved stove • Collecting wood and using an improved stove • Collecting wood or dung and using a three-stone fire
Electricity	• Reliable 240 V AC connection available for all uses • 240 V AC connection but poor quality and intermittent supply • Own low-voltage DC access for home applications • Access to third party battery charging only • No access to electricity at all
Mechanical power	• Mainly purchasing mechanically processed services. • Powered (renewable or fossil) mechanical devices available for most task • Powered (renewable or fossil) mechanical devices available for some tasks • Mechanical advantage devices available to magnify human/animal effort • No access to mechanical power. Hand power only with basic tools

The basis of sustainable development is pivotal in creating access to modern energy services. Actions to promote energy access sustainability are also regressing across time and scale. Barriers restricting wide energy access, governance, financing, planning, and human and organizational capacity are recognized, but difficult to address (Bazilian *et al.* 2012). New prospects may require a worldwide alliance of governance with fully-fledged actions and set targets beyond some political abstractions (UN AGECC 2010). On a national scale, energy potentials may seemingly promote energy access but demand the functionality of energy planning and political economy. At the household level, other systems also facilitate poor energy-use and behaviour.

As earlier discussed (in Section 1.1), two frameworks - Energy Cultures (EC) and Sustainable Energy Access (SEA) are considered in identifying systems and elements operating within energy poverty and access processes. These systems defining energy poverty levels are somehow, interlinked with energy access systems, such as political economy, among others, operating within national boundaries, to either improve or disapprove energy access in households. Unfavourable interactions between these complex systems can deepen energy poverty and limit energy access in households. Understanding complex systems in energy poverty and access processes requires a systems approach - Systems Engineering (SE) with Systems Thinking (SsT) - to establish relationships and achieve EAS.

The next section discusses the concept of a systems approach, such as SE and SsT, as useful tools, in providing solutions to energy poverty.

2.10 A SYSTEMS APPROACH – SYSTEMS ENGINEERING AND SYSTEMS THINKING

According to the International Council on Systems Engineering (INCOSE), SE is defined as pathways to developing effective systems by integrating system aspects into design syntheses through a validation process while viewing whole systems (INCOSE 2011). Systems can be unique in characteristics but the integration into a framework using the SE concept produces good results. SE considers the life cycle of each system development and throughout the operation of integrated systems to ensure interoperability, functionality, and accomplishment (Fumagalli 2012; Gadre, Esterman and Thorn 2017). The system life cycle reflects specific activities including, among others, the duration of a system, which depends on the nature, complexity, and function of whole systems. The life cycle begins with identifying a need in a system design, and then, employ operational use and maintenance until the system purpose is achieved, and eventually, at its end-of-life, retired, and disposed of, as shown in Figure 2.18. The system design allows changes at each operation node in response to greater outcomes of the whole system (Esa 2006).

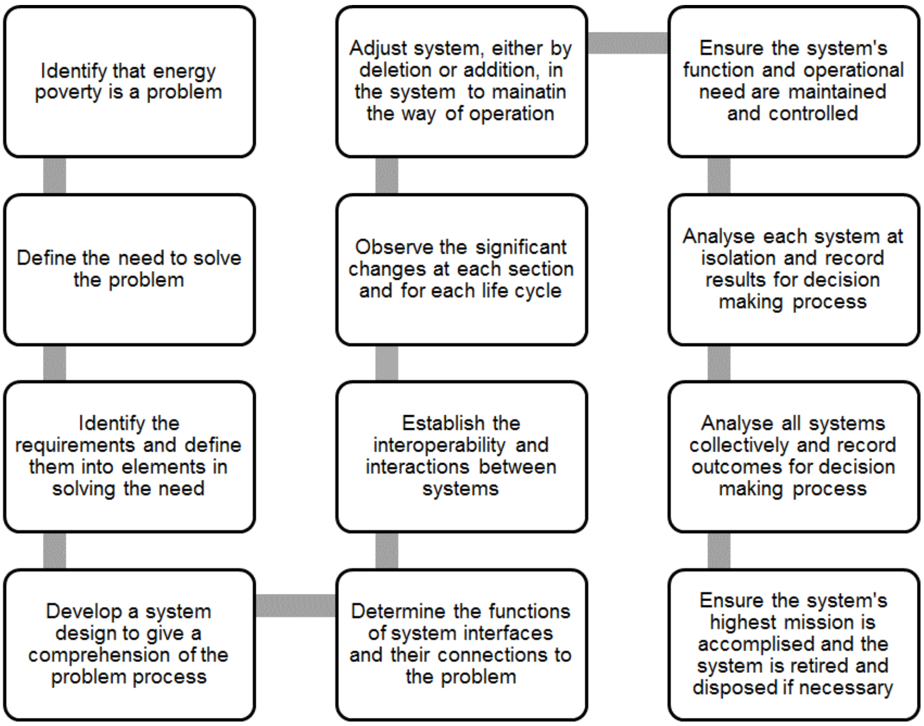


Figure 2.18 Chronological Steps in SE concepts, Designed for solving the Problem of Energy Poverty. (Adapted from: Esa, 2006)

As shown in Figure 2.18, there are sequential steps to be followed in isolating systems and establishing interactions in energy poverty and access processes. Before this, the effective application of SE requires a good understanding of the environment and challenges ahead (Fujimoto *et al.* 2017). One has to explore various approaches to system development and integrating diverse elements using the SE concept analysis (Vezzoli *et al.* 2017). The main objective of applying the SE concept in these processes is to develop a baseline solution (Sturdivant 2017) to energy poverty. The application of SE, primarily, advances through a process, starting from identifying a problem into defining a need and then, to achieving a particular function, not yet performed. One important step in SE is to identify the system interfaces in energy poverty and access processes, determine the functions, and establish the connections to a problem. With expected inclusions of new requirements (Bahill *et al.*, 2017; Dick, Hull and Jackson, 2017), sequential steps in SE, when followed logically, can provide a lasting solution to energy poverty.

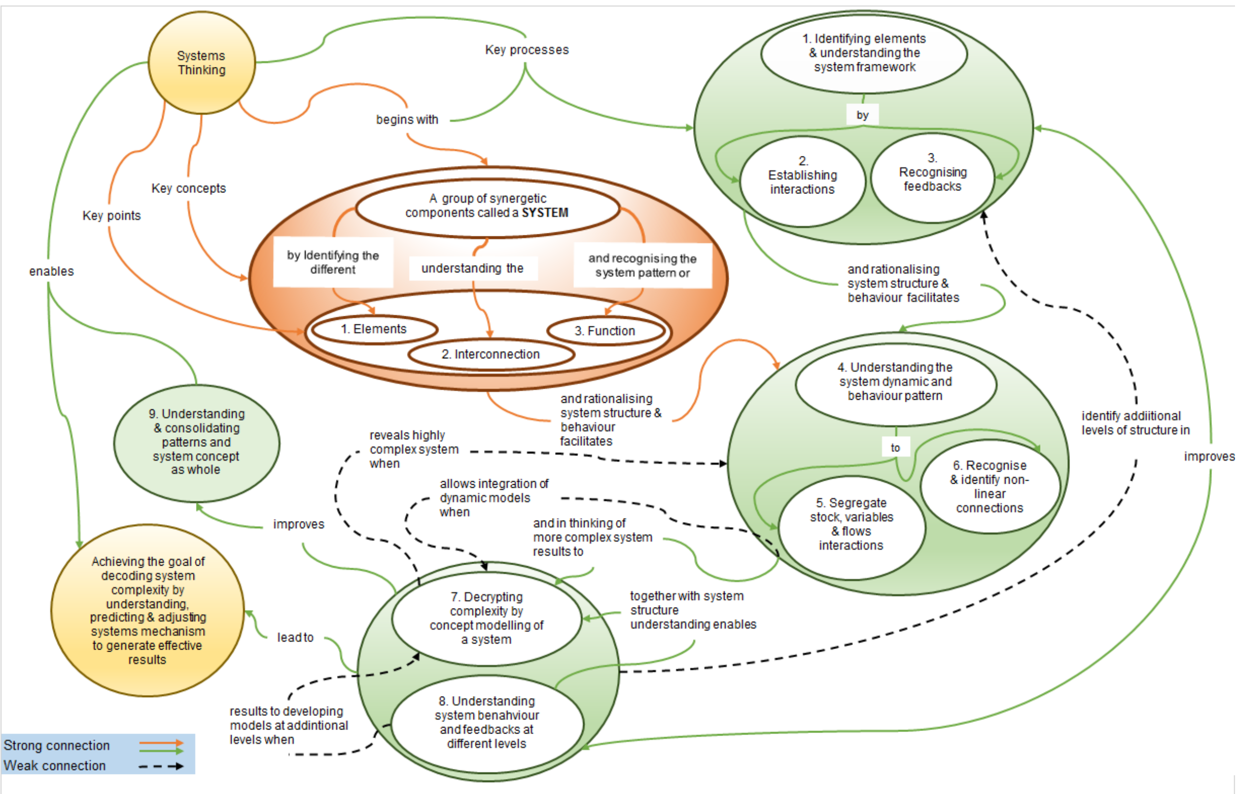


Figure 2.19 A Systemigram Defining the concept of Systems Thinking. (Adapted from: Arnold and Wade 2015; Meadows 2009).

Alternatively, Systems Thinking (SsT) accounts for activities not linked to the part of design syntheses in SE (Hoffenson and Söderberg 2015). Arnold and Wade (2015: 675) define SsT as "a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting behaviours, and devising modifications to them to produce desired effects [sic]". Richmond (1994), on the other hand, buttresses the "interdependency demand of an SsT approach". The common clause in several SsT definitions emphasizes thinking of a system as a whole entity, and not as individual parts, and in particular, to understand the interrelationships (Kalnins and Jarohnovich 2015; Behl and Ferreira 2014). The synoptic definition of SsT, describing the basic concepts and processes, is demonstrated in Figure 2.19.

As shown in Figure 2.19, systems can be entrenched within systems, resulting in the idea of a "system of systems". Among the key concepts of SsT - elements, function (purpose), and interconnection (synergy), elements show the least impact on a system unless entangled with purpose and interconnection. Elements are obvious parts of a system that make up the stocks. Stocks are the resource pool of a system, containing elements and underpinning the system framework but change, over time, through the action of flow. A system may only, or slowly, alter its state with a complete overhaul of elements, given that synergy and purpose remain unalterable. The least conspicuous part is the purpose but the most important concept that determines patterns of system behaviour. The purpose may become obsolete and levels of activities may differ or overlap. Well-coordinated purpose and sub-purposes are equally as important for effective system operation. If system purpose or interconnection is altered, a system may be distorted and become unrecognizable. The interconnections are critical as deviations in the relationships between, and within, systems may influence system behaviour. These three key points or concepts and their roles are equally important for the effective operation of a system (Behl and Ferreira 2014).

As shown in Figure 2.19, the key processes of the SsT approach, first, begin with identifying elements, recognizing the purpose, and understanding the interconnections (APPC 2014) of a group of synergistic components called a system. Understanding dynamics and behaviour patterns bring about segregating stocks, variables, and flows, and also recognizing non-linear connections, in a system. Then, decrypting the complexity by concept modelling promotes an understanding of reinforcing behaviours and feedback mechanisms, at various levels, in a system. This, in turn, improves understanding of a system and consolidation of concepts and patterns. The system goal is then achieved by decrypting complexity and understanding, predicting, and adjusting feedback mechanisms to generate effective results. Within key processes, there can be an addition or deletion of new processes for an improved understanding of system behaviour. These processes produce a pattern of behaviour in a system that can be either ‘reinforcing’, or ‘dynamic’ in nature.

System modelling using an SsT approach has proven useful in strategic planning, and management (Haines 2000), and public health (Homer and Hirsch 2006). As technological innovation grows, complex systems emerge with engrained interdependence with existing systems. While dynamic modelling explains the input-output relationships and changes over time, the system ‘reinforcing’ modelling emphasizes the weight of these relationships at a constant time. System modelling is represented in feedback loops to understand complex interactions in a multifaceted system (Kalnins and Jarohnovich 2015). Feedback loops and mechanisms produce multifaceted random effects but also elucidate the relationships, and promote understanding of multiple random effects. Strong and weak connections in feedback loops are equally as important in driving system behaviour. As illustrated in Figure 2.19, bold lines represent strong connections, whereas dotted lines represent weak connections. Since system relationships operate as an array of constant feedback loops, a system can always function beyond the final node of operation.

The IEA (2012) has identified the importance of SsT in exploring prospects of technology deployment in the energy sector (Shrubsole *et al.* 2018). Due to growing problems with new technologies, SsT can be employed to systemize linkages between the technology transfer process and its associated problems (Kalnins and Jarohnovich 2015). Systems thinking widens the knowledge of complex systems by decrypting factors affecting distinctive interactions in conforming to a mutualistic whole (Jackson 2006; Mulej 2007). It recognizes many facets of a system as single but different entities and bridges the synergy through an array of feedback loops. (Behl and Ferreira 2014). It analyzes each element in isolation but having synergetic relationships in producing a common goal from the overall system interactions. It builds on the idea that a system is greater than the sum of its parts, and should be studied, holistically (Behl and Ferreira 2014). With SsT principles, one understands the primary causes of complex dynamic behaviour to enable predictions of causes and adjustments of outcomes.

Largely, the impact of energy poverty strikes across spheres of socio-economic, ethics (Mehlwana 1997), and the environment (Gulati and Scholtz 2017). SsT with its usefulness in science (Rousseau 2018) and architecture (Meadows 2009), although integral in Information Technology (IT) and product design (Messenger and Ventre 2010), has been established to provide a platform for mitigating these impacts. Hence, applying SsT to energy poverty and access processes technically builds innovation in social and economic spheres. SsT is integral in SE, which enables human thinking in analyzing complex engineering designs (Bakshi and Fiksel 2003). Providing a solution to energy poverty using SE inherently summons SsT (Forlizzi, Sevaldson and Ryan, 2017).

Chapter 3 discusses the SE with SsT concept application into developing a new System Reinforcing Model (SRM) that can improve energy poverty and access processes.

2.11 CONCLUDING REMARKS

Presently, large populations of poor households lack access to electricity and modern energy services in the global south (Sokona, Mulugetta and Gujba 2012; Bohlmann and Inglesi-Lotz 2018; Thomson *et al*. 2018). This literature review outlined indicators and energy thresholds assessing energy poverty and energy access in these households (Ntaintasis, Mirasgedis and Tourkolias 2019; Okushima, 2019; Papada and Kaliampakos 2019). On the whole, energy poverty includes issues of poor energy consumption, resource depletion, and inequality in resource allocation (NPC (SEA) 2014). The literature advocates the impacts of poor energy production and consumption, as well as the key strategies to mitigating energy poverty (World Bank 2016). While energy poverty exacerbates in the global south, standard energy access requires that the minimum acceptable energy needs are constantly met in households.

The literature further identifies the important relationships between energy access and socio-economic development. From the literature, rural and urban poor households have also been shown to use less clean energy sources to meet their energy needs. The urban poor expends about one-third of household income on energy but high-income earners spend barely 6% of their household income (Adam 2010). Inequality in energy distribution also aggravates the intensity of energy poverty among the urban poor, revealed to be mostly concentrated in informal settlements in South Africa and also in similar communities in sub-Saharan Africa. Many factors, mainly centred on institutional constraints, have been established to oppose the grid-connection of informal settlements. Although many of them are grid-connected, informal households continue to use traditional energy sources, thus practicing multiple energy uses, particularly for space heating in winter.

Currently, the South African formal energy sector is struggling with electricity generation capacity and supply quality and quantity, hardly addressing energy poverty impacts. The unequal energy distribution is further worsened by a lack of well-defined energy planning schemes. The typical energy system in sub-Saharan Africa, and in particular, in South Africa, focuses on energy supply and security with no evidence of a clear agenda for sustainability schemes. The major challenge in energy poverty mitigation is to ensure sustainable energy access planning schemes that promote egalitarianism and reduce ecological footprints. Presently, the South African government has directed actions in place to manage supply shortages through energy demand-side management schemes as well as policies. Additionally, energy renewables are explored as a solution to reducing GHG emissions and improving cleaner energy use (Tomaschek *et al.* 2012). This literature overview has shown the importance of developing management schemes, addressing poor energy use, particularly at the household level. This scheme can take up a participatory approach to identify factors influencing poor energy-use practices. A systems approach, on the other hand, has been suggested as a useful tool to effectively integrate such factors into a model design that can promote energy access.

The next chapter provides a discourse on the concept application of a systems approach into energy poverty and access processes.

CHAPTER 3: APPLYING A SYSTEMS APPROACH TO MITIGATING ENERGY POVERTY

This chapter focuses on energy poverty and access processes, complex systems and elements operating within, and the application of a system approach - Systems Engineering (SE) and Systems Thinking (SsT) into these processes. The main interest in this chapter is the development of a proposed new System Reinforcing Model (SRM) that can improve energy access in an energy-poor community.

The chapter demonstrates the logical application of a systems approach into the new model development, discussed under subdivisions below:

- Energy Poverty and Access as Systems and Subsystems
- Developing New SRM Model
- Indexing the New SRM
- Concluding Remarks

3.1 ENERGY POVERTY AND ENERGY ACCESS AS SYSTEM OF SYSTEMS

As formerly mentioned[14], Energy Cultures (EC)[15] (Stephenson *et al.* 2010) and Sustainable Energy Access (SEA)[16] frameworks (Shrestha and Acharya 2015) are garnered toward developing a new SRM. Various systems and subsystems define processes within these frameworks. In EC, the framework has multiple systems and elements influencing energy poverty persistence in poor households. The SEA framework likewise has multiple systems within the process that improves energy access. These multiple systems and subsystems in energy poverty and access processes are very distinctive but expected to produce a common goal. The system interactions between, and within, can be synergistic in themselves. With an alteration in one system, an alteration can occur in another system, or subsystem (Jamshidi 2008). Effective consolidation of these multiple systems and subsystems generates a configuration of a System of Systems (SoS) that can either be infinite or definite in operation (Varga *et al*. 2017; Wright 2002).

[14] Section 1.1: DEFINING ENERGY CONSUMPTION BEHAVIOUR AND SUSTAINABILITY PATTERNS
[15] Figure 1.1 Energy Cultures Framework Comprising of Energy Poverty Systems Defining Energy-Use Patterns and Behaviour. (Source: Stephenson et al. 2010)
[16] Figure 1.2 Sustainable Energy Access Framework Comprising of Systems of Energy Poverty and Energy Access. (Source: Shrestha and Acharya 2015)

The operational cycle of each element in the SoS structure may slightly vary and there is a constant change of elements as long as the system goal as a whole is not yet attained. The structure recognizes entrenched behaviour, particularly where system patterns are self-reinforcing. Evolving technologies and social problems show to have a characteristic of multiplying complexity within systems (Zhu and Mostafavi 2017). Our socio-economic environment is also constantly reproducing new issues, demanding new requirements for emerging systems (Yang *et al.* 2010; Morandini *et al.* 2017). Additionally, it is challenging to identify actual requirements for new emerging systems (Bahill *et al.*, 2017; Dick, Hull and Jackson, 2017) due to the numerous vague definitions of most social problems. As new developments occur, the deletion and addition of elements occur to complement the system's new way of operation (Yang *et al.* 2010). Moreover, the relationships within the SoS configuration reveal the nature of operating systems that suggest specific actions to improve behavioural patterns.

Energy poverty is facilitated by multiple and complex systems that seem to be acting against energy access for quite some time now. The common emphasis in defining a 'system' in engineering considers a system as a set of things interconnected in such ways to generate a pattern of behaviour, over time. As earlier mentioned, a system can be defined by three key concepts - elements, interactions, and purpose, in defining behaviour and patterns (Behl and Ferreira 2014). A system can also be buffeted, constricted, or triggered by external forces but a system reaction to these forces is characteristic in itself (Meadows 2009). These systems, along with their subsystems, are operating in energy poverty and access processes, revealing their interoperability (Varga *et al.* 2017) in producing the desired results than that of an individual system. Each of these systems can be operational in its own right, even at the subsystem level.

The ability to categorize multiple systems and subsystems helps to provide clarity on the complexity of energy poverty and access processes. In decrypting complexity, there are some degrees of system flexibility in adjusting structures and applying changes that have minor impacts on the overall system configuration. Within the higher SoS configuration level, the interconnections between, and within systems may lead to more complexities. The SoS configuration can invoke SE techniques to isolate and connect systems and subsystems while invoking SsT approaches to elucidate the understanding of system interconnections.

The next section discusses the application of SE with SsT concepts into energy poverty and access processes to developing a proposed new SRM model design.

3.2 A NEW SYSTEM REINFORCING MODEL

There are four main system interfaces recognized in energy poverty and access processes, modified from the EC (Stephenson *et al.* 2010), and SEA frameworks (Shrestha and Acharya 2015). As presented in Figure 3.1, the first system interface (first row) contains systems of energy poverty, including *material cultures*, *cognitive norms*, and *energy practices*. These systems are also referred to as 'design decisions' because they assess the energy poverty level and help to shape energy-use behaviour in households. The second system interface (second row) comprises systems that enable energy access that are dependent on 'design decisions' systems for their assessments. The third row (the third system interface) encloses systems assessing the probable gains of available access options. The fourth row (the fourth system interface) contains systems that aim to promote EAS when all system interfaces coalesce, favorably. These latter systems are referred to as 'system designs' because design decisions consider them amply sufficient to promote energy access in a particular region (Gupta *et al.* 2018; van Gevelt *et al.* 2018). Each system can be addressed in isolation but within the wide-ranged system configuration in Figure 3.1. The open-end looping allows the addition of new systems and may produce complexity in system interactions.

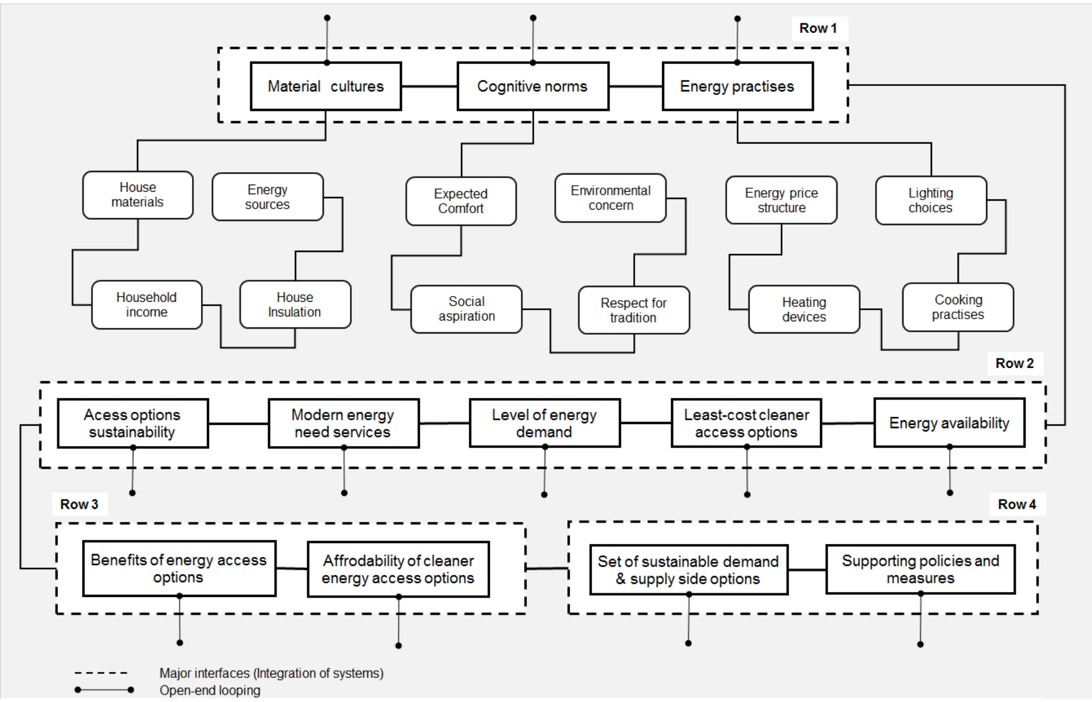


Figure 3.1, Four Main System Interfaces in Energy Poverty and Access Processes Showing its Systems and Subsystems.

These identified system interfaces are critical and interactive in defining a system function, directing a system purpose, and realizing a system goal. The desired interrelationships between the system interfaces aim to achieve a system goal, which is mitigating energy poverty and improving energy access. In the process of ensuring interoperability, design decisions and system designs must reproduce system elements to include all factors of social, cultural, economic, environment, institution, technology, people, and data (Esa 2006). Engineering systems using SE methods require that relevant system elements connect in operation and common purpose. With system interfaces held together using SE concept analyses, their synergistic relationships would be appropriately interpreted by employing SsT principles.

The system modelling of system interfaces and interconnections, represented in arrays of feedback loops using SE with SsT analyses and developed into a proposed new SRM, is presented in Figure 3.2. The proposed new SRM integrates various influences, including exogenous elements influencing patterns and behaviour of the model, which in turn, are influenced by them. The proposed new SRM consists of interrelated elements that feed into future energy access and management schemes. We recall that four main system interfaces operate within energy poverty and access processes. As shown in Figure 3.2, the top row contains design decisions (in grey circles), determining energy poverty level and quality outcomes on energy-use behaviour. The five system designs (in green circles and second row) assess the performance of design decisions. The two system designs (in orange) assess the performance, and also socio-economic strengths and energy benefits, respectively, in a target area. The other two in yellow and blue circles are system designs that either encourage or relegate EAS These last two system interfaces represented in rows 3 and 4 in Figure 3.1 are grouped and represented in row 4 in Figure 3.2. This is to effectively illustrate system interconnections in multiple arrays of feedback loops.

Like the other design decisions, *material cultures* comprise subsystems and elements that determine the system performance, as shown in Figure 3.2. *Cognitive norms* determine the preferences of an individual's energy technologies and energy use. *Cognitive norms* and subsystems help to understand socio-cultural inclinations and people's behaviour to energy choices. *Energy practices* comprise of four subsystems affecting the system operation in describing people's energy practices and appliances (Pelenur 2018; Cipriano *et al*. 2017). The subsystem, *energy price structure,* plays a fundamental role in the adoption of cleaner energy sources for satisfying energy needs.

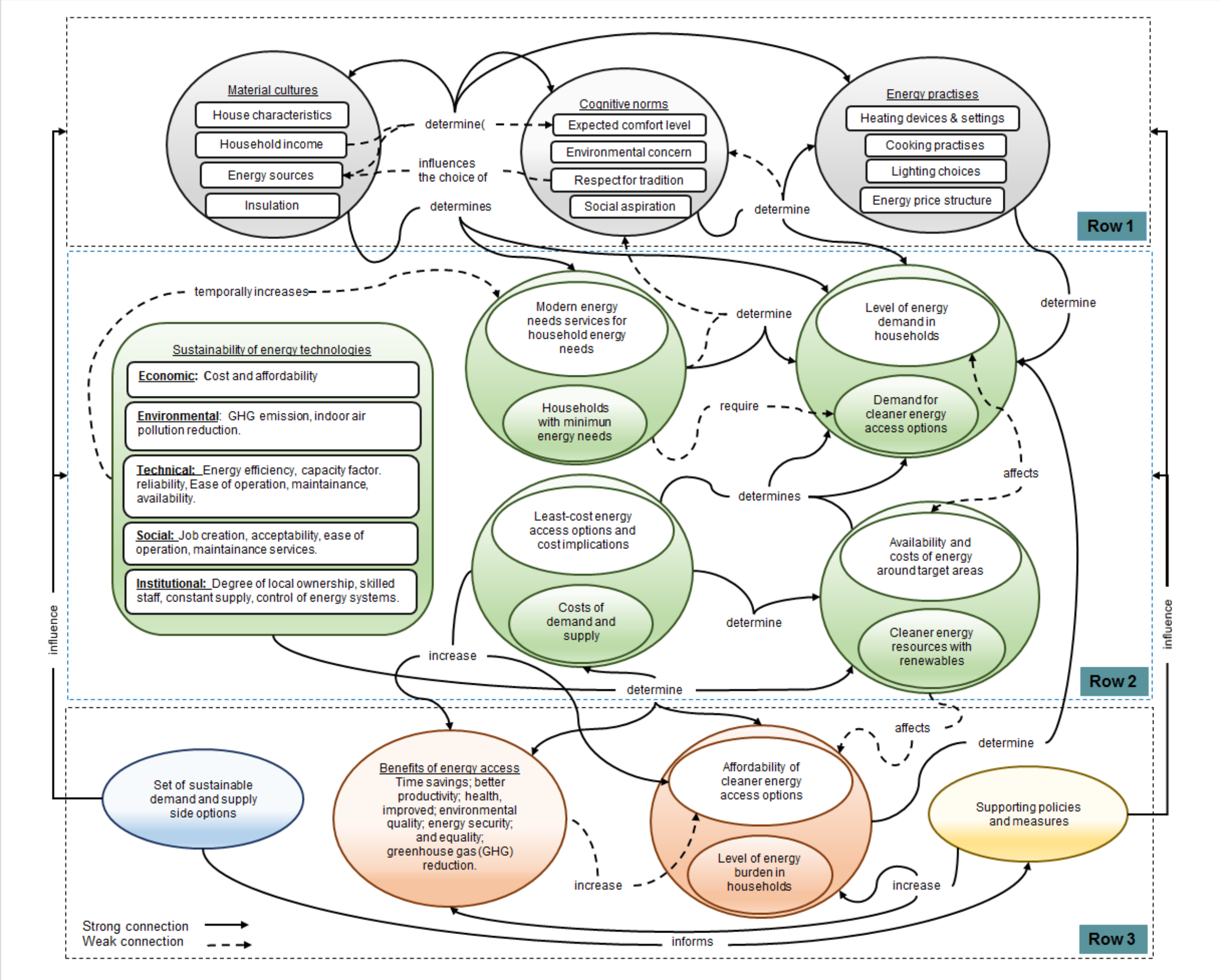


Figure 3.2 Proposed New System Reinforcing Model (SRM) for Energy Access Sustainability (EAS), Implementable at the Sub-Regional Level.

Among the system designs, *modern energy services* are used to determine the *minimum basic energy needs* in a target group (Figure 3.2). The *level of energy demand by poor households* estimates energy demands for consumption and production purposes in households. The assessment of *energy demand level* evaluates the present and future energy demands to meet energy needs, particularly the *minimum basic energy needs*, in households. This assessment identifies energy-poor households when rates of energy demand are below the acceptable standards while recognizing energy access quality. Drivers of *energy demand level* include household income, electricity access, household size, and growth, among many. The *energy demand level*, in turn, evaluates energy resources to determine their availability, affordability, and acceptability and to sustain the present and future energy demands (Narula, Sudhakara Reddy and Pachauri, 2017).

Availability and cost of energy types in target areas consider available energy access technologies, including renewables and non-renewables, as shown in Figure 3.2. These also inform the costs of available access options, as well as distribution and availability patterns (Shrestha and Acharya 2015). *Least-cost energy access options and cost implications* assess available and cheaper access options and cost implications, in terms of *costs of demand and supply*. The cost review of cleaner access options evaluates the total investments to develop affordable energy access programs (Narula, Sudhakara Reddy and Pachauri, 2017). This informs per unit cost and the total costs of cleaner access options in a target area. This customarily increases *affordability*. Investments, and operation and maintenance costs of generation, transmission, and distribution, can be evaluated for a local electricity supply system.

The *sustainability of energy technologies* screens energy technologies and available energy resources in determining option sustainability, as shown in Figure 3.2. The proposed new SRM lists five dimensions in evaluating option sustainability. The *technical* dimension analyzes energy service maintenance during the economic life of energy access options, in terms of reliability, availability, quality of supply, ease of operation and maintenance, and ability to respond to change in energy demand (Shrestha and Acharya 2015). The *economic* dimension focuses on the cost implications in terms of cost-recovery potential, cost reduction, and affordability. The *social* dimension assesses impacts on social security, such as social acceptability, job opportunity, and reduction in human drudgery, particularly in women and children. The *institutional* dimension defines the organizational capacity in sustaining energy access by degrees of local ownership and expertise, among others. Lastly, *environmental sustainability* evaluates the impact of energy access technologies on consumers, and the environment.

The *affordability of cleaner energy access options* determines if available access options are affordable in a target group. This acts as a progress indicator in any designed energy access program (Practical Action 2010) and informs the *energy burden* of an access option on household income. A large share of household income on energy use indicate a high *energy burden*, mainly influenced by household size, low device efficiency, and high per unit energy price. E*nergy access benefits* analyze both the present and future benefits of energy access options. For improved *energy access benefits*, *supporting policies and measures* must be considered. S*upporting policies and measures*, along with *a set of sustainable demand and supply-side options*, reduce energy poverty situations, and increase energy access in a target group.

As shown in Figure 3.2, the arrays of feedback loops reveal the relationships between, and within systems and subsystems across system interfaces. Strong connections are equally as important as weak connections, representing high- and low-level system dependency, respectively. As illustrated, *material cultures* e.g. *household income*, strongly determine *cognitive norms* and *energy practices,* which, in turn, are influenced by *material cultures. Cognitive norms* strongly determine *energy practices,* whereas *energy practices* are weak determinants of *cognitive norms*. *Material cultures* determine *modern energy services* and *energy demand levels by poor households*. There is a weak connection between the *cognitive norms* and *modern energy needs*, implying low-level dependency on each other for their operations. *Cognitive norms* strongly connect to the *level of energy demand* as any of the subsystems can trigger a particular access option and demand quantity. *Energy practices* determine the *energy demand level* and inform *supporting laws and policies* in influencing energy-use efficiency. By *supporting laws and policies*, *energy practices* can be altered and market *energy prices,* restructured. *Modern energy services* instigate the *energy demand level*, made possible by *least-cost energy access options*, and, in turn, promote *availability* and *affordability* in gaining *benefits of energy access*. *Affordability* also determines the *energy demand level,* particularly for cleaner access options. Otherwise, the *sustainability of energy technologies* promotes *least-cost energy access options*, *availability*, *affordability,* and *energy access benefits*, while increasing *modern energy services*, over time. *Social*, *economic*, *environmental*, *institutional*, and *technical* pillars of energy technologies, are required to be sustainable, in the least. Moreover, *energy access benefits* encourage *affordability* if one appreciates value over income. *Availability* weakly connects to *affordability* since *availability* does not equal *affordability*. *Affordability* and *benefits of energy access* strongly trigger *supporting laws and policies*, which, in turn, promote *sustainability of energy technologies* and *set of sustainable demand and supply-side options* such as investment potentials, capacity developments, policy amendment, etc.

Certain trade-offs may occur due to the nature of system interactions that require specific assessments based on a case-to-case scenario. For instance, the *availability* of an access option can guarantee *affordability* regardless of the *costs of energy demand* or having fewer *energy access benefits*. In such a scenario, a component assessment is required, which may slow the model interoperability but cannot impede on model purpose. In recap, the model development began with designing design decisions assessing patterns of energy use and behaviour. Thereafter, the inclusion of system designs assessing the design decisions' performance and enabling energy access. These system designs, already mapped to design decisions, then come around to including system designs, such as *supporting policies and measures* and a *set of sustainable options,* that either promote or slow EAS.

3.3 INDEXING THE NEW SYSTEM REINFORCING MODEL

The proposed new SRM has conceptual flexibility to embrace different methodologies in determining specific outcomes. These methodologies have to be integrative in modelling the outcomes of each system and the whole model. The basic methodology primarily includes primary data surveys - physical observations, householder questionnaires, and interviews (Stephenson *et al.* 2010). This methodology considers a participatory approach and specific primary data collection in addressing specific systems. It also provides custom-built solutions that produce definite outcomes to energy poverty mitigation in a target group. This survey is applicable in addressing all system aspects in the proposed new SRM but pertinent for addressing the design decisions *-material cultures*, *cognitive norms*, and *energy practices* (Stephenson *et al.* 2010). Secondary data can be employed for inferential and analytical purposes.

Various indicators and indexes have been used in estimating *modern energy services* and *minimum basic energy needs* in households (UN AGECC 2010; Nussbaumer *et al*. 2012). Nussbaumer *et al*. (2012) developed a Multidimensional Energy Poverty Index (MEPI) to measure energy access using an energy pool of five parameters in assessing *modern energy services* (Alkire and Santos 2014; Sher 2014; Nussbaumer *et al*. 2013; Alkire *et al*. 2012; Sadath and Acharya 2017; Pachauri 2011). Composite indices, such as Energy Indicators For Sustainable Development (EISD) (Streimikiene, Ciegis and Grundey 2007; Vera and Langlois 2007) and Energy Development Index (EDI) (Iddrisu and Bhattacharyya 2015) show relevance in quantifying energy deprivation metrics. Most of these tools have shown redundancy and ambiguity in quantifying and evaluating performance, and informing policy, over time (McGillivray 1991; Ravallion 2010). Other studies have analyzed energy access levels and thresholds of *modern energy services* (Day, Walker and Simcock 2016). An empirical estimate has used average energy consumptions in households, living below the income poverty line based on acquired data (Barnes, Khandker and Samad 2010). Importantly, Practical Action (2010) suggested that the *minimum basic energy needs* should include lighting, cooking, and heating. *Modern energy services* and the minimum acceptable thresholds, adaptable in this research study, are presented in Figure 3.3.

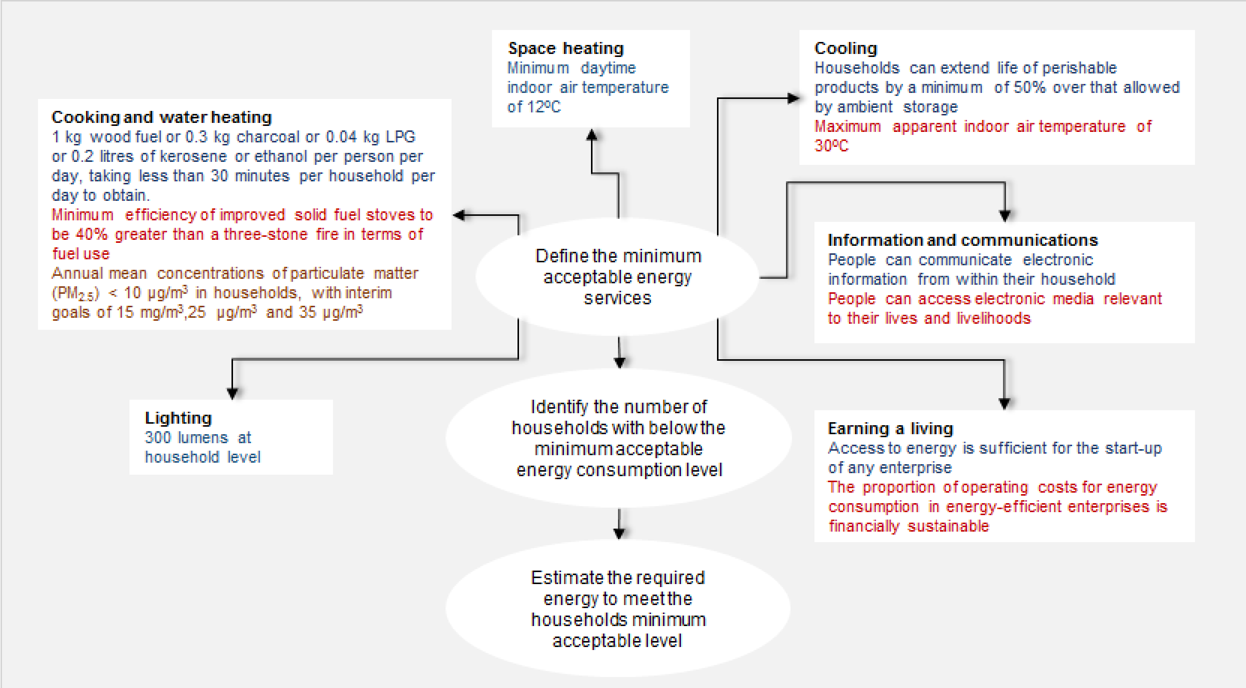


Figure 3.3 Modern Energy needs showing Minimum Acceptable Threshold levels and a Top-Down Approach (Centre Column) describing the Energy Demand Level in Households. (Modified from Practical Action 2010 and Shrestha and Acharya 2015).

The *energy demand level* has been sampled using various methods and approaches, such as the forecasting method (He *et al*. 2017; Ghalehkhondabi *et al*. 2017); end-use method (Blasch, Boogen and Kumar 2017; Mohammadi and Kulkarni 2017); econometric approach (Blasch, Boogen and Kumar 2017; Mohammadi and Kulkarni 2017); neural techniques (Kankal and Uzlu 2017; Muralitharan, Sakthivel and Vishnuvarthan 2018); and time-series approach (Kankal and Uzlu 2017; Muralitharan, Sakthivel and Vishnuvarthan 2018). As illustrated in Figure 3.3, the top-down approach is another method of assessing the energy demand profile that can be employed in this study. The energy demand profile estimates the *level of energy demand* by determining the number of households using energy products below the standard acceptable level while estimating required energy demands to meet the *minimum energy needs*.

The assessment of *availability and cost of energy types in target areas* mainly centres on five important factors, as shown in Figure 3.4. An empirical survey can also be used to inform the *availability and costs of energy types in target areas* and *least-cost energy access options and cost implications* in defining *costs of demand and supply*, and *sustainability of energy technologies*. For the *costs of demand and supply* for electricity, for example, demand-side options consider devices in use and also operation and maintenance costs of devices. Other available access options are considered where there is no electricity access. Such a typical example is the *costs of demand and supply* of biomass, which began with energy demand profiling, then availability and costs, and lastly, assessing demand and supply-side options (Figure 3.4)

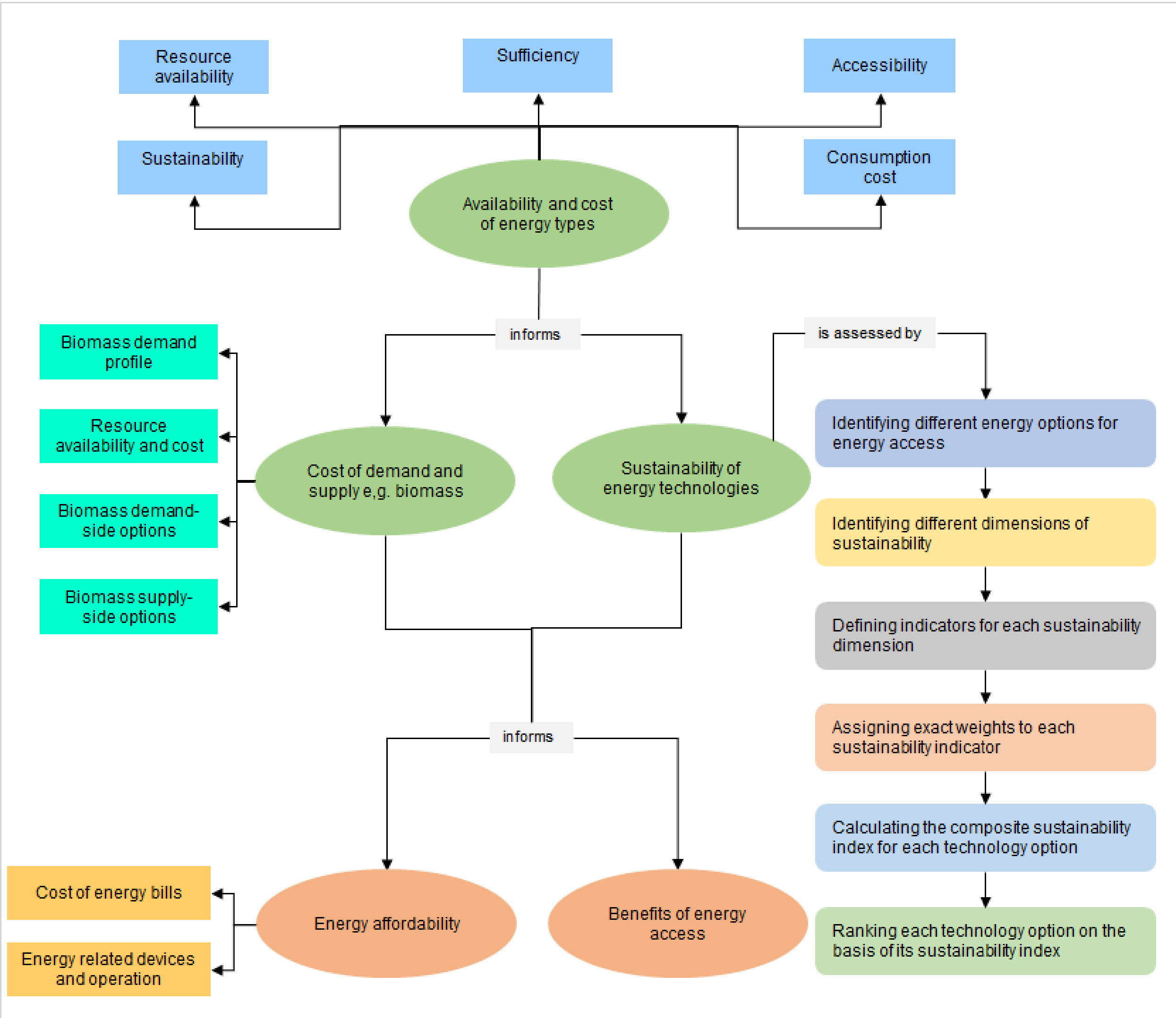


Figure 3.4 Some System Designs in the proposed New SRM, as well as their Attributes, Profiles, And relevant Methodologies.

Many approaches have been employed in assessing the *sustainability of energy technologies* (Arodudu *et al.* 2017; Madriz-Vargas *et al.* 2017; Lozano and Lozano 2018), including data envelopment analysis (Martín-Gamboa *et al.* 2017), and complex multi-layer system models (Coss *et al.* 2017). One sustainability approach employed a systems approach to analyzing product quality and performance (Hoffenson and Söderberg 2015). Brent and Kruger (2009) integrated sustainable frameworks into transferring renewable technologies but reported the inadequacy in technical sustainability in rural South Africa. A well-structured survey with clear indicators and desktop studies can be used to assess the *sustainability of energy technologies*

(Figure 3.4). Assigning composite indexes e.g. 'High', 'Medium' and 'Low' can also give a better validation of access options, concerning sustainability dimensions.

The *affordability of cleaner access option* determines energy expenditures in households. As shown in Figure 3.4, this assessment calculates the costs of energy bills and energy-related devices and operations (Shrestha and Acharya 2015). The *energy access benefits* have also been evaluated using human capital (Sun, Fang and Sun, 2018) and revealed preference approaches (Allcott and Greenstone, 2017; Kerr, Gouldson and Barrett, 2017). A Contingent Valuation Method (CVM) (Cheng *et al.*, 2017; Cho, Lim and Yoo, 2017; Xie and Zhao, 2018) distinctly quantifies the present and probable future *energy access benefits* and can be adapted in this study. For improved *energy access benefits*, *supporting policies and measures* and *a set of sustainable demand and supply side-options* must be recognized. These system designs can adopt a range of methodologies, from statutory policy reviews and desktop studies to that of primary data survey. Generally, new SRM methodologies to be adopted are dependent on the nature and purpose of system analyses, data availability, the study duration, and a range of questions to be addressed in a study (Shrestha and Acharya 2015).

3.4 CONCLUDING REMARKS

Applying systems concepts of disassembling a system into elements while maintaining functionality and interoperability between, and within energy consumerism, behaviourism, and sustainability has been challenging. Favourably, elements have been mapped as synergistic systems using SsT principles to demonstrate the interrelationships in the proposed new SRM (Figure 3.2). The new SRM was shown to delineate diverse elements underlying energy-use patterns and behaviour, and energy access, along with their synergisms. The model identified susceptible and powerful elements by decoding system purposes or behaviour and interconnections to producing the overall desired results. The SE/SsT approach and its application have proven useful in developing elements within systems operating in energy poverty and access processes into an energy access management framework.

It was shown that the proposed new SRM adopts a multimethod approach that allows one method to inform another. The model offers a valuable systems perspective of energy consumption intelligence and access sustainability. The new SRM also shows individualistic influences affecting model behaviour, although model systems are highly dependent on each other for their behaviour. When addressing misaligned model systems through specific interventions to balance it, the process of energy poverty can be shifted to improve energy access. The new SRM was shown to integrate well-informed interventions and strategies, particularly through *supporting policies and measures* in realizing consumers' needs. Such policies improving energy access in energy-poor households and adaptable in addressing problem system parts in the new SRM are reviewed in Chapter 4 below.

CHAPTER 4: POLICY REVIEW: ENERGY PRO-POOR POLICIES

This chapter reviews energy pro-poor policies, commissioned to improve energy access, particularly in poor and energy-poor households in South Africa, by employing the study methodology described in Subsection 1.7.1. The chapter addresses Research Objective 1[17] by aiming to address Research Question 1[18], whilst including to address the following sub-questions, below:

1. How effective are the existing implementation strategies in reaching the right beneficiaries at whom these policies are aimed?

2. Will benchmarking energy pro-poor policies in the 1998 Energy White Paper document (DME 1998) in sub-Saharan Africa validate policy effectiveness to continue to mitigate energy poverty in households in South Africa?

3. Have the objectives of energy pro-poor policies in the 1998 Energy White Paper document (DME 1998) been achieved?

4. Are irregularities in policy implementation processes, a result of financial, institutional, technological, or environmental challenges?

4.1 ENERGY WHITE PAPER TO POLICY IMPLEMENTATION

The energy sector plays socioeconomic roles in energy production and service delivery in households. It also contributes to economic growth, the creation of employment, and social infrastructure in households. The 1998 Energy White Paper motivates policy objectives and priorities to developing new policies, favouring the poor, and bridging inequality in energy distribution in the South African energy sector (DME 1998). Energy policies considered pro-poor have been commissioned since 1998, in response to achieving policy objectives and priorities in the White Paper document (DME 1998), as described in Table 4.1. Other policy objectives, not related to improving energy access, are geared more toward addressing wide-ranging issues of sustainable energy supply and environmental health. To acknowledge the

[17] Section 1.3: RESEARCH AIM AND OBJECTIVES. 1 Examining energy pro-poor policies and programmes put in place to reduce poverty and energy poverty in South Africa.
[18] Section 1.4: RESEARCH QUESTIONS. 1 Are existing energy pro-poor policies adequate to mitigate energy poverty in energy-poor households in South Africa?

ingenuity of energy pro-poor policies, it is important to determine their implementation processes and progress, over time.

Table 4.1 Energy White Paper policy objectives showing some of the policy priorities, relating to energy pro-poor policies. (Adapted from Department of Minerals and Energy, 1998)

Energy White Paper Policy Objectives	Policy priorities	Energy pro-poor policies
	• Establish voluntary guidelines for the thermal performance of low-income dwellings	Reconstruction and Development Programme (RDP) (1998)
	• Improve the delivery of household energy services, including electrification	National Electrification Programme (NEP) (Between 1994 and 1999)
		Integrated National Electrification Programme (INEP) (2001)
	• Develop a national electrification policy, planning, and financing system	Free Basic Electricity Policy (FBE) (2003)
		Inclining Block Tariff (IBT) (2010)
	• Stimulate the development of new and renewable sources of energy	Non-Grid (and Mini-Grid) Electrification Policy (2002)
1. Increasing access to affordable energy services	• Treat off-grid electrification in the same way as grid electrification	Free Basic Alternative Energy Policy (FBAE) (2007)
2. Improving energy governance	See Department of Minerals and Energy, (1998) for priorities of these policy objectives. Also, see Spalding-Fecher, (2002) for some progress thus far on policy objectives and some of the priorities	
3. Stimulating economic development		
4. Managing energy-related environmental impacts		
5. Securing supply through diversity		

At the moment, most rural South African cannot be grid-connected, due to the financial implications of grid-electrification, and low energy per capita consumption in households. Similarly, urban poor areas, mainly including informal settlements, have no easy access to electricity and other basic social services. The South African government has been trying to improve energy access and consumption efficiency in these areas through the White Paper document (DME 1998). The core objectives of this document, relative to the framework of energy pro-poor policies, include improving energy security and access, clean energy use and appliances, energy affordability and governance, diversified energy supply, economic development, and reducing energy-related environmental and health impacts, mostly at the household level (Table 4.1) (Davidson *et al*. 2006; Mohlakoana 2014). As formerly stated, six policies are identified as relevant to improve energy access in households. These policies, according to its earliest year of commissioning, are summarized in Figure 4.1 below.

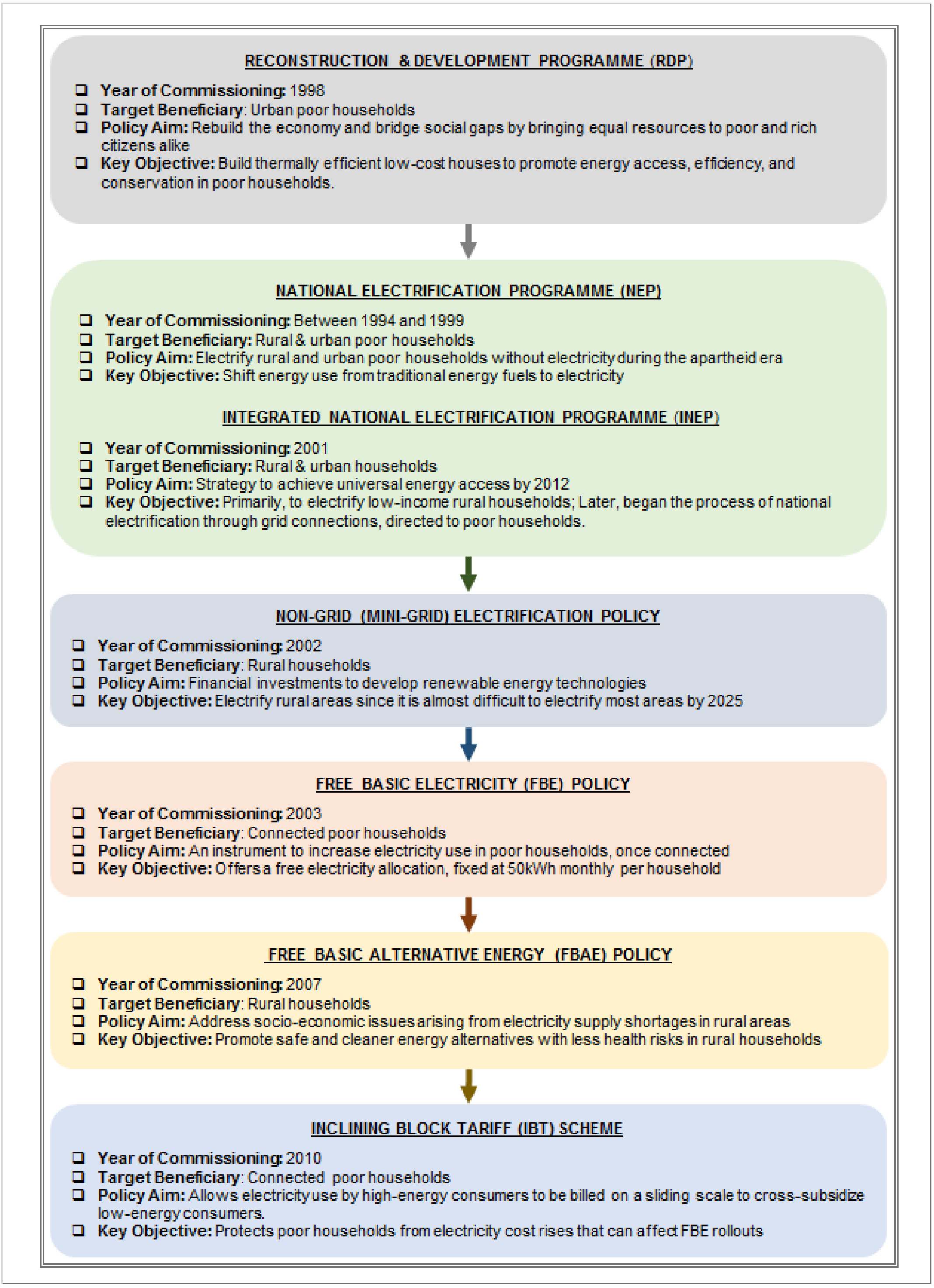


Figure 4.1 Energy pro-poor policies, relevant in improving energy access and energy-use efficiency in households.

According to the 1998 Energy White Paper (DME 1998), the frameworks of energy pro-poor policies presented in Figure 4.1 are suitable for energy poverty mitigation in South Africa. However, Sustainable Energy Africa (2014) reported that these supposed powerful pro-poor policies expressed in the 1998 Energy White Paper (DME 1998) have proven inadequate for mitigating energy poverty in South Africa. The White Paper document acknowledges the importance of energy access and requires future policies to focus on service delivery of basic energy needs in households. Also, before the White Paper old document, the RDP base document first laid the foundation for developing the conceptual frameworks of these energy pro-poor policies, especially those of NEP and INEP programmes (DoE 2015), promoting national electrifications. Accomplishing the objectives of these older policy documents is fundamental in evaluating policy effectiveness and socio-economic development in South Africa. Consequently, this section provides a broad but collective review of energy pro-poor policies to validate the effectiveness and ongoing government efforts, addressing Research Question[19] and Sub-Question 2[20]. These policies are critiqued, according to the earliest year of commissioning, as presented in Figure 4.1 and subsections below.

4.1.1 Reconstruction and Development Programme (RDP)

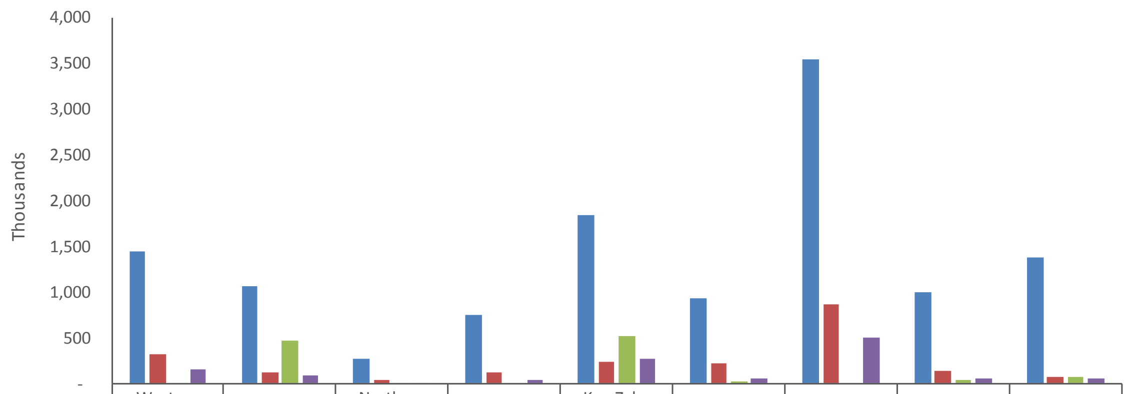
Among the first draft by the South African government was the Reconstruction and Development Programme (RDP) policy (DME 1998), which was initiated in 1994 to jumpstart government goals and plans for service delivery. This period marked the beginning of a large-scale provision of energy services and the process of energy poverty mitigation by the government. The period between 1992 and 1994 characterized a political transition, leading to the authorization of electrification programmes within the RDP policy (Davidson *et al.* 2006). Like old policy documents of the 1990s, the RDP policy (DME 1998) chiefly focused on rebuilding the economy and bridging the social gaps by bringing equal resources to all citizens, alike (Table 4.2).

Table 4.2 Key Concepts - Reconstruction and Development Programme (RDP) policy

	Reconstruction and Development Programme (RDP)
Year of commissioning	1998
Target beneficiary	Urban-poor households
Policy aim	Rebuild the economy and bridge social gaps by bringing equal resources to poor and rich citizens alike
Key objective	Build thermally efficient low-cost houses to promote energy access, efficiency, and conservation in poor households.
Policy funding	Subsidized and government
Policy implementer	Department of Human Settlement (DHS)
Target met (No of households) and period	3 905 254 in 2016 (Stats SA 2016)

[19] Section 1.4: RESEARCH QUESTIONS. 1 Are existing energy pro-poor policies adequate to mitigate energy poverty in energy-poor households in South Africa?
[20] CHAPTER 4: POLICY REVIEW: ENERGY PRO-POOR POLICIES. 1 How effective are the existing implementation strategies in reaching the right beneficiaries at whom these policies are aimed?

Originally, the RDP policy (DME 1998) was developed to promote national electrifications, particularly providing electricity to those deprived in the apartheid era. The policy led to formulations of energy policies, regulatory frameworks for electricity pricing, tariffs, and subsidies and lays the foundations for improved functional structures in electricity supply and demand sectors. The key objective is to build thermally efficient low-cost houses as a way to promote energy access, energy-use efficiency, and conservation in poor households. Another objective is to reduce poor practices of using local energy fuels and appliances for water and space heating in energy-poor homes (Walsh, Wesselink and Janisch, 2011). Right now, the government delivers free and low-subsidized formal houses to poor citizens through the RDP policy (DME 1998).

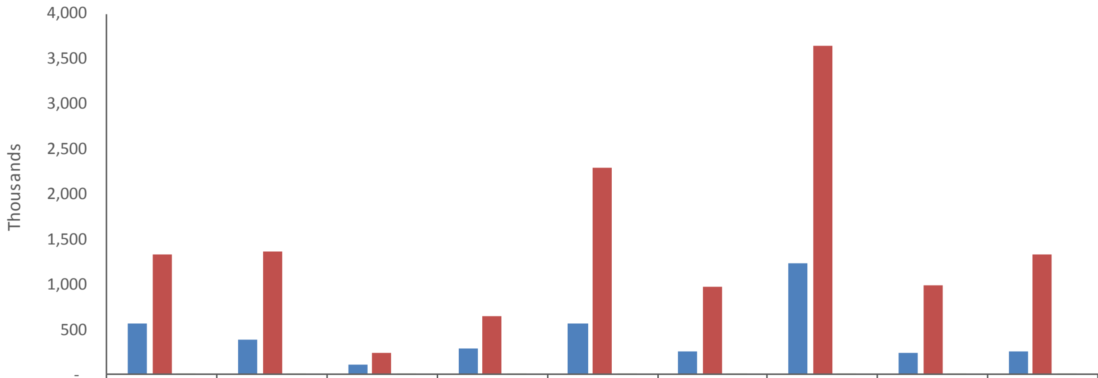


	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo
Formal dwellings	1,446,025	1,069,677	281,982	760,080	1,838,616	933,832	3,551,995	1,006,179	1,376,623
Informal dwellings	320,022	130,885	45,246	132,448	245,167	229,544	878,246	135,039	77,371
Traditional dwellings	9,401	471,699	8,245	15,509	520,244	23,146	10,763	39,992	81,746
Others	158,168	100,994	18,195	38,542	271,618	61,998	509,203	57,540	65,204

Figure 4.2 Census 2016 showing Distributions of Informal Dwellings (both backyard and not in the backyard) across Provinces in South Africa. (Source: Stats SA 2016)

There has been rapid urbanization in urban metros that resulted in over 13% of the total population living in informal dwellings. As shown in Figure 4.2, roughly 14.7 million households reside in, formal, traditional, and other dwellings, while about 2.2 million live in informal dwellings. Meanwhile, city dwellers are expected to grow by 7.8 million by 2030, driven by an increase in rural-urban migration, and poverty persistence in rural areas (SEA 2014). At the time of this writing, both state-subsidized and free RDP houses are being developed and sprawled across the provinces, with an estimation of 3 905 254 such houses delivered by 2016 (Figure 4.3). Supposedly, South Africa ought to be a ‘shack-free’ society presently, since RDP houses exceeded informal dwellings in statistics in 2016 (Figure 4.2;

Figure 4.3). However, Stats SA (2016) [21] reported more than 12 million households live in shacks and not in RDP houses in 2016. Not entirely ruling out data errors and incompatibility, these conflicting reports and backlogs might have occurred due to different arising factors influencing data records. Such factors might include household growth (DoE 2015) and fragmentation (HDA 2012), multiple RDP housing bids[22], and increased rural-urban migration (Turok and Borel-Saladin 2016).



	Western Cape	Eastern Cape	Northern Cape	Free State	KwaZulu-Natal	North West	Gauteng	Mpumalanga	Limpopo
Living in RDP houses	571,997	386,802	105,541	289,414	559,302	261,693	1,227,729	241,801	260,976
Not living in RDP houses	1,335,243	1,372,311	244,759	652,680	2,300,600	976,842	3,641,899	987,316	1,331,224
Unspecified	1,614	859	422	578	1,606	1,048	4,346	634	1,471

Figure 4.3 Distributions of Informal Households not Living in RDP (Government Subsidised Houses) Across Provinces. (Source: Stats SA 2016)

As shown in Figure 4.3, almost 28% of informal households are not living in RDP houses in Gauteng, roughly 17% in KwaZulu-Natal, 10% in the Eastern Cape, Limpopo, and Western Cape provinces, respectively. The least proportions of households are located in the Mpumalanga, North West, Free State, and Northern Cape provinces. Stats SA (2016) also reported about 3.6 million RDP housing backlogs in South Africa, with about 1.2 million delivered in the City of Cape Town. According to HDA (2012), one member out of more than 450 000 informal households is on the waiting list for an RDP housing option. Over 50% of households have been on the waiting list for about five to seven years in the Western Cape, Gauteng, and Eastern Cape provinces (HDA 2012). As seen in Figure 4.3, a large number (12 842 874) of informal households might require RDP houses while some (12 578) were

[21] Secondary data obtained from the SuperWEB or SuperCROSS of Statistics South Africa (StatsSA). The SuperCross was acquired from the StatsSA office in Cape Town in the form of discs. The SuperWeb is accessible on http://superweb.statssa.gov.za

[22] The information was gathered during the field survey. Most informal households in the primary case study area have RDP houses but either sold it or put on rental. These households then start a new process of bidding for an RDP house while still living in shacks.

unspecified whether they reside in RDP houses or not. Service providers are likely to be burdened by the rising demands for service needs, which are also expected to increase since majorities of rural-urban migrants are mostly poor and somehow coerced to reside in informal settlements.

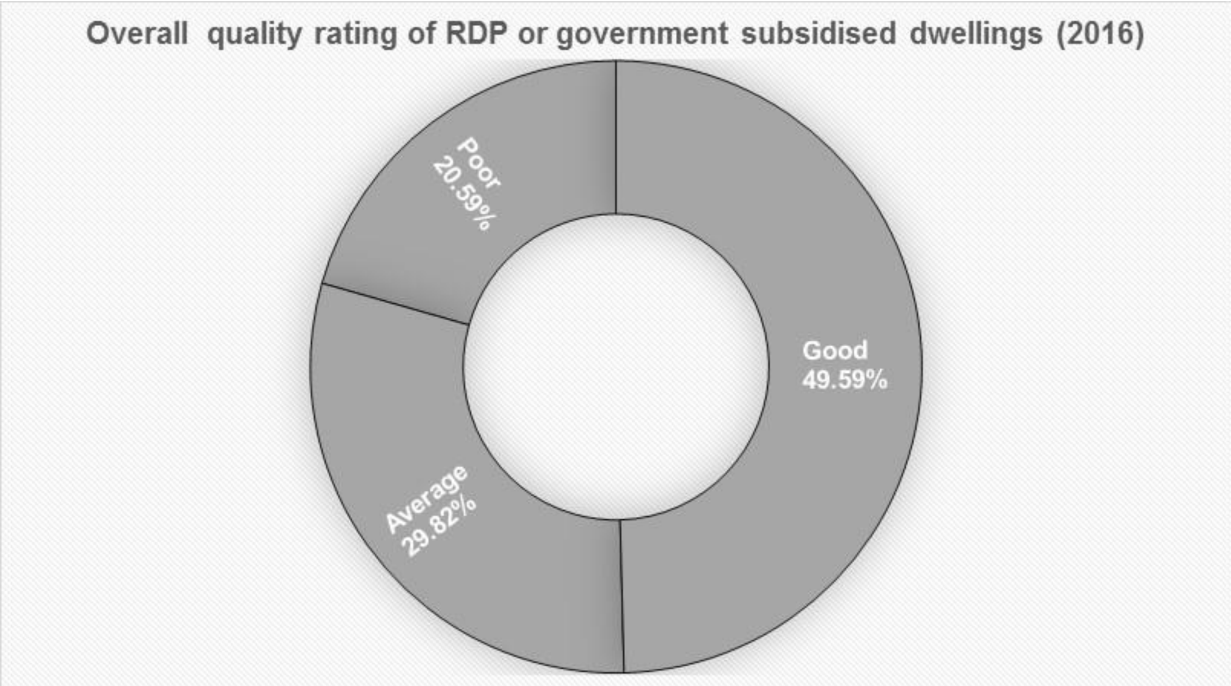


Figure 4.4 Survey on Overall Quality Rating of upgraded RDP houses across provinces in South Africa. (Source: StatsSA 2016b)

Hitherto, earlier-built RDP houses had no ceilings, were poorly insulated (SEA 2014), and lacked thermally efficient designs. On the other hand, households living in these earlier-built houses spend a large part of their income on energy, trying to maintain space heating during winter, while concurrently harming their health (Muringathuparambil *et al.* 2017). According to SEA (2014), about 3 million RDP houses delivered are without ceilings. Not until 2014, a new RDP housing scheme commenced with upgrades on the earlier-built RDP houses to improve energy-use efficiency. The most effective policy intervention adopted was to install low-cost ceiling retrofits and wall insulation to improve thermal performance since thermal energy use easily escapes through wall lattices. About 0.5% of these earlier-built RDP houses were improved, thermally in 2006 (Davidson *et al.* 2006). More than 8 000 RDP houses were retrofitted with 40 000 projected to be developed in the City of Cape Town (Collective Thrie Energy, 2018). The ongoing Kuyasa Clean Development Mechanism (CDM) project thus far installed Solar Water Heaters (SWHs) and thermal insulating ceilings in nearly 2 300 RDP houses in Kuyasa (Walsh, Wesselink and Janisch 2011). According to the survey conducted on the RDP housing upgrading, health was recorded to improve (81%) and energy expenditure reduced to less than R100 in households (Walsh, Wesselink and Janisch 2011). Another similar survey reported similar feedbacks but included improved energy use in households in some regions in Cape Town (Collective Thrie Energy, 2018). The overall quality was rated 50% - good, 30% -average, and 21% - poor in 2016, as shown in Figure 4.4.

At the moment, the RDP housing delivery has developed different viewpoints on the formalization approach, from the state-led to both participatory and rental possibilities. The common goal of these viewpoints is to balance the RDP housing delivery with increasing numbers of informal households. It is, however, important to develop sustainable housing options, with improved access to social facilities, modern energy services, and employment opportunities. As a result, a 'sustainable innovative integrated human settlement plan' was initiated to facilitate practical solutions to solve RDP challenges and also transform the city structure in the City of Cape Town. This plan has shown significant results since 2013, also aiming to deliver about 652 000 RDP houses by 2031 (Human Settlement Directorate 2017). Key expectations of the plan include moving from building houses to integrating green conditions, satisfying growing demands, and promoting better participation in housing opportunities and markets (Human Settlement Directorate 2017). With the integration of the human development plan and other effective strategies and policies, RDP backlogs can be cleared, thus making South Africa, a 'shack free' society, at the earliest.

4.1.2 Integrated National Electrification Programme (INEP)

Between 1994 and 1999, the South African government first commissioned the National Electrification Programme (NEP) (DoE 2015) to electrify rural and urban-poor households without electricity access during the apartheid era. The NEP programme (DoE 2015) was initiated as a target-based strategy to grid-connect a large number of households within a specified time. As shown in Table 4.3, the chief objective was to shift energy use from traditional energy fuels to electricity (DoE 2015). Resources and funds were available, also electricity generation surpluses to meet the set target. Coupled with the cross-subsidization scheme, NEP funded electrifications in more than 2 million households from 1994 to 2000 (Table 4.3). The connection costs were cross-subsidized for the target beneficiaries but the poorest households were unable to afford it. Only one-third of the target population gained electricity access before 1990 (Ogunlade *et al.* 2007). Eventually, connection costs gradually declined and Eskom exceeded the set target of 2 million households within the pre-2000 era (Table 4.3).

Table 4.3 Key Concepts - National Electrification Programme (NEP) and Integrated National Electrification Programme (INEP) policies

	National Electrification Programme (NEP)	Integrated National Electrification Programme (INEP)
Year of commissioning	Between 1994 and 1999	2001
Target beneficiary	Rural and urban energy-poor households	Rural and urban energy-poor households
Policy aim	Electrify rural and urban poor households without electricity during the apartheid era	Strategy to achieve universal energy access by 2012
Key objective	Shift energy use from traditional energy fuels to electricity in energy-poor households	Primarily, to electrify low-income rural households; Later, began the process of national electrification through grid connections, directed to energy-poor households
Policy funding	Cross-subsidization and government	Government-funded
Policy implementer	Eskom	Eskom
Target met (No of households) and period	2 070 000 between 1994 and 2000 (Mohlakoana, 2014)	104 619 in 2001 (DoE 2015)
		2 703 921 from 2001 to 2010 (DoE 2015)
		329 022 from 2011 to 2013 (DoE 2015)

As earlier mentioned, the period of political change played a key part in designing new electrification policies and strategies. Under the remit of the Department of Energy (DoE), the Integrated National Electrification Programme (INEP) was commissioned in 2001. This programme was introduced as a strategy for reaching universal energy access by 2012 (DoE 2015). In the post-2000 era, INEP coordinated distribution patterns and methods of electrifications and provided funds from the national treasury (DoE 2015). Primarily, this government-funded programme was to electrify rural households, facilitated by surplus generation capacity and low-cost innovative techniques. Initially, Eskom concentrated on electrifying urban households before 2000 and commenced rural electrifications after 2000 through pro-active and target-driven operational processes. Subsequently, INEP (DoE 2015) began the process of national electrifications, mainly directed at poor households. In 2001, households connected were low in number (Table 4.3) but increased significantly, varying between 2000 and 2005, 2007, and 2012 (DoE 2015). The programme connected over 2 million households in 10 years and more than 300 000 in 3 years (Table 4.3).

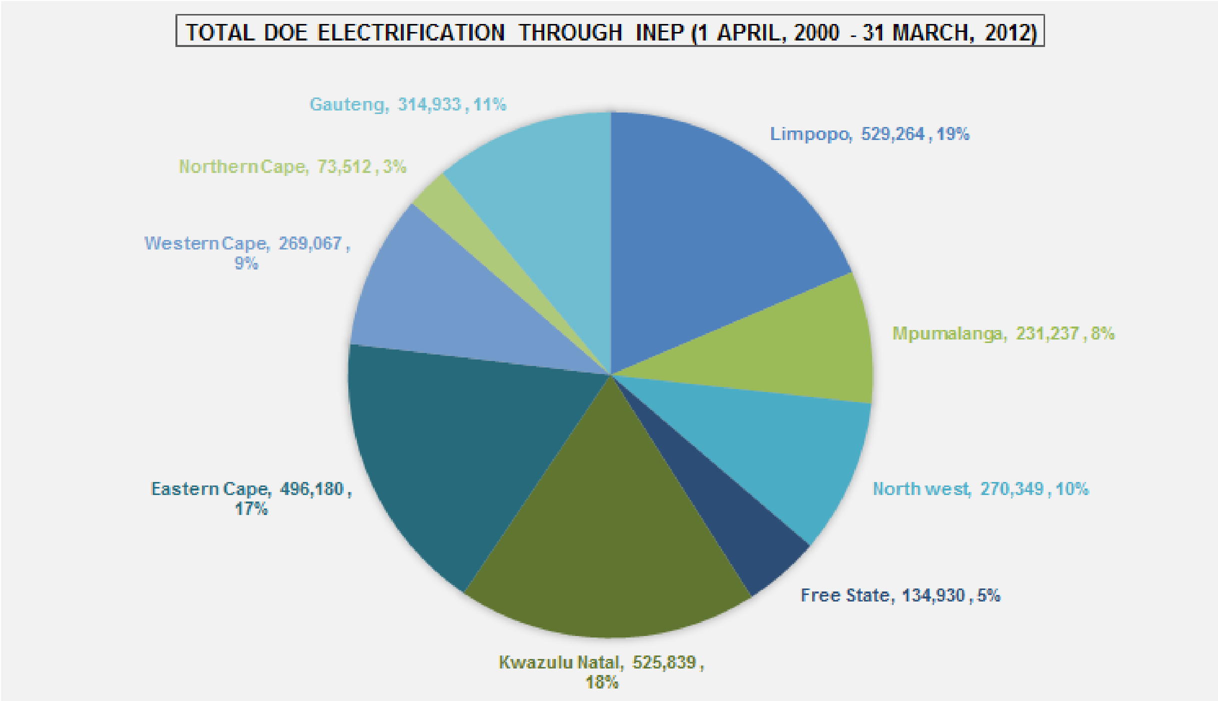


Figure 4.5 Total Electrification of Households across Provinces through INEP from 2000 to 2012. (Source: DoE 2015)

As shown in Figure 4.5, the Northern Cape and Free State provinces had the least grid connections from 2000 to 2012, while over 10% of grid-connection gained in Limpopo, KwaZulu-Natal, the Eastern Cape, and Gauteng provinces, respectively. There was a breakthrough in national electrifications when more than 5 million households were grid-connected from 1990 (pre-2000 era) to 2007 (post-2000 era), funded mainly from the national treasury and not cross-subsidies (Ogunlade *et al*. 2007; Bekker *et al*. 2008). This marked a remarkable feat in South African electrification programmes, receiving recognition both nationally and internationally (SEA 2014). Later on, annual connections dropped due to increased investments in infrastructure and other rigorous financial processes occurring in Eskom in the post-2000 era. Out of about 5.5 million households without electricity in 2011, about 2.08 million of the population had growth in household size (Figure 4.6). While households with electricity access and without growth were 75.81%, households with growth totalled to 85.34% (Figure 4.6). With a continuous increase in household growth, service providers are likely to be burdened with expected increases in energy demand and service delivery, shortly.

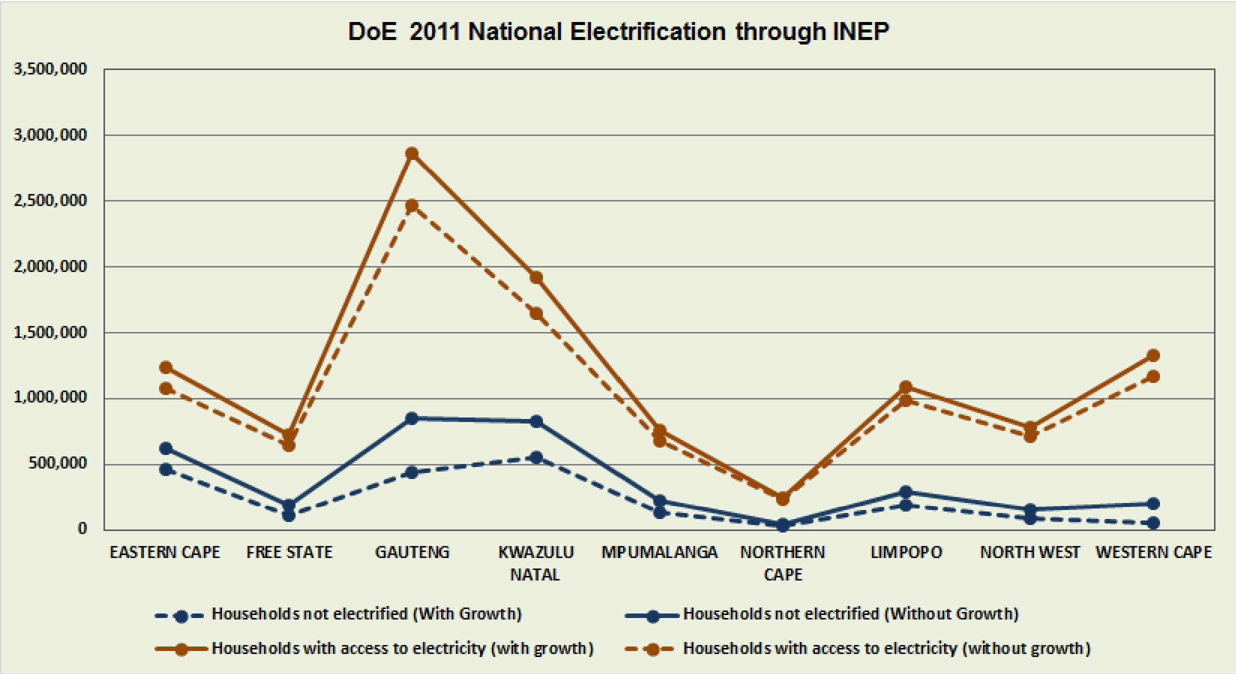


Figure 4.6 DoE National Electrifications Showing Electrified and Non-Electrified Households, along with Households with Growth and Without Growth Across Provinces in 2011. (Source: DoE 2015).

By 2012, universal energy access was not met in South Africa, which might be ascribed to financial constraints, poor infrastructural developments, and supply shortages within energy service authorities, per the literature[23], exacerbated by increased rural-urban migration and household growth. As a result, the DoE set a new target of reaching 97% of national electrifications by 2025. Municipalities and local governments, as well, embraced new approaches to address various issues, concerning energy access and use within the INEP structure (DoE 2015). These organizations set realizable connection targets and allocation criteria, define priority areas, allocate funds, subsidize projects, and determine grid and off-grid energy target mixes (DoE 2016). Successively, Stats SA (2016) reported an almost three-fold grid-connection in 2016 (Figure 4.7) from the 2012 level (Figure 4.5). The Limpopo province increased from grid-connecting about 529 000 households in 2012 to 1.4 million in 2016, whereas the Gauteng province rose from about 314 000 to 4.2 million (Figure 4.5; Figure 4.7). By and large, national electrifications increased within the period (Figure 4.5; Figure 4.7), validating INEP's ongoing efforts (DoE 2015). A total of more than 14 million households have gained electricity across the provinces, with the least proportion of these households in the Northern Cape province (Figure 4.7).

[23]2.3: ENERGY DISTRIBUTION AND CHALLENGES PARTICULAR TO SOUTH AFRICA; and Section 2.4: INEQUALITY IN ENERGY DISTRIBUTION: PROFILING INFORMAL SETTLEMENTS

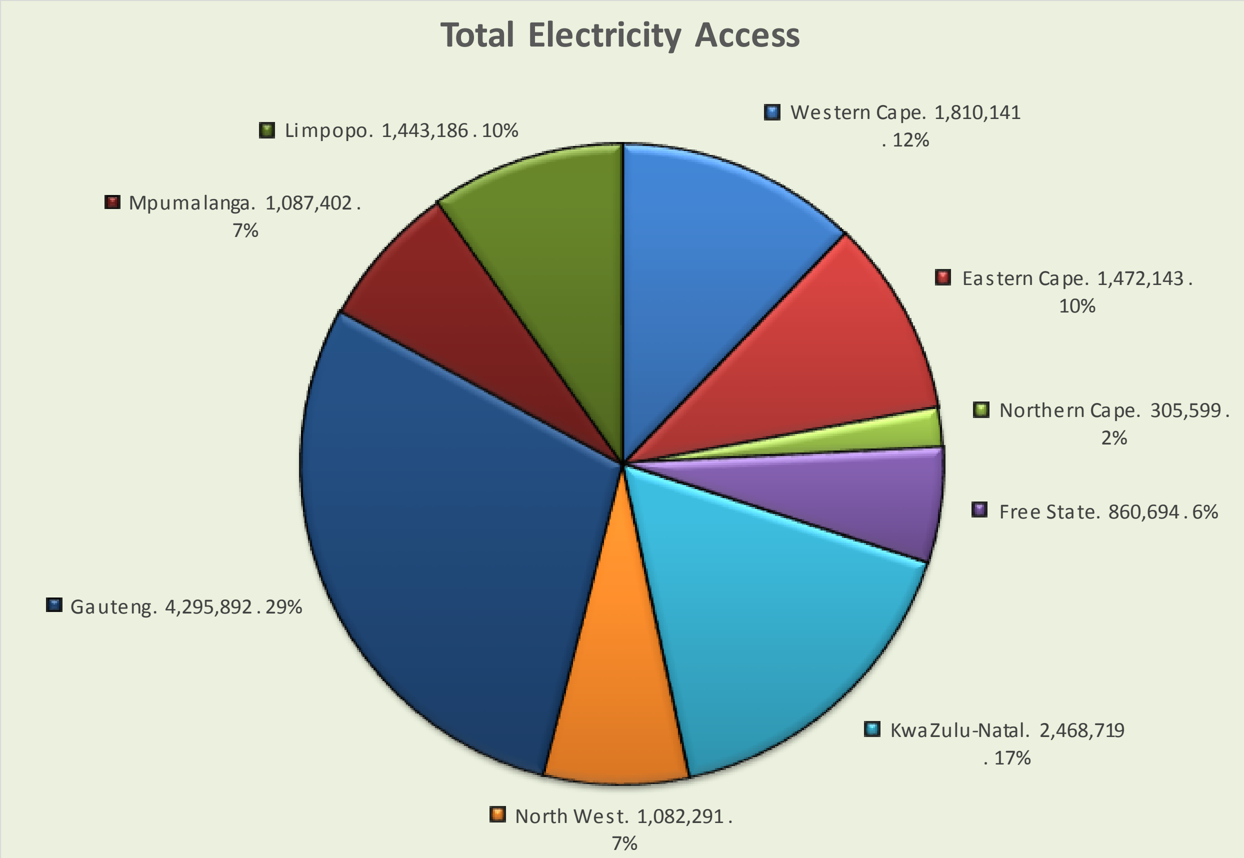


Figure 4.7 Community Survey 2016 Showing Distributions of Households with Electricity Access Across Provinces. (Source: Stats SA 2016).

NPC (SEA) (2014) projected a two percent annual increase of households without electricity access in South Africa, According to Stats SA (2016), there were more than 14 million households connected and 2 097 242 households, not connected (and unspecified) in 2016. Under the INEP programme (DoE 2015), there were 13.5 million households connected and about 2.1 million, without electricity in 2015 (Table 4.4). As shown in Table 4.4, the highest electrification backlogs were in the Gauteng and KwaZulu-Natal provinces. About 91% of households were connected and 160 000 households, not connected in the Western Cape province (Table 4.4). Alternatively, Stats SA (2016) reported roughly 1.1 million formal, and 871 787 informal households were without electricity in 2016. Of particular note is that connected informal households of about 1.9 million in 2014, declined to 1.3 million in 2016 (Stats SA 2016). This decline can be applauded and attributed to increased RDP housing delivery, the volatility of informal areas in terms of abandonment, urban restructuring, or infrastructural development across provinces.

Table 4.4 DoE Total Electrifications and Backlogs Of Households Per Province Through the INEP Programme. (Source: DoE 2015)

PROVINCE	PROJECTED HOUSEHOLDS (April to March 2017)	HOUSES WITHOUT ELECTRICITY	HOUSES ELECTRIFIED	ACCESS PER PROVINCE
EASTERN CAPE	1,826,480	353,125	1,473,355	80.67%
FREE STATE	891,184	110,352	780,832	87.62%
GAUTENG	4,231,251	704,248	3,527,003	83.36%
KWAZULU NATAL	2,748,760	501,262	2,247,498	81.76%
MPUMALANGA	1,164,143	98,533	1,065,610	91.54%
NORTHERN CAPE	326,250	41,071	285,179	87.41%
LIMPOPO	1,534,999	50,689	1,484,310	96.70%
NORTH WEST	1,149,559	152,075	997,484	86.77%
WESTERN CAPE	1,768,694	160,547	1,608,147	90.92%
TOTAL	**15,641,320**	**2,171,902**	**13,469,418**	**86.11%**

Within pre- and post-2000 eras, NEP, and INEP programmes (DoE 2015) have shown remarkable efforts in improving electricity access in South Africa. At this point, the core framework of the RDP policy document (DME 1998), i.e. to provide electricity access to disadvantaged communities, is achieved and still in process. As the rural-urban migration increases, informal settlements also increase, and continuously cripple, among others, the financial capabilities of service providers to cater to growing demands for service delivery. In South Africa, every citizen has the constitutional right to electricity access, regardless of the location (DoE 2011). Therefore, INEP is currently burdened with electrifying informal households, which are also required to be funded from the national treasury. Besides, the set target of achieving 97% national electrification by 2025 may be missed due to outstanding backlogs and growing numbers of informal households across the provinces.

4.1.3 Non-Grid (and Mini-Grid) Electrification Policy

The 1998 Energy White Paper (DME 1998) on the non-grid electrification policy was commissioned in 2002 (DoE 2012) as part of the INEP programme (DoE 2015). As shown in Table 4.5, the key objective was centred on the financial investments to develop renewable energy technologies, since it is almost difficult to electrify most rural households by 2025 (Ogunlade *et al.* 2007). Private concessionaires and Energy Service Companies have been licensed to roll-out this policy in energy-poor households within concession areas. The concession areas are areas marked for the roll-out of the non-grid electrification policy (DoE

2012). Far along, non-grid renewables were permitted in energy-poor households beyond the marked areas. The capital costs are primarily borne by the concessionaires and the monthly charges, including service and maintenance costs, are funded by end-users. There is also a motive to promote energy access and diversify schemes by introducing this policy option in informal households (White, Bank and Jones, 1997).

Table 4.5 Key Concepts - Non-Grid (and Mini-Grid) Electrification Policy

	Non-Grid (SHS) Electrification Policy	**Mini-grid Electrification Policy (also known as Household Electrification Strategy (HES))**
Year of commissioning	2002	2013
Target beneficiary	Rural households	Rural and urban energy-poor households
Policy aim	Financial investments to develop renewable energy technologies	Electrify about 300 000 households from 2014 to 2025 in South Africa
Key objective	Electrify rural areas since it is almost difficult to electrify most areas by 2025	Allows exploring affordable energy technologies such as mini-grids
Policy funding	Partly government; partly end users	Partly government; partly end users
Policy Roll-out	Private concessionaires and Energy Service Companies	
Target met (No of households) and period	7 000 in 2005 (Davidson *et al.* 2006)	
	51 000 in 2011 (Njekelana 2013)	
	65 174 in 2013 (Njekelana 2013)	
	353 594 in 2016 (Stats SA 2016)	

Non-grid renewables are provisional alternatives to electricity and low-cost options for poor households (DoE 2012). These renewables are mostly indigenous and accessible and can contribute to sustainable development and energy security against any international crisis. The Solar Home System (SHS) has been identified as a renewable way among many energy renewable technologies to improve energy access in poor rural homes. SHS is a small 50W Photovoltaic PV panel, equivalent to about 250Wh use per day, designed per individual household (DoE 2012). It is a technical energy alternative that provides electricity for only lighting service within realistic cost standards against that of grid electricity. SHS is also a sustainable way to respond to carbon emission reductions, improve health, and reduce other environmental issues arising from using less efficient energy fuels.

The non-grid SHS is temporary for remote rural communities until the grid connection is possible. Without the SHS option, most rural households continue to use less clean energy products in meeting their energy needs (Brent and Rogers 2010; Patel and Chowdhury 2018). The least-cost model approach for non-grid electrifications in rural areas considers, predominantly the target level and quality of energy access, characteristics of local grids, population density, available local resources, and costs of energy technologies (Nerini *et al.*

2016). The non-grid SHS option has higher operational and maintenance costs that can decelerate the option sustainability. For instance, the cost of using solar PV is more than threefold the estimated cost (39 USD/tCO2) for traded CO^2 emission permits (Baurzhan and Jenkins 2016). Even the subsidized cost of SHS is five times more than non-subsidized electricity tariffs designed for formal households in South Africa.

As shown in Table 4.5, 7 000 solar systems were mounted in four concession areas in 2005 (Davidson *et al.* 2006). In 2011, about 51 000 households were using SHS in the country (Njekelana 2013). The progress was slow for a while because the electricity policy restricted areas within the grid proximity from non-grid access. A review by Davidson *et al*. (2006), unfortunately, reported that most poor rural households were not able to afford the non-grid SHS. There are reservations and concerns in local municipalities that accepting non-grid electrifications may disqualify future grid networks (Wlokas 2011). Regardless of all implications, mounted non-grid SHS increased to 65 174 in households by 2013 (Njekelana 2013). In 2016, the policy (DoE 2012) connected 353 594 households (Figure 4.8). About 40% of the total SHS were installed in the Gauteng, 14% in the Eastern Cape and KwaZulu-Natal, 12% in the Western Cape, and the least parts of 3% in the North West and Northern Cape provinces, respectively (Figure 4.8).

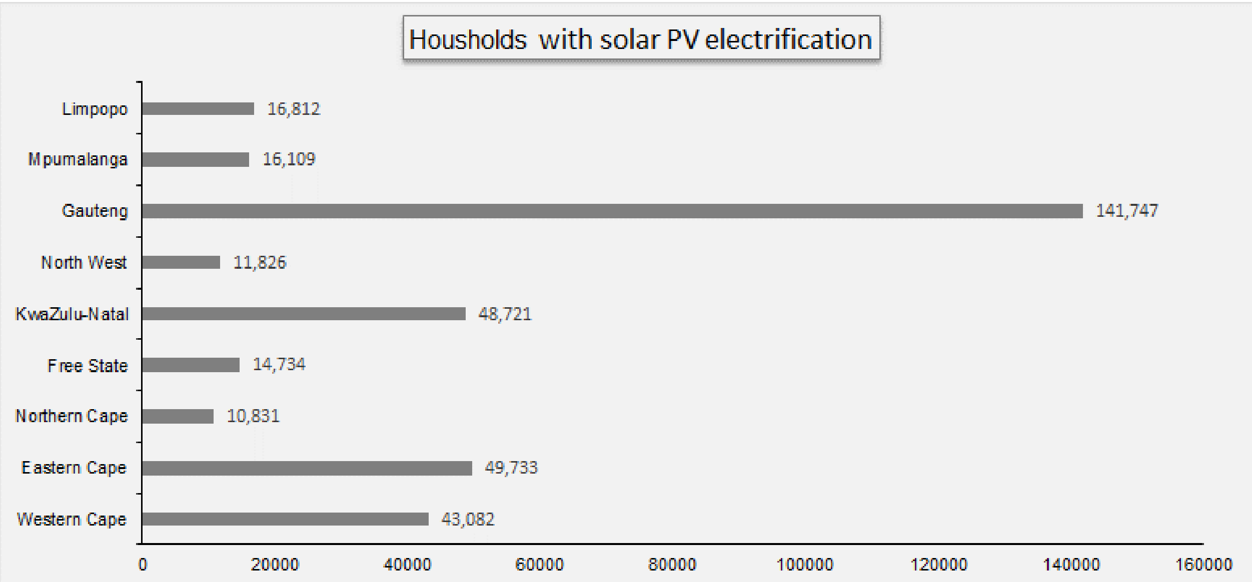


Figure 4.8 Distributions of Households Using Solar PV Electrification Across Provinces in 2016. (Source: Stats SA 2016)

The non-grid SHS does not meet household thermal energy needs such as cooking, heating, ironing, and refrigeration. The DoE, hence, demands that concessionaires embrace an energization approach, otherwise known as an integrated energy provision. The energization approach allows inclusions of energy fuels such as coal, paraffin, and LPG in the service delivery of SHS to meet thermal energy needs in households (Ogunlade *et al.* 2007). The approach allows multiple energy uses, rather than solely focusing on electricity as a single energy carrier in households. It becomes an option connoted by the government as the right strategy for increasing energy access in local communities. The initial non-grid projects in the Eastern Cape excluded this approach due to existing challenges with the supply of the SHS option alone. But, an energy mix of non-grid SHS and low-cost LPG was successfully implemented and supplied to energy consumers in the northern KwaZulu-Natal province (Davidson *et al.* 2006).

As shown in Table 4.5, the Household Electrification Strategy (HES) that allows affordable energy technologies was introduced in 2013 within the non-grid electrification policy (Scharfetter and Van Dijk 2017). The strategy aims to electrify about 300 000 energy-poor households from 2014 to 2025 in South Africa, which led to explorations of mini-grid electrification options. Unlike the non-grid, the mini-grid is another least-cost electricity-producing unit, powered by diesel engines or local energy renewables with adequate load densities suitable to power small towns and villages. The mini-grid option generates higher power outputs that permit the use of medium to high energy-intensive appliances such as refrigerators, hairdryers, and water pumps. It can support productive and income-generating activities (Sommer 2018) and are to be connected to the main grid when consumption levels reach certain economic strengths. A few studies have evaluated both the strengths and weaknesses of mini-grid at a small scale, hence validate the option resourcefulness when advanced (Brent and Rogers 2010; Azimoh *et al*. 2016; Patel and Chowdhury 2018). Presently, no policies or schemes are available to support hybrid mini-grid solutions for rural electrifications in South Africa. More so, hybrid mini-grids are not, at present, common in developing countries, except with a few exceptions such as Columbia.

4.1.4 Free Basic Electricity (FBE) Policy

The DoE (2016) acknowledged that poor households need a low-capacity electricity supply, consume low energy per capita, and can securely afford subsidized electricity prices. Accordingly, the Free Basic Energy (FBE) Policy, otherwise known as the Electricity Basic Support Services Tariff (EBSST) policy, was commissioned in 2003 (DME 2003). The FBE policy is funded by Local Government Equitable Share (LGES) and through cross-subsidies, while Eskom acts as the distributor on behalf of the municipalities (Eskom 2016). The FBE policy (DME 2003) has been profiled as a valuable instrument for increasing electricity use in poor households, once connected (Table 4.6). The policy is made available for both grid and non-grid energy consumers at 80% subsidy (R48.00 equivalent per month) of the service fee (DME 2003). The policy offers free electricity to poor households, fixed at monthly 50kWh allocation per household (DME 2003). Poor households are to receive the free FBE, upon purchasing the standard minimum electricity units per month, according to individual service providers. Occasionally, poor households are unable to procure the set minimum units every month to be eligible to receive the free 50kWh allocation.

Table 4.6 Key Concepts of - Free Basic Electricity (FBE) Policy

	Free Basic Electricity (FBE) Policy
Year of commissioning	2003
Target beneficiary	Connected poor households
Policy aim	An instrument to increase electricity use in poor households, once connected
Key objective	Offers a free electricity allocation, fixed at 50kWh monthly per household
Policy funding	Cross-subsidies and Local Government Equitable Share (LGES)
Policy Roll-out	Eskom
Target met (No of households) and period	1 177 250 in 2016 (Eskom 2016)
	1.8 million in 2018 (Masekameni *et al.* 2018)

Adam (2010) has shown that the free FBE of 50kWh provided just about 15% of energy consumption of energy services including space heating, lighting, boiling, cooking, and refrigeration in poor households. Also, a recent study has reported that poor households in Soweto rejected installations of pre-paid meters because the FBE subsidy was insufficient to meet their basic energy needs (Kambule *et al.* 2019). Adam (2010), as a result, proposed a weekly rather than monthly free 50kWh allocation, amounting to 200kWh FBE per month. According to Adam (2010), the financial shortfalls to the limit increase can be compensated through cross-subsidies, levies, taxes, and national revenues. At the moment, the FBE is integrated within the sliding scales of Inclining Block Tariff (IBT)[24] structures to improve affordability and protect poor households from sharp electricity tariff rises (Njekelana 2013; EGD 2018).

The free allocation essentially depends on the contractual agreements between the service providers and energy consumers (DoE 2012). For the time being, municipalities prioritize the FBE subsidy in informal and rural households, ranging between 20 kWh - 100 kWh monthly allocation at different electricity supply sizes of 20Amps, 60Amps, and other conventional

[24] To be discussed in Subsection 4.1.6

configured rates (Ogunlade *et al.* 2007). For instance, eThekwini Metropolitan Municipality allocates 65kWh free electricity monthly and supply size limited to 40A single-phase for consumers using less than 150kWh per month at 9.5% of service charge (eThekwini Municipality 2012). Also, the City of Cape Town Municipality allocates 50kWh FBE to consumers below 350c/kWh block distributions[25]. The total policy rollouts of 870 060MWh were consumed in the 2014/15 financial year and 960 348MWh in the 2015/16 financial year (Eskom 2016). Out of the 278 municipalities, 243 signed with Eskom to implement the FBE subsidy (SALGA 2012).

The old method of policy rollout accumulates the FBE subsidy to a designated point for redistribution, based on regional capacities. A new and transparent method was launched that funds free basic services at a fixed monthly amount of R275.17 per household (Njekelana 2013). This method provides estimates on ideal costs, standard thresholds, and affordability for each free basic service. Out of the fixed monthly amount, a total of R56.29, coupled with a 10% maintenance fee, is allocated to energy services. Unlike the old method, the new method allows better redistributive patterns and schemes in both municipalities and households (Njekelana 2013). The new method was used to estimate the total of R5.7 billion granted by LGES for energy services, only (Njekelana 2013). The FBE policy has standards guiding allocation and rollout methods in municipalities (Adam 2010). When the old method did not target the right beneficiary effectively, the new method increased FBE beneficiaries within a decade, particularly in rural areas. The beneficiaries increased from 47% in 2001 to 74% in 2011, also the consumers' units receiving the free FBE (Njekelana 2013). The DoE (at 59%), National Treasury (at 30%), and Stats SA (at 51%) reported conflicting proportions of households receiving FBE benefits, nationwide (SEA 2014). As shown in Table 4.6, FBE recipients amounted to over 1.1 million households and roughly 911 000, in reality, that collected FBE tokens in 2016 (Eskom 2016). In 2018, target beneficiaries increased to about 1.8 million households, as a result of increased subsidies, made accessible by service providers (Masekameni *et al.* 2018). Currently, actual figures of FBE recipients (DoE 2016) are yet undetermined in most municipalities and South Africa, at large.

[25] Discussed in CHAPTER 5: Subsection 5.1.3: Trends in electricity tariffs (Inclining Block Tariffs (IBT) designed)

4.1.5 Free Basic Alternative Energy (FBAE) Policy

INEP (DoE 2015) concentrated on grid-connecting urban areas that slowed down grid connections in rural areas (NPC (SEA) 2014). Accordingly, the Free Basic Alternative Energy (FBAE) policy (DME 2007) was founded in 2007, and implemented in rural households where INEP and FBE rollouts are impossible to penetrate due to shortages in infrastructural developments. As shown in Table 4.7, the FBAE policy aims to address socio-economic issues arising from supply shortages and promote cleaner energy alternatives with fewer health risk impacts in rural households (DME 2007). The FBAE subsidy (DME 2007) embraces the FBE equivalence of R56.29 per month. The policy provides selected energy carriers, including paraffin, LPG, coal, and bio-ethanol gel, to be distributed in energy-poor households. Each energy carrier selected per municipality is based on the jurisdiction area, job creation opportunities, environmental friendliness, affordability, sustainability, and adaptability (SEA 2014).

Table 4.7 Key Concepts - Free Basic Alternative Energy (FBAE) Policy

	Free Basic Alternative Energy (FBAE) Policy
Year of commissioning	2007
Target beneficiary	Rural households
Policy aim	Address socio-economic issues arising from electricity supply shortages in rural areas
Key objective	Promote safe and cleaner energy alternatives with fewer health risks in rural households
Policy funding	Cross-subsidies and Local Government Equitable Share (LGES)
Policy Roll-out	Local municipalities and External service providers
Target met (No of households) and period	40 000 in 2014 (NPC (SEA) 2014)

The main actors in the FBAE implementation are local municipalities with the active participation of target actors and stakeholders. The local municipalities are to identify the supposed areas with households that require FBAE benefits and also select suitable and sustainable energy carriers to fund and deliver in households. They are to create policy awareness and the best ways of consuming the selected energy carriers in households. The attitude of target actors also plays a significant role in the policy implementation process, particularly at the municipal level. The FBAE supply chain is primarily managed by municipalities, who then appoint external service providers when municipal resources are inadequate to provide services but under the municipal supervision. Municipalities also integrated FBAE goals into the Integrated Development Plans (IDPs) as another strategic approach to achieving a better implementation process of the FBAE policy.

The LGES began to fund both FBE and FBAE policies at R56.29 in 2013, increasing target funds but provided better support systems for rural municipal distributors. According to Cooperative Governance and Traditional Affairs (CoGTA)[26], only 40 out of 226 local municipalities implemented the FBAE policy (DME 2007) in 2014, and 14 of them in the Eastern Cape in 2012 (Mohlakoana 2014). Some local municipalities complied with policy conditions by supplying both selected energy carriers and non-grid SHS in 2010 and 2011 (Njekelana 2013). More than 40 000 rural households, including schools, and clinics, are receiving FBAE benefits (NPC (SEA) 2014) (Table 4.7). Since its inception, the policy implementation process has been lagging and local municipalities have been unsuccessful in effectively distributing selected energy carriers in energy-poor households in rural areas.

4.1.6 Inclining Block Tariff (IBT) Policy

The National Energy Regulator of South Africa (NERSA) introduced into the electricity regulatory framework in South Africa, the Inclining Block Tariff (IBT) policy in 2010 (SEA 2014). Primarily, NERSA is responsible for regulating electricity pricing and costs and formulating rules for IBT implementations in municipalities. As shown in Table 4.8, the IBT system operates by billing electricity use on a sliding scale for high-energy consumers (SEA 2014) to cross-subsidize low-energy consumers. Alternatively, the IBT system (SEA 2014) cushions or protects poor households from rising electricity prices, which may affect FBE rollouts and encourages efficient electricity use for high-energy consumers (Adam 2010; Njekelana 2013). The IBT system is regulated and modified as subsidized electricity tariff structures, differentiated into various distribution blocks or consumption ranges (Kelly and Geyer 2018). With IBT regulatory patterns, lower distribution blocks increase at lower tariff rates and higher distribution blocks increase at higher tariff rates.

[26] CoGTA is a national department responsible for coordination and monitoring (of provinces and municipalities) as well as funding the FBAE implementation through LGES

Table 4.8 Key Concepts - Inclining Block Tariff (IBT) policy

	Inclining Block Tariff (IBT) Policy
Year of commissioning	2010
Target beneficiary	Connected poor households
Policy aim	Allows electricity use by high-energy consumers to be billed on a sliding scale to cross-subsidize low-energy consumers
Key objective	Protects poor households from electricity cost rises that can affect FBE rollouts
Policy funding	Cross-subsidization
Policy Roll-out	Eskom and Municipalities

Originally, the flat billing system allowed both wealthy and poor households to consume electricity at the same rates, unlike the IBT system. The IBT policy brought a change in electricity tariff structures by attempting to maintain low-income households in lower consumption bands. This policy is integrated with the FBE subsidy (DME 2003) to improve electricity use in connected poor households. Now, the IBT sliding scheme maintains low-income households within the consumption brackets that allow FBE allocations, while simultaneously, shielding them from electricity price hypes. Up to now, the IBT policy (SEA 2014) has been successfully implemented by NERSA who constantly monitors policy compliance in accordance with guidelines and standards of electricity pricing in various municipalities.

Eskom and municipalities (of about 30%) implement the IBT policy (SEA 2014), which somehow has reduced municipal income flow and delivery of basic services. Essentially, municipalities cross-subsidize low-energy consumers from the revenue generated from electricity sales. In some municipalities, the costs of electricity supply to a large number of cross-subsidized low-energy consumers exceed the supply costs to a small number of high-energy consumers. In municipalities where high-energy consumers are reasonably small, implementing the IBT policy is not so common. Most municipalities continue to use the flat billing system since the sliding scale IBT cannot effectively cross-subsidize low-energy consumers. This is also influenced by the communal meter sharing effect that occurs when electricity consumed by multiple poor households are billed on a single (communal) pre-paid meter.

Table 4.9 Percentage Difference Between the Costs and Revenues of Electricity Sales in Municipalities with the Largest Distribution Capacities. (Source: Mountain 1994, Stats SA 2015: in Kelly and Geyer 2018).

%	Jo'burg	Ts'ane	Ekur'leni	Emfuleni	Rust'brg	Mang'ng	eThek'ni	Msun'zi	Um'tuze	Buffalo	NMB	CoCT	Ave
1992	23.0%	21.0%	14.7%	20.0%	n/a	16.0%	12.0%	19.0%	n/a	15.0%	11.0%	16.0%	16.8%
2006	8.2%	11.1%	13.1%	10.4%	13.4%	n/a	16.8%	22.8%	21.3%	11.2%	9.3%	13.3%	13.7%
2007	13.6%	11.9%	16.3%	15.2%	12.0%	n/a	17.8%	21.9%	16.9%	-4.7%	21.5%	5.2%	13.4%
2008	-0.3%	15.1%	11.2%	16.0%	10.6%	40.9%	19.2%	16.1%	-4.6%	10.8%	14.5%	3.7%	12.8%
2009	3.6%	10.2%	-6.9%	19.6%	15.0%	25.6%	16.2%	11.2%	6.0%	16.1%	19.3%	9.9%	12.1%
2010	6.3%	15.7%	6.1%	24.6%	19.9%	21.2%	13.9%	-3.6%	26.6%	6.5%	23.4%	9.3%	14.2%
2011	8.3%	21.9%	7.8%	16.0%	14.3%	12.7%	16.3%	15.4%	-3.3%	2.8%	12.4%	13.2%	11.5%
2012	9.5%	8.8%	7.4%	14.4%	22.0%	15.8%	14.1%	14.3%	15.8%	5.2%	14.7%	4.9%	12.3%
2013	8.1%	8.8%	7.4%	15.5%	15.4%	9.8%	13.8%	18.1%	19.0%	8.1%	5.2%	4.7%	11.1%
2014	7.9%	3.8%	6.8%	15.5%	15.7%	7.3%	14.4%	13.0%	18.9%	12.5%	12.4%	6.4%	11.2%

+2 std dev | +1 std dev | >1 std dev< | -1 std dev | - 2 std dev

Table 4.9 presents the gross electricity revenues and operational financial costs in some municipalities in 1992 (during the apartheid era) and between 2006 and 2014 (the period when IBT has been implemented). Some municipalities run on a financial deficit attributable to a decline in electricity sales surplus and because "the larger number of cross-subsidized low-income households demands higher costs to supply than the much smaller pool of high usage residential and business customers" (Kelly and Geyer 2018: 212). According to Kelly and Geyer (2018: 212),

> "The average municipal electricity sales surplus in the four years (2007–2010) before IBT is 13.1%, dropping to 11.5% within the four years (2011–2014) after IBT, equivalent to a net revenue reduction of R1.06 billion in municipalities (Table 4.9) in 2014 alone" [sic].

Regardless, determining electricity tariff structures has been a contestation of institutional interactions to setting electricity pricing and guideline for the percentage increase in South Africa (Trade and Industry Chamber (TIC) 2010). According to NERSA, electricity tariffs should be cost-reflective and as well, ensure the financial sustainability of energy services. NERSA also considered different municipal tariff settings within the benchmarking methodology of the policy scheme to improve the cost reflectivity in the cross-subsidy (SEA 2014). On the other hand, NERSA focused on excluding any surcharges, not related to the supply costs, and neglects possible shortfalls in the benchmarking methodology (Trade and Industry Chamber (TIC) 2010). The IBT policy is supposedly faced with several roadblocks, particularly a lack of erstwhile knowledge of electricity use levels to predict revenues within municipal distributors (Trade and Industry Chamber (TIC) 2010). Essentially, IBT cross-subsidizes low domestic users from high domestic users, and commercial businesses. Poor households have benefited from the regulatory IBT, even though municipal interests were neglected. Kelly and Geyer (2018) have considered that revenue loss cannot be completely dependent on the IBT sliding scale scheme in municipalities.

4.2 BENCHMARKING ENERGY PRO-POOR POLICIES

By adopting the study methodology described in Subsection 1.7.1, similar energy policies in Ghana and Botswana were reviewed and compared to energy pro-poor policies in the 1998 Energy White Paper (DME 1998). As previously mentioned, these countries were selected because they share almost the same populations without electricity access, similar to South Africa. Many countries, including these two selected countries, in Sub-Saharan Africa, have commissioned energy pro-poor policies, as a comprehensive solution to energy poverty mitigation, just like in South Africa and as shown in Table 4.10.

Table 4.10 Comparisons between Energy Pro-Poor Policies and Similar Policies in Ghana and Botswana.

	South Africa	**Ghana**	**Botswana**
Primary Objective	**Energy pro-poor policies, programmes, strategies, and plans**		
Pro-poor reduction strategy – delivery of free/subsidized formal housing options	Reconstruction and Development Programme (RDP) in 1998 (DME 1998)	N/A	N/A
To achieve electricity access nationwide; Electrify rural and urban poor households	National Electrification Programme (NEP) between 1994 and 1999 (DoE 2015)	National Electrification Scheme in 1989 (NES) (Energy Commission 2006)	Energy Master Plan
Targeting urban poor and rural households	Integrated National Electrification Programme (INEP) in 2001 (DoE 2015)	Self-Help Electrification Program (SHEP) (Energy Commission 2006)	National Energy Policy (NaEP) (Mzezewa 2009)
Solar home systems (SHS) (and hybrid mini-grids) electrification/renewables in rural areas	Non-grid (mini-grid) Electrification Policy in 2002 (DoE 2012)	National Off-Grid Rural Electrification Program (OEP) (Asumadu-Sarkodie and Owusu 2016) Mini-grid Electrification Policy in 2016 (Arranz-Piera *et al.* 2018)	Rural Electrification Program (REP) (Mzezewa 2009)
Free electricity allocation	Free Basic Energy (FBE) in 2003 (DME 2003)	N/A	N/A
Cleaner alternative energy provision for low-income households	Free Basic Alternative Energy Policy (FBAE) in 2007 (DME 2007)	Ghana Energy Policy - LPG	Biomass Energy Strategy (BEST) (Mzezewa 2009)
Electricity pricing subsidy - billing on a sliding scale	Inclining Block Tariff (IBT) in 2010 (SEA 2014)	Lifeline subsidy (Energy Commission 2006)	N/A

4.2.1 Similar energy pro-poor policies in Ghana

Policymakers in Ghana (Table 4.10) have commissioned several energy policies and programmes to advance energy supply and consumption in households. Originally, in 1989, Ghana commissioned the National Electrification Scheme (NES) to expand electricity in settlements not exceeding a population of 500 (Kemausuor *et al.* 2012). The NES policy promoted socio-economic wealth by attracting foreign investments and decelerated rural-urban migration in Ghana. As a follow-up scheme to NES, the Self-Help Electrification Program (SHEP) was introduced to promote electricity access in remote communities in Ghana. These two policies become a part of integrated rural development programmes of the district assemblies in Ghana (Energy Commission 2006). Subsequently, the SHEP policy increased electricity access to 76% in 2016 from the 2010 access level (at 64.2%) (Serwaa Mensah, Kemausuor, and Brew-Hammond 2014; Asumadu-Sarkodie and Owusu 2016). Other plans, including the Energy for Poverty Reduction Action Plan (EPRAP) and Strategic National Energy Plan (SNEP), founded in 2006, also support the process of reaching universal energy access in Ghana. While the SNEP plan targets supply and demand sectors, EPRAP targets only the demand sector (Kemausuor *et al.* 2012).

As presented in Table 4.10, the national Off-Grid Electrification Program (OEP) was commissioned to expand electricity access in remote and off-grid communities through renewables energy technologies in Ghana (Asumadu-Sarkodie and Owusu 2016). OEP adopts Solar PV systems for only lighting service in off-grid rural areas (Abdul-Salam and Phimister 2016; Kemausuor and Ackom 2017). This programme extended electricity access to remote communities and also increased socio-economic markets for solar PV in Ghana (Atsu, Agyemang and Tsike, 2016). There was also a set target of connecting 19 000 communities, installing 2 000 charging centres within a 5 km distance, and a 16% penetration rate in over 2 000 towns between 2018 to 2020 (Asumadu-Sarkodie and Owusu 2016). In 2016, Ghana, furthermore, initiated the Mini-grid Electrification Policy and projected to hit 100% universal energy access by 2020, particularly in rural areas (Arranz-Piera *et al.* 2018). Nonetheless, the off-grid renewable systems in Ghana require improvements in institutional upgrading, social acceptance, accuracy, and cultural justice, to ensure option sustainability (Feron 2016). The Ghana Energy Policy also aimed to increase 50% access to LPG, mainly in the domestic sector in 2015 but was unsuccessful because commercial vehicles mostly took advantage of the subsidy.

Ghana also adopted a lifeline subsidy targeted to increase electricity access in poor households (Table 4.10). The subsidy mostly considers poor households in the energy pricing matrix by reducing electricity prices. This subsidy has been unsuccessful in effectively shielding these households from rising electricity prices (Szabó *et al.* 2011).

4.2.2 Similar energy pro-poor policies in Botswana

Botswana commissioned many policies (Table 4.10) such as the National Energy Policy (NaEP)[27] to promote sustainable and reliable energy supply, particularly in disadvantaged communities (Mzezewa 2009). Botswana also explored off-grid electricity options, including solar power products and mini-grids, in the Rural Electrification Program (REP). The REP program increased electricity access mainly in rural areas, doubling to 49% of access by 2008 but was limited due to a lack of sustainable funding setups (Mzezewa 2009). The Biomass Energy Strategy (BEST) was also introduced to develop sustainable ways of meeting biomass energy supplies (Mzezewa 2009). Another follow-up initiative was the provision of more wood stoves. This initiative failed because the target group was unable to afford the wood stoves.

4.2.3 Benchmarking energy pro-poor policies

When the first commissioned policy in South Africa, the National Electrification Programme (NEP) (DoE 2015), connected about 66% of households between 1994 and 2000 (Mohlakoana 2014), the NES policy in Ghana only gained 64.2% of electricity access by 2010 (Mensah, Kemausuor and Brew-Hammond 2014). In totality, below one-third of the population has electricity access in Ghana (UNDP, Energy Commission and Ministry of Foreign Affairs of Denmark 2016). As Ghana recorded about 76% of electricity access in 2016, South Africa reported about 88% with the inception of the Integrated National Electrification Programme (INEP) (DoE 2015), with barely less than nine percent of the population without electricity access in 2016 (Stats SA 2016).

In Ghana, over 5 000 non-grid SHS options are mounted whereas about 353 000 installed in South Africa through the non-grid policy (Stats SA 2016). Just similar to Ghana, South Africa has also explored small-scale projects on mini-grids in some rural villages but yet to pass this initiative as a policy.

[27] The actual acronym for National Energy Policy is (NEP). For the purposes of clarity, this was coined as (NaEP) in this study to differentiate from National Electrification Programme (NEP)

As an alternative, South Africa commissioned the FBAE policy (DME 2007), addressing a whole suite of socio-economic issues rising from poor energy use and service delivery. This policy aims to promote safe energy use and reduce energy-related health risks by identifying desirable beneficiaries to maximize effectiveness. Unlike similar policies in Ghana and Botswana, the FBAE policy selected safe energy carriers, to be distributed based on pre-conditioned assessments and given free of charge at a minimum rate of R55 per household (DME 2007)

The IBT policy (SEA 2014) has been successful in regulating electricity pricing and fairly adequate in shielding low-energy users from sharp tariff increases in South Africa (Kelly and Geyer 2018), compared to that of Ghana. Not unlike the IBT policy (SEA 2014), the Ghana lifeline subsidy is also affected by the communal meter sharing effect, where the unit cost of electricity consumption skyrockets to a higher unit cost due to the sharing of a single pre-paid meter by multiple poor households (Energy Commission 2006).

From the comparative study review above, the South African government has demonstrated remarkable progress in advancing energy access through the White Paper document (DME 1998). When benchmarked against the two countries - Ghana and Botswana, South Africa reveals to be way ahead with the commissioning of FBE (DME 2003) and RDP (DME 1998) policies as there are no such policies in these countries (Table 4.10). While FBE allows free electricity quota in connected poor households, RDP delivers free/subsidized houses to poor households. With exceptions to these two policies in Ghana and Botswana, as well as its conceptual frameworks, it can be reasoned that South Africa has the right policies and programmes to mitigate energy poverty, hence addressing Research Sub-question 2[28]. Energy-pro-poor policies are yet to effectively mitigate energy poverty and achieve universal energy access due to setbacks embedding policy frameworks.

The section below discusses various drawbacks in policy implementations limiting policy effectiveness in South Africa.

4.3 DRAWBACKS IN POLICY IMPLEMENTATIONS

Some energy pro-poor policies effectively implemented have also demonstrated laudable progress in advancing energy access over the past decades in South Africa. Even so, energy

[28] CHAPTER 4: POLICY REVIEW: ENERGY PRO-POOR POLICIES. 2 1. Will benchmarking energy pro-poor policies within sub-Saharan Africa validate policy effectiveness to continue to mitigate energy poverty in households in South Africa?

poverty persists in households. Policy implementation processes are now faced with many challenges limiting policy effectiveness. The key challenges in policy implementations are failure to target desirable beneficiaries and a lack of required resources. Table 4.11 presents summaries of recognizable policy drawbacks, together with actions taken thus far to address these drawbacks, as well as up to date policy progress.

Table 4.11 Summaries of Policy Drawbacks, as well as Most Recent Achievements and Improvements.

Energy pro-poor policies and year of commissioning	**Most recent progress and undertaken actions, nationally**	**Major downsides limiting policy effectiveness and sustainability**
Reconstruction Development programme (RDP) (1994) (DME, 1998)	Over 3.9 million (Stats SA 2016)	• High housing demand • Long-standing waiting list • Multiple bids for RDP housing • Upgrade of earlier-built RDP houses • Rising construction cost • Non-adjustable builders' subsidies
Integrated National Electrification Programme (INEP) (2001) (DoE 2015)	• Over 14.8 million (Stats SA 2016) • Connection cost reduction (Bekker *et al.* 2008)	• Limited funds • Servicing backlogs • Illegal connection • The high growth of newly built

Non-Grid (Mini-Grid) Electrification Policy (2002) (DoE 2012)	Over 353 000 (Stats SA 2016)	• Institutional flaws (Feron 2016)
		  ○ Instability
		  ○ Weak regulations
		  ○ Lack of decentralization
		  ○ Institutional adaptability
		  ○ Revenue shortfall
		  ○ Limited technical and financial resources
		• Unaffordability by poor households

Free Basic Energy (FBE) Policy (2003) (DME 2003)	• FBE - about 1.8 million (Masekameni *et al.* 2018)
	• FBAE – over 40 000 (NPC (SEA) 2014)
	• Ongoing workshops to create awareness and influence cultural preference
	• Human capacity support from national initiatives
	• Management systems are presently facilitated by CoGTA.
	• Ongoing communication among stakeholders.
		• Institutionally
		  ○ Funding challenges
		  ○ Inconsistency in FBE disbursements
		  ○ Lack of reporting, monitoring, and evaluation systems
		• Socially
		  ○ Unaware of FBE policy and benefits among energy poor

Free Basic Alternative Energy Policy (FBAE) (2007) (DME 2007)		• Lack of financial, institutional technical, and human resources • A cultural preference for alternative energy • Expensive energy carriers when compared to grid-connection
Inclining Block Tariff (IBT) (2010) (SEA 2014)	• Eskom and about 30 % of municipalities apply IBT (Kelly and Geyer 2018)	• Municipal revenue lost • Non-profitable to poor homes - communal meter sharing

The RDP policy (DME 1998) has shown some notable progress in housing delivery in South Africa. Currently, the programme is faced with challenges, mainly of financial constraints in clearing backlogs and meeting new housing demands (Table 4.11). Majorities of informal households have been on the waiting list for over 10 years and counting. Shortly, more than 12 million informal households living in shacks are expected to bid for RDP houses (Stats SA 2016). These challenges are worsened by the ongoing campaign to improve earlier built low-efficient RDP houses. The economic diversion to thermal upgrading and ceiling retrofits of earlier built RDP houses, coupled with multiple RDP bids and limited funds and resources further restrict policy effectiveness and implementation (SEA 2014; Stats SA 2016). Other policy challenges not listed in Table 4.11 include poor location, unemployment, cost of homeownership, and rapid urbanization.

In the same way, the INEP programme (DoE 2015) has increased electricity access in households, over time as shown in Table 4.11. But, over 871 000 informal households are currently without electricity in South Africa (Stats SA 2016). Challenges limiting policy implementation are particularly the lack of funds to carry out grid-connections in informal households. The DoE, in effect, funds electricity reticulation and connection of informal households, once criteria are met (see DoE 2011: 6-8). Due to limited funds, the DoE discourages the twofold grid-connection when erstwhile connected informal households eventually moved to a new location. INEP is also burdened with clearing electrification backlogs, electrifying new houses, and further frustrated by rising electrification costs. Again, there are high rates of illegal connections in informal households (DoE 2011; King and Amponsah 2012), likely one of many the drivers of peak system demand loads in the supply sector. According to SEA (no date), the diurnal peak demand loads stemming from informal households occur because majorities of informal households are unemployed and spend more time at home. These ongoing illegal connections overload the system and regrettably, are unaccounted for, which results in increased revenue loss in municipalities (DoE 2011).

The non-grid policy (DoE 2012) has also improved electricity access through Solar SHS installations in rural households. In Table 4.11, the non-grid policy has multidimensional weaknesses, strongly rooted in institutional, economic, environmental, and socio-cultural structures. Essentially, institutional sustainability is flawed (Feron 2016) because of the skepticism of embracing non-grid SHS and risking rural electrification in municipalities (Njekelana 2013). The DoE (2012) also reported that high operational costs of non-grid electricity are institutionally unsustainable. Yet, the integrated energization approach switches the focus away from exclusive non-grid electrification (Davidson *et al.* 2006). Other policy challenges include, among others, proof of employment and the ability to maintain monthly payment by end-users (Davidson *et al.* 2006). Alternatively, high investment costs, technical complexity, and household low income and energy use limit the predisposition of mini-grid developments in rural areas. Mini-grid electricity can be cost-effective when end-users benefit from available subsidies. However, available subsidies are inadequate to promote the use of mini-grids in rural households (Brent and Rogers 2010). Also, the financial costs of mini-grid electricity use increase as electricity prices increase, making it unaffordable for low-income households (Oliva H., Macgill and Passey 2016). Mainly, the investment costs of hybrid mini-grids accumulate from obtaining renewables resources e.g. water and wind, which are often unavailable in very remote villages. One study, in support, reported that using renewables resources to power hybrid mini-grids can be cost-effective in achieving rural electrification (Patel and Chowdhury 2018). As a rural development solution, Azimoh *et al*. (2016), nevertheless, argued that hybrid mini-grids cannot entirely support most income-generating activities in South African villages. Instead, Patel and Chowdhury (2018) assessed another potential electrification option - a micro-hydro battery micro-grid - that could sustain both technical and economic benefits in rural areas.

The FBE policy (DME 2003) has increased electricity consumption in connected low-income households through allocations of free electricity. As presented in Table 4.11, the major challenge is the inconsistency in policy disbursements by service providers. There are also conflicts in FBE management, which involves a lack of proper reporting, monitoring, and evaluation systems, particularly at the local government level. The free electricity quota is available for low-income households to access but has been unable to reach the intended beneficiaries. Two self-targeting approaches, such as indigent register and consumption thresholds, are employed to identify poor households in municipalities. While the indigent register limits desirable beneficiaries in number and genuineness, consumption thresholds qualify more wealthy than poor households due to communal meter sharing effects. These approaches limit the genuineness of the FBE candidacy and result in most low-income households being considered ineligible to receive FBE. Again, most poor households are unaware of the policy since most municipalities do not create awareness (Masekameni *et al.* 2018). For example, in four governmental sites comprising of 165 households, only 9% are aware of the subsidy and 91% are unaware (Masekameni *et al.* 2018). More than 99% of municipalities have registered FBE beneficiaries, with no existing functional management schemes to cater to them. More so, occasional diversions of grants to other unrelenting demands in municipalities limit policy effectiveness. No grid-connections in remote rural areas also restrict policy benefits in rural households. FBE benefits are practically irrelevant in informal areas with high levels of electricity theft.

Sustaining energy access was anticipated through the FBAE (off-grid) policy (DME 2007) to promote the use of cleaner energy in households. The FBAE policy (DME 2007) has been unsuccessfully administered in rural areas since its inception. As shown in Table 4.11, the challenges are mainly due to a lack of institutional and practical structured strategies in implementing policy. Due to human, technical, and financial implications as well, most municipalities do not implement the policy. Other challenges include delays or lack of indigent registers and municipal decisions, and unregulated costs of selected energy carriers. The unregulated costs of these energy carriers are, sometimes, costlier than either grid or non-grid electricity consumption. In addition, socio-cultural preferences to particular energy choices restrict FBAE initiatives in energy-poor households (Mehlwana 1997; Njekelana 2013). At this point, only a small proportion of households receive FBAE benefits in rural areas in South Africa.

The IBT policy (SEA 2014) cross subsidizes and protects low-income households from the electricity price hype. But, the major flaw of the IBT system is not shielding low-income households from high costs of electricity use due to communal meter sharing (Table 4.11). Majorities of informal and rural households are not even electrified to benefit from the IBT subsidy. On the other hand, NERSA seemed to neglect the discrepancy between cost base and supply cost factors in municipalities, whilst setting electricity pricing guidelines (Kelly and Geyer 2018). This results in municipal revenue loss, along with a decline in electricity sales surplus. For instance, in 2012, revenues from sales surpluses dropped by R400 million in the eThekwini metropolitan municipality (Govender 2010: in Kelly and Geyer 2018); and roughly by R80 million from 2010 to 2012 in Mangaung Local Municipality (CENTLEC 2010: in Kelly and Geyer 2018). In some cases, municipal distributors would generate huge losses from electricity sales, limiting municipal capabilities to cross-subsidize low-income households. Today, NERSA and municipal distributors are faced with the responsibility to maintain affordable energy services among poor energy consumers. Also, NERSA is yet to integrate various municipal variations and compositions into the benchmarking methodology used for setting electricity tariffs in South Africa (Salvoldi 2004).

In addressing sub-question 3[29], the policy objectives of the 1998 Energy White Paper (DME 1998) have been achieved to a greater extent. As discussed above, policy drawbacks have revealed to influence not achieving, completely, the policy objectives in the White Paper

[29] CHAPTER 4: POLICY REVIEW: ENERGY PRO-POOR POLICIES. 3 Have the objectives of energy pro-poor policies in the 1998 Energy White Paper document (DME 1998) been achieved?

document. These drawbacks consist of institutional flaws, fiscal deficits, and poor socio-technical structures, generating irregularities in policy execution. Major policy drawbacks include non-targeting of the right beneficiaries and whole policy objectives, therefore, responding to study sub-question 4[30]. Ultimately, the review has provided qualitative and quantitative shreds of evidence, useful for designing well-informed policy interventions and strategies. Based on the context-specificity of this study review, transformative ambitions of these policies can be realistic through effective interventions and implementation processes, well-rooted in multidimensional and systemic approaches. As a solution, review-based recommendations, improving policy effectiveness, and informing future policy decisions, are discussed in the section below.

4.4 RETHINKING POLICIES AND RECOMMENDATIONS

Through the RDP programme (DME 1998), since 2004, the government has been trying to improve the lives of millions of shack dwellers by 2020 and make South Africa a 'shack-free' society. Some plans have been restructured to reduce challenges in RDP development and delivery, mostly at the state level. Notable progress has been recognized but imperceptible drawbacks in policy do require attention. The proposed recommendations for the RDP programme (DME 1998) presented in Table 4.12 are expected to balance out increasing demands, backlogs, and multiple RDP housing bids. Policy reforms on RDP largely solicit financial innovations through private investments, among others. Importantly, designing countermeasure strategies that dissuade households from commercializing RDP houses, whilst maintaining the RDP programme (DME 1998) as a poverty alleviation scheme it was commissioned to be.

[30] CHAPTER 4: POLICY REVIEW: ENERGY PRO-POOR POLICIES. 4 Are irregularities in policy implementation processes, a result of financial, institutional, technological, or environmental challenges?

Table 4.12 Policy Recommendations on Matters Affecting Policy Effectiveness

Energy pro-poor policies and year of commissioning	**Review-based Recommendations, particularly on major drawbacks limiting policies**
Reconstruction Development programme (RDP) (1994) (DME, 1998)	• Further advancements in the institutional, socio-economic, and technical management systems at state and national levels. The financial system is essential for policy operations and should consider the involvement of private investors to support RDP development, delivery and upgrading, and clearing housing backlogs.
	• Innovative designs or initiatives to monitor multiple bids or requests of RDP housing options should be put in place. Without this check, the programme will continue to benefit few households, while stacking up backlogs and long waiting lists that are non-representative in actuality.
Integrated National Electrification Programme (INEP) (2001) (DoE 2015)	• According to the DoE (2016), INEP has subsidized a quota of the capital cost of grid-connection (DoE 2015). In the past few years, the unsubsidized quota has over-doubled due to increasing financial constraints in municipalities. It may be worthwhile that the unsubsidized quota of the connection cost remains either static, in decline, or wholly subsidized, in the near-term[31] to improve electricity access in informal households
	• Financial supports from private investors and other organizations as well as strong government backup are needed in electrifying informal households.
Non-Grid (Mini-Grid) Electrification Policy (2002) (DoE 2012)	• If possible, there should be an upgrade on non-grid systems to increase the operational capacity to meet more than the lighting service in households. Also, improvements in financial logistics will ensure the sustainability of the access option and the environment.
	• Allow public participation and private investments into mini-grid projects when the policy is finally passed, to enable the expansion of mini-grid systems in rural areas.
	• There is a need to design a practical methodology for designing and controlling mini-grids according to the settings of South African rural areas. By adequate planning and optimizations of natural resources such as hydro and wind, electricity generation costs of using hybrid mini-grid systems will also be reduced (Azimoh *et al.* 2016)
Free Basic Energy (FBE) Policy (2003) (DME 2003)	• Through enhanced public communication, upgraded community engagement, and awareness strategies to increase FBE consumptions, particularly in rural areas
	• There should be an increase in the 50 kWh fixed FBE allocation, following Adam's (2010) estimations. Some municipalities provide more than the fixed allocated FBE but others continue to provide the fixed amount or even less the fixed quota.
Free Basic Alternative Energy Policy (FBAE) (2007) (DME, 2007)	• The FBAE execution needs to be monitored with periodic verifications of poor households and reporting to CoGTA. The national government should also be actively involved in the monitoring process by evaluating the cost-effectiveness and quality of services received by beneficiaries. These protocols will provide clear pathways in designing the requirements to promote FBAE successful implementation in rural communities
	• The ongoing reform in FBAE planning and strategies, previously campaigned by Borchers and Dobbins (2007) and Mohlakoana (2014), should be preserved. These strategies are to create awareness and change cultural perceptions of energy choices within a target group through workshops and education
	• There should be a regulatory scheme to monitor energy costs of selected energy carriers within FBAE, since these carriers are, sometimes, costlier than the cost of using grid electricity.
Inclining Block Tariff (IBT) (2010) (SEA, 2014)	• The communal meter sharing, spiking up electricity costs for low-income households, should be objectively considered in future policy strategies and plans.
	• NERSA should consider different municipal compositions in the benchmarking methodology to reduce revenue loss.

[31] This recommendation is further validated later in this study by examining the forecast relationships between meter installations and connection costs in the City of Cape Town. These two parameters were observed to increase, correspondingly, through to 2030. Fully discussed in Chapter 5, Section 5.1: HISTORICAL TRENDS and FORECASTS: ELECTRICITY ACCESS RATES, CONNECTION COSTS, and TARIFFS.

Although the INEP programme (DoE 2015) has connected millions of households since its commissioning, there are still large electrification backlogs in informal households. This is worsened by financial constraints, institutionally, and municipal revenue loss through ongoing illegal connections in informal settlements. INEP, before now, has developed strategies addressing the twofold electrification funding, and as well, set criteria for subsidizing grid-connection costs in informal households (DoE 2016). INEP (DoE 2015) needs clear-cut recommendations, as proposed in Table 4.12, in order to advance electricity access by 2030, particularly in informal households. These recommendations will aim to advance electricity access and reduce electricity thefts in informal settlements. Apparently, electrifying informal households reduce municipal revenue loss and befalling accidents during electricity theft activities. These matters are currently subject to municipal credit control measures, as well as ongoing forums in all governmental tiers (Bantsijang no date).

Rural dwellers may be less enthusiastic about non-grids and mini-grids partly due to limited power capacity and lack of subsidies in these options. These renewable options can be more cost-effective in terms of operational and maintenance costs but certainly, demand advance modifications under the policy and retail market arrangements. Most recent reformations were conducted on optimal sizing and control of hybrid mini-grid systems with no designed methodical approach to actual implementations (Meje, Bokopane and Kusakana, 2018). Policymakers are currently facilitating distributions of these technologies, while at the same time, handling the impact on key stakeholders. The non-grid (mini-grid) policy also requires some technical and financial adjustments based on proposed recommendations described in Table 4.12.

The danger of the FBE policy mainly lies in peak load events and costs of peak power supply (Howells *et al.* 2006). Howells *et al*. (2006) argued that FBE distorts household energy expenditure by encouraging electricity use for cooking during high peak system loads, even though energy alternatives such as LPG deliver an additional worth of at least 6% at no additional public cost. The policy has increased electricity use and reduced energy burdens in connected poor households (Ye, Koch and Zhang, 2018) even without its awareness in some areas (Kambule *et al.* 2019). CoGTA and other national initiatives have imitated actions to increase FBE awareness in the country, although Masekameni *et al*. (2018) argued about the effectiveness of those actions. This study, in sync with Masekameni *et al*. (2018), proposes practical actions for future policy reforms, as summarized in Table 4.12.

There are no proper reporting and monitoring of the FBAE policy in service authorities (DME 2007). National initiatives including CoGTA, DoE, SALGA, and Eskom are taking actions to support both FBE (DME 2003), and FBAE (DME, 2007) policy implementations, at the municipal level (Bantsijang no date)[32]. There are ongoing workshops to create awareness for these two policies at all governmental tiers - provincial, municipal, and district. Mohlakoana (2014) suggested an interactive system involving the active participation of actors and stakeholders, at all governmental levels. Two studies have also recommended ways to improve FBAE at all tiers (see Borchers and Dobbins 2007; Mohlakoana 2014). This study augments literature and ongoing actions by proposing some interventions presented in Table 4.12 to improve FBAE effectiveness. To a considerable extent, these proposed recommendations improve cleaner energy access and relapse household socio-cultural inclinations to specific energy choices (SEA 2014). They can also facilitate capital investments in the financial, institutional, and technical systems to support a better policy implementation process. In the interim, the off-grid FBAE can act as a stop-gap until a more sustainable access solution is provided to improve energy access in informal settlements, particularly those settlements developed on unplanned and under-developed land that can be reclaimed by the government at any given time.

Major complications in cost-recovery and cross-subsidization of the IBT policy include the communal meter sharing effect and municipal revenue loss. These complications bring about reinstating the flat billing system in some municipal distributors and may affect policy sustainability. The IBT policy has improved energy-use behaviour to power consumption, particularly in poor households using a single pre-paid meter (Thakur and Chakraborty 2016). The policy can be more effective when pertinent challenges are addressed, based on recommendations summarized in Table 4.12. As it stands, the DoE has empowered municipalities to implement cross-subsidization surcharges to reduce revenue loss and support local development, and technical and economic efficiency, excluded in the rigid NERSA benchmarking methodology (Kelly and Geyer 2018).

In summary, this study review has provided policymakers with a series of review-based recommendations and interventions that require pragmatic actions in improving policy effectiveness and implementations. These recommendations are expected to align with political

[32] Matthews Bantsijang - Director of Electricity Policy. A presentation accessible on *https://pmg.org.za/files/130618doefbe.ppt*

economy and governance and also provide a better outlook for designing target-based policy schemes in South Africa. With future policy reforms grounded on these proposed recommendations, the correct beneficiaries will be targeted, policy implementation processes will be improved and the whole policy objectives, achieved, whilst concurrently addressing study sub-questions 1 and 3[33].

4.5 CONCLUDING REMARKS

A working energy sector depends on and is not limited to the core objectives of maintaining constant energy supply, introducing efficient energy-use methods, and constantly developing alternative access options. In addition, developing technical innovations in energy sectors requires flexible and smart policies balancing demand and supply, since effective policies expedite energy access. Hitherto, the literature discussed challenges[34] in the South African energy system and ways[35] of advancing energy access in South Africa, and in sub-Saharan Africa, at large. The South African government also recognized the persistence of energy poverty in poor households in the country. Also, the government has been improving cleaner energy access in these households through energy pro-poor policies. Over time, energy access levels have increased at the household level by way of introducing context-specific and sustainable actions within the frameworks of these policies.

The policy study in this chapter has revealed that policy objectives are met, albeit, not completely, coupled with some progress, since commissioning. By 2016, INEP (DoE 2015) connected over 14 million households. FBE (DME 2003) reached further to benefit about 1.8 million households by 2018 (Masekameni *et al.* 2018). FBAE (DME 2007) and non-grid SHS (mini-grid) (DoE 2012) policies facilitate clean energy access and consumption in rural households. The IBT policy (SEA 2014) shields low-income households from constant sharp upswings in electricity tariffs. The RDP programme (DME 1998) improves the lives of slum dwellers and their energy-use efficiency and has thus far delivered more than 3 million RDP houses in South Africa. These policies are also proven as useful tools to energy poverty mitigation in households when compared to similar policies within the sub-Saharan African context. To a large extent, government efforts and progress have been validated in promoting clean energy access and energy service delivery in households for the past 20 years.

[33] CHAPTER 4: POLICY REVIEW: ENERGY PRO-POOR POLICIES. 1. How effective are the existing implementation strategies in reaching the right beneficiaries at whom these policies are aimed? 3. Have objectives of energy pro-poor policies expressed in the 1998 Energy White Paper (DME 1998) been achieved?
[34] Section 2.3: ENERGY DISTRIBUTION AND CHALLENGES PARTICULAR TO SOUTH AFRICA
[35] Section 2.8: CONTROLLING ENERGY POVERTY

The policy study also identified challenges in policies limiting effective energy poverty mitigation in households. Major challenges such as financial constraints and non-targeting approaches have been highlighted as significantly limiting policy effectiveness and implementation in South Africa. Consequently, this policy study provided review-based recommendations to circumvent these challenges, agreeing with other policy studies in the country (Borchers and Dobbins 2007; Mohlakoana 2014; Kelly and Geyer 2018). Perhaps, actions have been previously taken or are currently taken to address most policy recommendations in this thesis (Borchers and Dobbins 2007; Mohlakoana 2014; Kelly and Geyer 2018). Some challenges in policies, such as multiple RDP housing bids and electricity thefts, have been neglected for so long, even in literature. No solutions have been offered to address these imperceptible challenges during this research. Tackling these subtle policy challenges requires critical strategies, according to the recommendations suggested in this research, to advance policy resourcefulness and transparency in policy implementation processes.

Finally, this policy study has provided significant action-based policy interventions and strategies, addressing a whole suite of issues significantly limiting policy effectiveness and energy poverty mitigation, when integrated into a policymaking process. With government compliance and stakeholders' involvement, these interventions will improve cleaner energy access and consumption efficiency at the household level, which potentially can undermine inequality in energy distribution in the supply sector. With the right reforms on policies, electrification structures, and resources will potentially improve in the energy sector and electricity access equally distributed between rich and poor households. Eventually, policy reformations based on policy challenges will promote the correct targeting of desirable beneficiaries and energy access sustainability. As for now, policymakers ought to consider fundamental relationships between new energy technologies and socio-cultural concerns, defining a target group, into the policymaking process. The way it is, rethinking pro-poor policies, based on imperceptible challenges in policy, will eventually improve policy effectiveness, mitigation of energy poverty, energy access sustainability, and future policy benefits in South Africa.

CHAPTER 5: RESULTS AND DISCUSSIONS

Having addressed Research Objective 1 in Chapter 4 above, this chapter addresses Research Objectives[36] 2, 3, 4, and 5, primarily centred on electricity access, spatial analysis, energy-use patterns, and SRM application. For each objective, the chapter discusses result analyses and discussions, categorized into sections below, describing:

- Historical trends and predictions of electricity access and connection costs; and historical trends and analyses in electricity tariffs in the City of Cape Town - the secondary case study area.
- Land-Cover (LC) classifications and Land-Cover Change (LCC) analysis and detection of informal areas in the City of Cape Town.
- Energy-use patterns and other energy-related data, and relationships between parameters in the Sofia Settlement – the primary case study area
- Finally, the application of the new SRM in the primary case study area and presentations of results and discussions.

5.1 HISTORICAL TRENDS and FORECASTS: ELECTRICITY ACCESS RATES, CONNECTION COSTS, and TARIFFS

This section addresses Research Objective 2[37] by employing the study methodology in subsection 1.7.2 in addressing Research Question 2[38] and sub-questions below:

1. Will the forecast relationships between access rates and costs achieve total electricity access by 2030 in informal households?

2. Are subsidized costs and tariffs affordable to improve electricity access and consumption, respectively, in informal households, when compared to non-subsidized structures?

[36] See Section 1.3: RESEARCH AIM AND OBJECTIVES
[37] See Section 1.3: RESEARCH AIM AND OBJECTIVES. 2 Assessing trends in electricity access and related matters, and predict future scenarios supporting total electricity access by 2030 at a regional level, using the City of Cape Town
[38] Section 1.4: RESEARCH QUESTIONS. 2. What is the trend in electricity access over a historical 8-year period? Will assessing electricity access and related matters in such a period, be suitable to predict future progress in achieving total electricity access by 2030 at a regional scale?

In this section, analyses of study results and lastly, the discussions are categorized into subsections below:

3. Trends in (electricity) access rates (meters installed) and forecasts
4. Trends in (electricity) access costs (connection costs) and forecasts
5. Trends in electricity tariffs (the IBT sliding scale designed scheme) and other contingencies
6. Discussions: Implications of forecasted parameters and future scenarios

5.1.1 Trends in access rates (meter installed) and forecasts

As previously discussed (in subsection 1.7.2), the historical records of meters installed (hereafter, access rates) in the City of Cape Town were employed to assess rates of grid-connections from 2010 – 2018. For these assessments, the household population without electricity access in 2016 was benchmarked and the year 2016, set as the base year. This approach is to serve as a guide in analyzing the historical access rates, as well as future scenarios, to achieving total electricity access by 2030, set by the United Nations (2014) to reduce energy poverty. As shown in Table 5.1, nine percent (4 764) of formal households (including houses, flats, blocks of flats, and apartments), and nearly 91% (46 889) of informal households (backyard and not backyard located[39]) were without electricity access in 2016. Altogether, the total population of more than 51 000 formal and informal households was without electricity access in 2016 - the base year (Table 5.1).

Table 5.1 Community survey 2016 of households with and without electricity in the main dwellings in the greater City of Cape Town. (Source: Stats SA (2016).

Main dwellings	Households with electricity access (%)	Households without electricity access (%)
Informal dwelling/shack not in the backyard	7.60	73.56
Formal dwelling/house or brick/concrete block structure on a	79.65	7.31
Traditional dwelling/hut/structure made of traditional mater	0.16	0.34
Flat or apartment in a block of flats	4.82	0.16
Formal dwelling/house/flat/room in backyard	3.01	1.57
Informal dwelling/shack in the backyard	4.19	13.24
Room/flatlet on a property or larger dwelling/servants quart	0.20	0.19
Caravan/tent	0.01	0.11
Other	0.37	3.52
Total number of households	**3 651 448**	**51 653**

[39] Informal households, in backyards, live in shacks developed on erstwhile vacant land behind formal/residential dwellings; Informal households, not in backyards, live in shacks developed on erstwhile vacant land, not behind formal/residential dwellings;

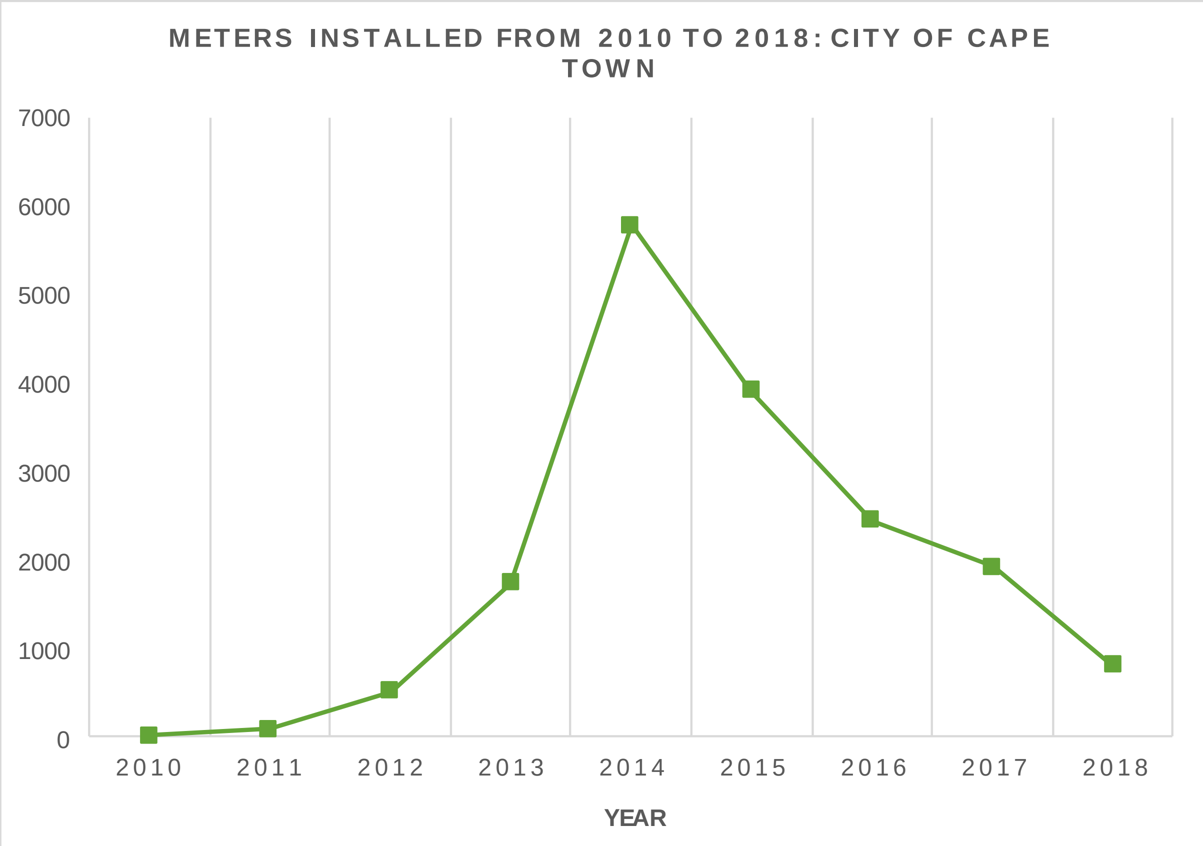


Figure 5.1 Historical events of access rates (meter installations) within the 8 years in the City of Cape Town. (Source: EGD 2018)

As shown in Figure 5.1, the time plot of historical access rates in the City of Cape Town followed a sinusoidal pattern. From 2010 to 2012, meters installed were stagnantly slow in households. The peak access rate, within the period, of about 34% was attained in 2014. This might be due to huge investments in infrastructure and increased national electrification by Eskom, in the early post-2000 era[40]. Out of the total number of 51 653 households without electricity access in the 2016 base year, merely 2 436 meters were installed. Presumably, increased meter installations in 2014 and 2015 might have been more prevalent in formal households that led to only nine percent with no access in the base year. Access rates progressively dropped from 2014 forwards, accounting for only five percent of meter installations in 2018. From 2016 to 2018, a total number of 5 148 households, including formal and informal, were connected, which resulted in a remaining number of 46 505 households without electricity access in the base year.

[40] Subsection 4.1.2: Integrated National Electrification Programme (INEP). The implementation progress of INEP, particularly that between the pre-2000 and post-2000 eras

By using forecasting techniques described in subsection 1.7.2, historical access rates were projected to assess future scenarios of electricity access and the prospect of achieving total access by 2030 in the City of Cape Town. We recall that the United Nations (2014) set to achieve total electricity access by 2030. Also, the household population without electricity access in the base year is benchmarked in analyzing the forecast trend (2019 – 2030). Importantly, the forecast analyses considered a Business-As-Usual (BAU) scenario – a scenario where normal operational processes are maintained, with no alterations whatsoever, within service providers. This line of thought is adopted to recognize organizational dynamics, influencing historical access rates to perchance affect future access rates based on the BAU scenario.

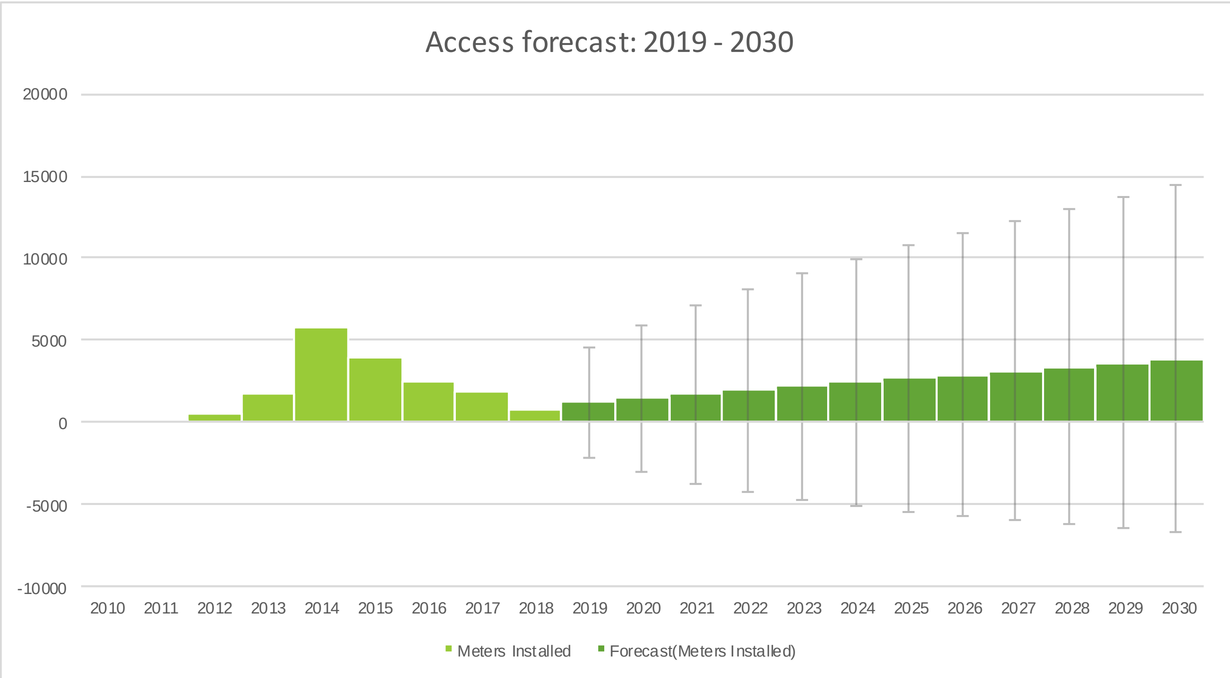


Figure 5.2 Historical events of meter installations from 2010 to 2018, and the projections from 2019 to 2030 in the City of Cape Town. Source: EGD (2018).

As shown in Figure 5.2, forecasted access rates gradually increase across the forecast period (2019 - 2030) based on a BAU scenario, with the least outputs generated from 2019 to 2021. Within this period, a total of 30 379 meters were installed, connecting about one-third of households without access in the base year. With a shift in a BAU scenario in the form of institutional modifications, policy reforms, subsidies, among others, the upper limits of forecasted events can be reached. The upper limits of forecasted events are the predicted maximum values of events, whereas the lower limits return expected minimum values. The upper limits (confidence level = 95%) generated 120 223 installed meters in the period, connecting the total population without access in the base year and gaining total electricity access by 2030. With a tail-off in a BAU scenario, such as financial constraints, reduced services, among others, the lower limits of forecasted events are reached. At these limits (confidence level = 95%), no meters are installed, also generating 59 465 uninstalled meters. This possibly will occur if a tail-off in a BAU scenario is aggravated by new residential developments during the forecast period.

Table 5.2 Predictions and Scenarios of Access Rates in Reaching Total Electricity Access by 2030, Benchmarked Against the Total Household Population Without Electricity Access in the Base Year (2016) in City Of Cape Town.

Assumptions of different forecast scenarios	**Predicted year to achieving total electricity access**
100% electricity access in 4 764 formal households without access – BAU scenario	2022
100% electricity access in 46 889 informal households – BAU scenario	2034
100% electricity access in 46 889 informal households – Tail off in BAU trajectory	Infinite (∞)
100% electricity access in 46 889 informal households – Major shift in BAU trajectory	2025
100% electricity access in the City of Cape Town – BAU scenario	2035
100% electricity access in the City of Cape Town – Major shift in BAU trajectory	2025
100% electricity access in the City of Cape Town – Tail off in BAU trajectory	Infinite (∞)

As previously indicated, 4 764 formal and 46 889 informal households, totalling 51 653 households were without electricity access in 2016 (Stats SA 2016). Analyzing forecast scenarios is to assess future events of access rates and probable periods to achieve total electricity access in the City of Cape Town. As presented in Table 5.2, the total population without electricity access in the base year can be grid-connected and gaining total electricity access by 2035, i.e. five years beyond the set year by the United Nations (2014). In formal households, total electricity access can be achieved by 2022, and by 2034 in informal households. Even with a major shift in the BAU trajectory, total electricity access is only achieved by 2025 in informal households, while a tail-off in a BAU scenario consistently increases a lack of electricity access. It is necessary to consider parameters such as the affordability of connection costs (DoE 2015), and electricity tariffs (SEA 2014), as well as available subsidies (DoE 2016), to increase access in informal households and achieve total access by 2030 in the City of Cape Town. The section below analyzes connections costs (hereafter, access costs) and the relationships between access costs and access rates (meters installed). The following section thereafter analyzes the historical trends in IBT-designed electricity tariff structures.

5.1.2 Trends in access costs (connection costs) and forecast

The historical records of connection costs were employed to analyze the costs of meter installations, over time, in the City of Cape Town. This section analyzes the historical and forecast trends in access costs and its relationships with access rates. Increasing electricity access, particularly in informal households, demands that connection costs are affordable (Winkler *et al.* 2017). The City of Cape Town designed and employed two structures of connection costs - Subsidized Connection Costs (SCC) and Non-Subsidized Connection Costs (NSCC). Analyzing these two structures assesses affordability levels of connection costs, particularly to the benefits of low-income households. The SCC structure comprises of subsidized access costs designed for single-phase energy users, including low-income earners and informal households. NSCC is non-subsidized access costs, designed for high-income earners or energy consumers of up to 60A single phase.

Table 5.3 Table showing Access Rates (Meters Installed) and Access Costs (SCC), Significance of Relationships between them, and Annual Percentage Increase in SCC. (Source: EGD 2018)

Financial Year	Access rates (No of meters installed)	SCC excl. VAT (ZAR); single-phase connection	% annual increase in SCC (%)	Between access rates and SCC (X^2)	Significance alpha level = 0.05
2010	2.00	179.82	-	0.037	<0.05
2011	77.00	197.37	9.76	0.024	<0.05
2012	506.00	210.53	6.67	0.003	<0.05
2013	1731.00	221.93	5.41	0.003	<0.05
2014	5783.00	555.26	150.20	0.019	<0.05
2015	3910.00	587.72	5.85	0.004	<0.05
2016	2436.00	621.05	5.67	0.000	<0.05
2017	1915.00	657.72	5.90	0.004	<0.05
2018	797.00	695.18	5.70	0.037	<0.05
Total	**17157.00**	**3926.58**			
Mean	**2263.61**	**906.29**			
Standard deviation	**1415.47**	**486.37**			
X^2 (Critical value)		**15.51**			
p-values (Pearson)		**0.015**			

The relationships between the historical trends of SCC and access rates and the percentage change in SCC within the period (2010 – 2018) are summarized in Table 5.3. As presented in Table 5.3, access costs concurrently increase with access rates up until 2014, when meter installations began to decline. For SCC per meter installation, both groups' values gradually increase across the period. There is a difference ($p < 0.05$) between, and within, these two groups. Moreover, less than 10% annual increase in SCC occurs throughout the assessment period, except in 2014. With more than a 150% annual increase, SCC increased from R222 in 2013 to R555 in 2014. Remarkably, the highest access rate of more than 5 000 meter installations was gained in 2014. SCC at R695 installed 797 meters in 2018, increasing to R733.39 in the 2018/2019 financial year (EGD 2018b *pers. com*).

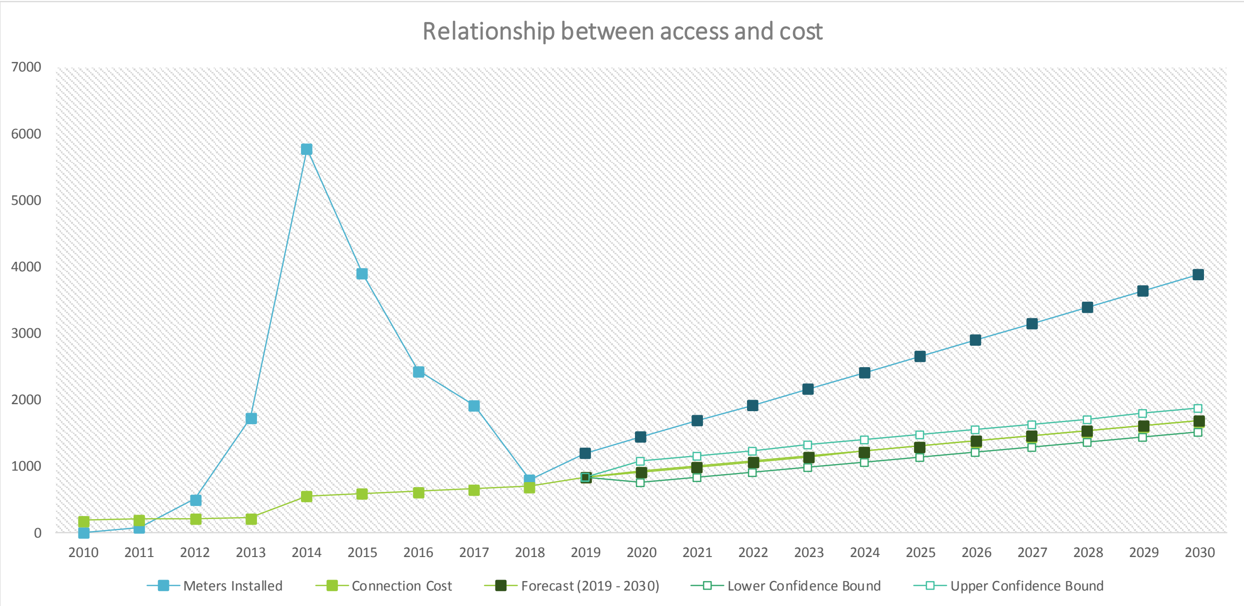


Figure 5.3 Relationships between Historical and Forecasted Access Rates (Meters Installed) and Access Costs (SCC) in the City of Cape Town. (Source: EGD 2018).

Analyzing the relationships between the forecasted events assesses the future impact of connection cost per meter installation to achieving complete electrifications by 2030. As presented in Figure 5.3. the time-based relationships reveal an increasing trend in forecasted SCC across the forecast period (2019 – 2030), similar to the trend in projected access rates. These two groups independently incline, separating the two time-plots and widening the gap between them. At this rate, higher access rates can be gained at higher subsidized costs. We recall that a larger population of low-income households such as informal households were without access in the base year, even with SCC at R621 (Table 5.3). With inclining SCC, achieving total electricity access by 2030 may be impractical if improving access rates in informal households depend, only on household income. The upper or the lower limits (conf. level = 95%) of forecasted SCC can be obtained, if the BAU scenario is altered. With a major shift in BAU, in the form of subsidies, new policies, and other measures, attaining the lower limits of forecasted events is possible. From the literature[41], energy policies, relevant in

[41] Section 4.3: DRAWBACKS IN POLICY IMPLEMENTATION

improving energy access, mostly in informal households, are presently imbued with several drawbacks limiting policy effectiveness.

Table 5.4 Summarized Univariate Analysis of Non-Subsidized Costs (NSCs) And Subsidized Costs (SCs) from 2010 to 2018 in the City of Cape Town. (Source: EGD 2018)

Statistic	Non-subsidized cost (in Rand, excl. VAT) per connection; 60A single-phase (New residential supplies;)	Subsidized cost (in Rand; excl. VAT) per connection; 20A single-phase connection
No. of observations	10.00	10.00
Minimum	953.51	179.82
Maximum	2432.00	733.39
1st Quartile	1626.75	213.38
Median	1719.74	571.49
3rd Quartile	1867.10	648.55
Mean	1761.80	466.00
Variance (n-1)	166694.85	54055.25
Standard Deviation (SD) (n-1)	408.28	232.50

To evaluate the affordability level of the SCC structure, the NSCC structure is employed as a comparative tool. As shown in Table 5.4, the historical trends of these two groups were summarized using the univariate analysis in describing the relationships and comparisons between, and within the groups. Similar to the historical trend in SCC, NSCC also increases across the period (2010 to 2018) (EGD 2018b *pers. com*). The analyses within NSCC events reveal higher Mean, SD, first quartiles, third quartiles, and the median (the second quartile of events) than those of SCC. Annual increases in NSCC were predominantly less than 15.5%, except in 2011 and 2018, having about 62%, and 42%, respectively (EGD 2018b *pers. com*). While the highest NSCC was at an amount of R2 432 per meter installation in the 2018/19 financial year, SCC was at R733 (EGD 2018b *pers. com*). SCC may not show to improve electricity access in informal households or achieve total electricity access by 2030 but this structure has been allegedly designed to be affordable by low-income households.

5.1.3 Trends in electricity tariffs (Inclining Block Tariffs (IBT) designed)

As previously discussed in subsection 4.1.6[42], NERSA introduced the IBT policy into the electricity regulatory framework in South Africa in 2010 to protect poor households from electricity cost rises (SEA 2014). Electricity tariffs may not promote electricity access in households but tariff affordability improves electricity use. Like access costs, analyzing the historical records of electricity tariffs assesses the affordability levels between the tariff structures in the City of Cape Town. The City of Cape Town employs three tariff structures

[42] Subsection 4.1.6: Inclining Block Tariff (IBT)

designed – for low-energy users (subsidized - FBE services within the lifeline consumption blocks), domestic users (partly subsidized - receives FBE when consumption is <450 kWh per month), and home users (non-subsidized - no FBE services apply) (EGD 2018b *pers. com*). Subsidized tariffs for low-energy users comprise of various consumption blocks (or distributions), imbued with free FBE allocations. While domestic users' tariffs are partly subsidized in some limited blocks, home-users' tariffs are exclusively non-subsidized. Both domestic and home users are billed using a twofold structure - electricity tariffs and energy service charges for network access and administration fees. According to EGD (2018b *pers. com*), domestic and home users (with a municipal property valued at >R1million) are natural persons (single-phase users) using electricity in private residential establishments.

Table 5.5 Historical Events of Subsidized IBT Structure Designed for Low-Energy Users (Supplies = 20 Amps), Imbued with FBE Allocations in the City of Cape Town. (Source: EGD 2018b *pers. com*)

	LIFELINE ENERGY TARIFF (per month; excl. VAT)				**FBE and Lifeline for FBE**	
Year	**Free Basic Energy (FBE) service apply**				**Ave.(c/kWh)/month = Ave. (c/kWh) over any consecutive 12 months**	
Block (c/kWh)	**<400**				**<400**	
2009	53.90				50	
Block (c/kWh)	**0.50**	**50.1 - 150**	**150.1 - 450**		**<400**	
2010	0.00	58.11	70.47		50	
Block (c/kWh)	**0 - 150**	**150.1-350**	**350.1 - 600**	**>600**	**<450**	
2011	61.6	81.04	107.43	118.06	50	
2012	64.93	89.95	118.11	140.18	50	
Block (c/kWh)	**<350**		**>350**		**<250**	**250 - 450**
2013/14	79.70		185.00		60	25
2014/15	84.31		204.65		60	25
2015/16	91.06		252.12		60	25
2016/17	97.09		268.81		60	25
2017/18	102.00		205.65		60	25
2018/19	110.30		222.39		60	25

The single subsidized energy-related tariffs for low-energy users, distributed at different consumption blocks at a temporal scale, are presented in Table 5.5. As shown in Table 5.5, lifeline consumers of <400 kWh/month are billed whilst integrating the FBE subsidy. For instance, the free allocation (say 60 kWh) forms the first part of the 350 kWh consumption block, which means that the first 60kWh is free and the subsequent 190 kWh is billed at appropriate rates. The free allocation was initially set at 50 kWh. From 2013 onwards, consumers of <250 kWh monthly receive up to 60 kWh FBE, and consumptions between 250 kWh - 450 kWh receive 25 kWh FBE. According to EGD (2018b *pers. com*), policy beneficiaries using prepayment meters without procuring electricity units in a month cannot receive the FBE subsidy, unless claimed at a vending outlet. Energy consumers using credit meters are credited with a free subsidy, provided it is consumed during the metering period (EGD 2018b *pers. com*). As shown in Table 5.5, lifeline electricity tariffs increase across consumption blocks, indicating that higher consumptions accrue higher tariffs. There was a higher annual increase in 2011 and might be ascribed to a 25.8% tariff increase by Eskom that led to a municipal bulk increase of 26.71% in the 2011/2012 financial year (Fowles 2011). Similarly, lifeline electricity tariffs increase at time series, say for example, in the >350 kWh block, until a decline of about 31% of annual change in 2016/17. In this same consumption block, the lifeline tariff increased by eight percent, standing currently at R222 in the 2018/2019 financial year.

Table 5.6 Historical Trends in 'Partly Subsidized' and 'Non-Subsidized' Tariffs designed for Domestic and Home Users, Respectively, distributed in Consumption Blocks (Supplies = 100 Amps), in the City of Cape Town. (Source: EGD 2018b, pers. com)

YEAR	DOMESTIC ENERGY TARIFF					HOME USERS TARIFF			DOMESTIC CONSUMERS
	Municipal property valuation between R400k and R1m (excluding VAT)					A municipal property value of R1m and above			FBE and FBE Lifeline
					Service charge (R/day)			Service charge (R/month)	Ave/month = Ave. over any consecutive 12 months
Block (c/kWh)	**400 - 800**		**>800**		**for >800**				**<400**
2009	77.37		64.44		3.40				50
Block (c/kWh)	**<1500**		**>1500**		**for >1500**				**<400**
2010	93.31		79.97		6.58				50
Block (c/kWh)	**<600**		**>600**						**<450**
2011	107.43		118.06		-				50
Block (c/kWh)	**0 - 150**	**150.1-350**	**350.1 - 600**	**>600.1**					**<450**
2012	113.20	118.11	118.11	140.18	-				50
Block (c/kWh)	**0-600**		**>600.1**			**0-600**	**>600.1**	**0-600 and >600.1**	**No FBE**
2013/14	125.00		152.00		-	-	-	-	-
2014/15	134.76		163.87		-	-	-	-	-
2015/16	154.30		187.63		-	-	-	-	-
2016/17	164.51		200.05		-	-	-	-	-
2017/18	169.12		205.65		-	-	-	-	-
2018/19	182.89		222.39		-	161.15	222.39	130.44	-

The twofold structures designed for high-energy consumers - domestic and home users, are presented in Table 5.6. Before the IBT policy in 2010 (SEA 2014), higher electricity consumption attracts lower tariffs (from 2009 to 2010) and domestic users were charged for energy services, until 2011. Similar to lifeline tariffs, domestic tariffs increase across consumption blocks. For partly subsidized domestic tariffs, only consumers of <400 kWh receive the free 50kWh (from 2009 to 2010) but increased to <450 kWh consumption in 2011 and 2012 and no FBE benefits in recent times. The non-subsidized twofold electricity tariff structure for home users was introduced in the 2018/2019 financial year, with no FBE benefits. The service charge is monthly and applicable to all consumption blocks for home users.

From the comparisons, lifeline tariffs can be alleged to be IBT well-regulated and FBE-subsidized to allow improved electricity use by low-energy users. This attempts to validate NERSA efforts in shielding low-income households from sharp rises in electricity prices Initially, domestic users' tariffs were partly subsidized, mainly allocating free 50 kWh to consumers of <400 kWh and <450 kWh. Remarkably, electricity tariffs were equivalently standing at R222.39 in the 2018/19 financial year in >350 kWh and >600kWh consumption blocks for the lifeline and domestic/home users, correspondingly (Table 5.5; Table 5.6). Since the 2013/14 financial year to date, FBE benefits within domestic users' tariffs have been excluded, making both domestic and home users' tariff structures, currently non-subsidized.

5.1.4 Discussions: Implications of access forecasts and future scenarios

The historical analysis (2010 - 2018) in access rates (subsection 5.1.1) has shown electricity access progress in the City of Cape Town, even beyond the base year, addressing in part, Research Question 2[43]. The forecast analysis (2019 - 2030) reveals future access rates and different scenarios to achieving total electricity access by 2030 when benchmarking against households without access in the base year. Access rates declined from 2015 to 2018 and drawbacks[44] in the INEP programme (DoE 2015) might have contributed to the decline. The forecast analysis showed that access rates increase from 2019 to 2030 but cannot connect households without access in the base year or achieve total electricity access by 2030, thus addressing, completely, Research Question 2[43]. The forecast analysis reveals that formal households without access in the base year can gain total electrifications by 2030. Informal households without access in the base year may require some form of policy or institutional modifications, among others, to alter the BAU pattern and achieve total electricity access by 2030.

Access costs have been established to facilitate increased access rates in households. The historical analysis (2010 – 2018) (subsection 5.1.2) has revealed that access costs steadily increased as access rates. In the forecast period (2019 - 2030), the forecasted events and relationships between, and within, access rates and access costs also increased. The way it is, achieving total electricity access by 2030 with the current SCC may be impractical, therefore

[43] Section 1.4: RESEARCH QUESTIONS. 2. What is the trend in electricity access over a historical 8-year period? Will assessing electricity access and related matters in such a period, be suitable to predict future progress in achieving total electricity access by 2030 at a regional scale?
[44] Section 4.3: DRAWBACKS IN POLICY IMPLEMENTATION; Paragraph 3.

addressing Research Sub-Question 1[45]. The NSCC structure may have validated SCCs' affordability and NERSA efforts in trying to improve electricity access in low-income households and partly addresses Sub-Question 2[46]. In actuality, NSCC was designed for high-income earners to cross-subsidize low-income earners (Kelly and Geyer 2018). With no alteration in the SCC structure, the forecast reveals an unremitting lack of electricity access, particularly in informal households without access in the base year. With a positive shift in a BAU trajectory, access costs can achieve the lower limits (conf. level = 95%) of forecasted events and total electricity access by 2030 in the City of Cape Town.

Electricity tariffs are critical in improving electricity demand and use in connected poor households (Inglesi and Pouris 2010) but not electricity access. The lifeline electricity tariff structure (subsection 5.1.3) was designed for low energy consumers with low-energy demand capacities (Trade and Industry Chamber (TIC) 2010). The cross-subsidy (SEA 2014), mainly targeting domestic users of 20 Amp single-phase supply, has demonstrated to provide FBE benefits in some consumption blocks in the earlier years (DoE 2016). Generally, historical models (2009 – 2018/19) show increasing trends in IBT tariff structures for low-income, domestic, and home energy users. The subsidized IBT structure with FBE benefits shows to be reasonable to improve electricity use in low-income earners, compared to non-subsidized structures and partly addresses Research Sub-Question 2[46].

With access costs increasing within the forecast period, electricity tariffs are expected to increase, also. It is also expected that a temporal increase in electricity tariffs may retard electricity use (SEA no date) or possibly, increase electricity theft (SEA 2014), in informal households. Supported by Adam (2010), subsidized connection costs and electricity tariffs imbued with FBE cannot increase electricity access and efficient consumption in informal households and again respond, completely to Research Sub-Question 2[46]. We must remember that informal households are mostly unemployed and depend, solely on government grants (StatsSA 2011). To a large extent, the electricity demand level depends on the elastic relationship between household income and electricity prices (Ye, Koch, and Zhang 2018). Allegedly, subsidized-designed IBT, integrated with FBE benefits and no service charges, are

[45] Section 5.1: 1. Will the forecast relationships between access rates and costs achieve total electricity access by 2030 in informal households?

[46] Section 5.1: 2. Are subsidized costs and tariffs affordable to improve electricity access and consumption, respectively, in informal households when compared to non-subsidized structures?

expected to be affordable by low-income earners. Regardless, the DoE[47] has encouraged municipalities to include surcharges, which might have led to the introduction of the twofold tariff structure designed for home users in the recent 2018/19 financial year.

One can, therefore, conclude that access costs and electricity tariffs need to be in decline concurrently, over time, to achieve total electricity access by 2030 in the City of Cape Town. Other available prospects can improve energy access but may demand stakeholders' participation[48] in strategizing energy access planning. A major shift can be set off from a community-based definition of energy access, given that access rates equal BAU patterns. Another shift can be kick-started based on household definitions[49] of energy access while considering a tail-off in a BAU scenario (Mensah, Kemausuor and Brew-Hammond, 2014). Access costs and tariffs do require some adjustments in well-funded policies to balance improving energy access against rapidly growing informal households in South Africa (HDA 2012). As a solution, informal areas are mapped and monitored to measure intensification (growth) process and other landscape processes in the City of Cape Town, as analyzed and discussed in Section 5.2 below.

[47] As already mentioned in Section 4.4: RETHINKING POLICIES AND RECOMMENDATIONS. Refer to IBT policy and recommendations within.

[48] The stakeholders' participation in driving the energy access process by applying the new SRM model at the community level is demonstrated. To be discussed in Section 5.4: APPLYING THE PROPOSED NEW SYSTEM REINFORCING (SRM) MODEL.

[49] Informal households define ways of improving energy access and use when electricity access is delayed, as would be discussed in Section 5.3: ENERGY USE AND RELATED DATA, PATTERNS, AND RELATIONSHIPS; particularly in Subsection 5.3.5: Energy productivity and expected benefits

5.2 CLASSIFICATION AND CHANGE ANALYSIS OF INFORMAL AREAS

This section addresses Research Objective 3[50] and Research Question 3[51] through the study methodology described in subsection 1.7.3. This section centres on Land-Cover (LC) classification and Land-Cover Change (LCC) of informal areas in the City of Cape Town, agreeing with Munch *et al*. (2017). The objectives are to map informal areas at a temporal stretch; assess trends in LC change; and lastly, analyze LC conversions and dynamisms, over time.

5.2.1 Land-Cover (LC) mapping of informal areas: From 2010 to 2016

As previously described in subsection 1.7.3 (data processing), the D1 dataset (reference 2011 LC) has low data accuracy and precision in representing informal areas' boundaries. Some polygons were incorrectly mapped while some informal areas were not mapped in the least. Subsequently, D1 was reworked (manually) to improve data accuracy using 2010 and 2016 aerial photographs - reference set (2). Two datasets were newly generated, D2 (Edited 2011_2010 LC) and D3 (Derived 2016 LC) datasets, having improved data precisions in defining informal areas' boundaries and characterizing the actual land-cover class. D1 was reworked using the 2010 aerial photographs, while D2 was edited using the 2016 aerial photographs. When comparisons are carried out between the sampled datasets and the two periods (2010 and 2016), we must remember that D1 has lower precision than the D2 and D3 datasets. The LC maps of informal areas in the City of Cape Town, representing the three sampled datasets – D1, D2, and D3, in a two-time step, are presented in Figure 5.4 - Figure 5.6.

[50] Section 1.3: RESEARCH AIM AND OBJECTIVES. 3. Land cover (LC) Mapping and Land-Cover Change (LCC) monitoring of informal settlements on a spatiotemporal scale to indirectly measure rates of poverty with energy poverty propagation in the City of Cape Town as a case.
[51] Section 1.4: RESEARCH QUESTIONS. 3. Will mapping and monitoring informal areas define the state of (energy) poverty and land-cover change processes over time, at a regional scale?

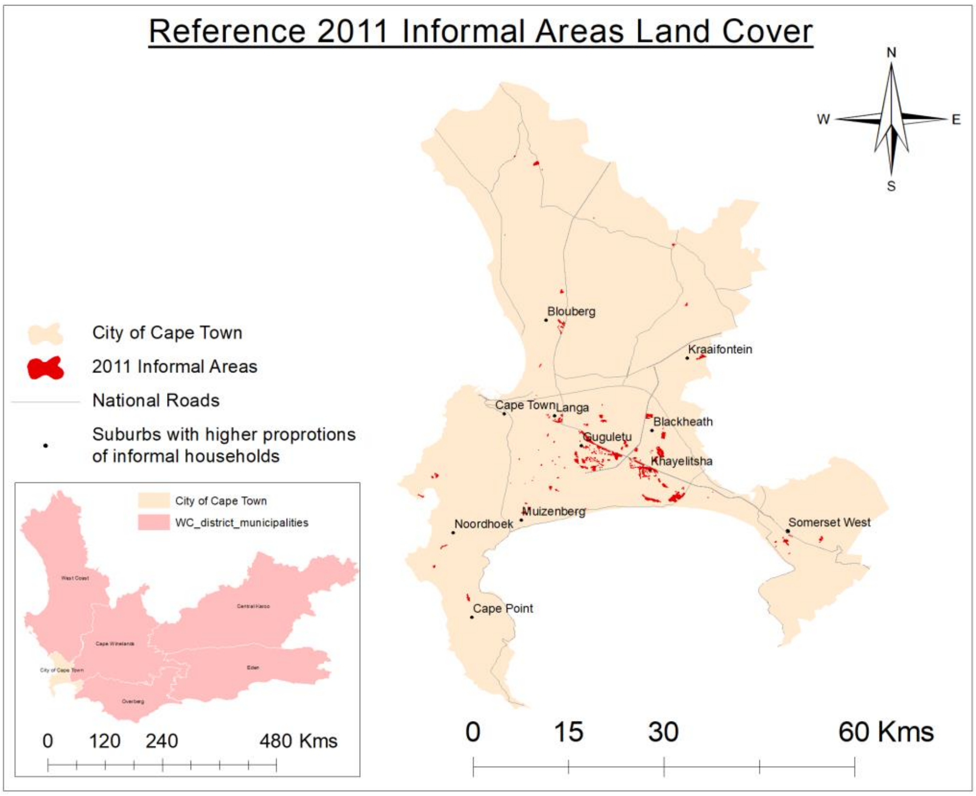


Figure 5.4 Map of Land cover (LC) of Informal Areas in the City of Cape Town - Reference LC 2011 (D1) Dataset

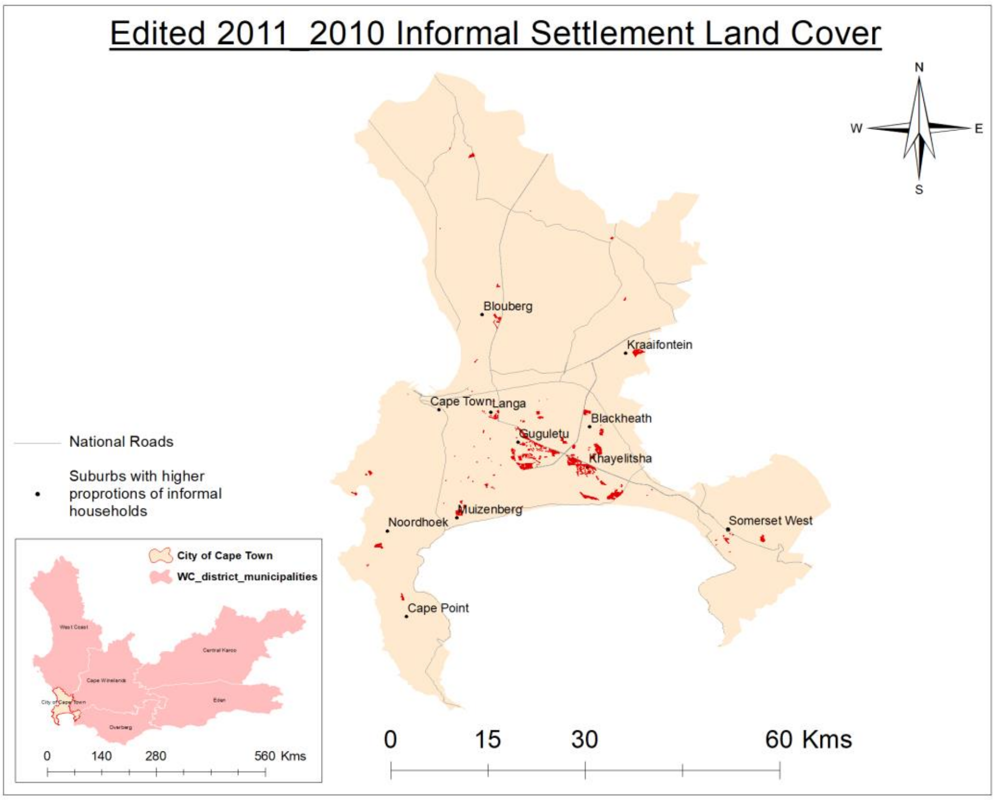


Figure 5.5 Map of Land cover (LC) of Informal Areas in the City of Cape Town - Edited 2011_2010 (D2) Dataset

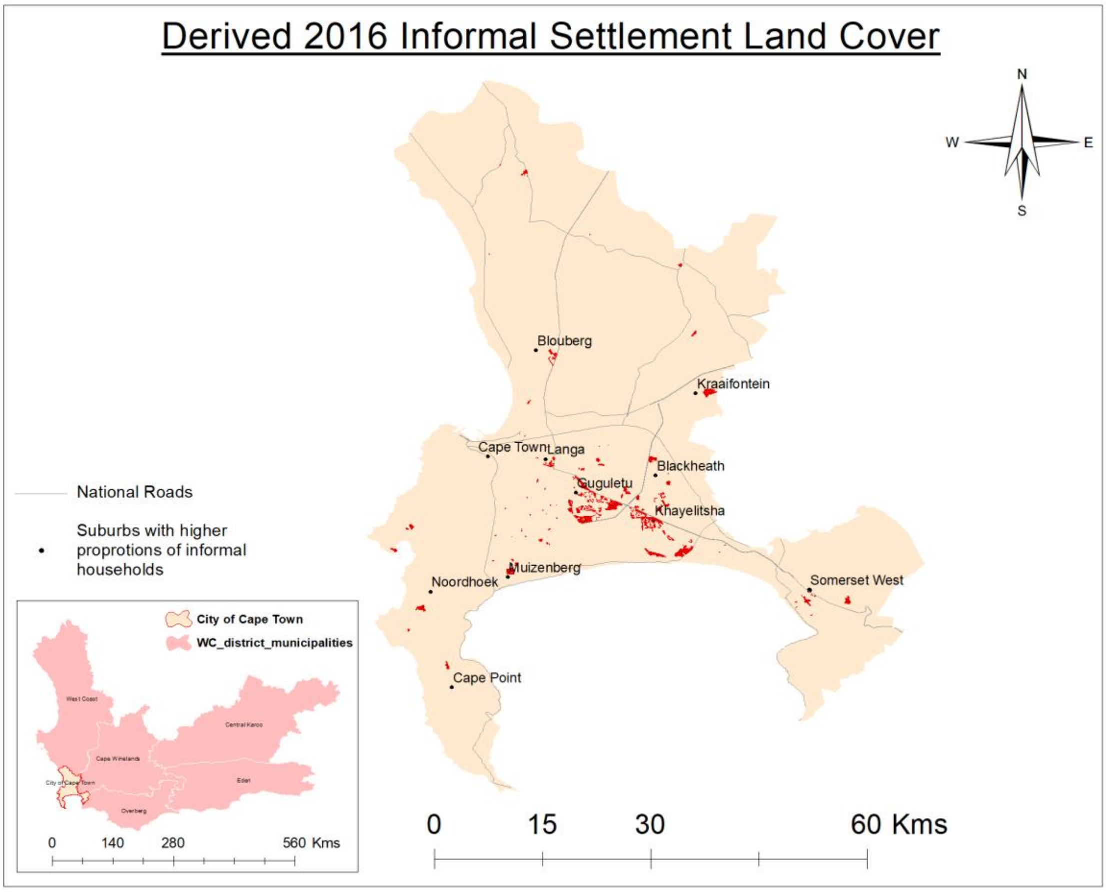


Figure 5.6 Map of Land cover (LC) of Informal Areas in the City of Cape Town - Derived 2016 (D3) Dataset.

5.2.2 Land-Cover Change (LCC) of informal areas: From 2010 to 2016

As formerly mentioned (subsection 1.7.3), two datasets - DD4 and DD5, were generated from the LC change analysis between sampled LC datasets (Figure 5.4 - Figure 5.6). DD4 was generated from the LC change analysis between the D1 and D3, whereas DD5 was generated from the LC change analysis between the D2 and D3. Comparisons were made between the newly generated datasets in assessing LCC, over time in the City of Cape Town. As earlier mentioned, the D1 dataset has low accuracy in LC mapping of informal areas but also an underlying dataset in DD4. However, the two-data scope analysis investigates the two-dimensional LC change concepts with the intent of gauging the validity of generated LCC datasets. The LCC maps for the two-data scopes, representing DD4 and DD5 datasets, are presented in Figure 5.7 and Figure 5.8.

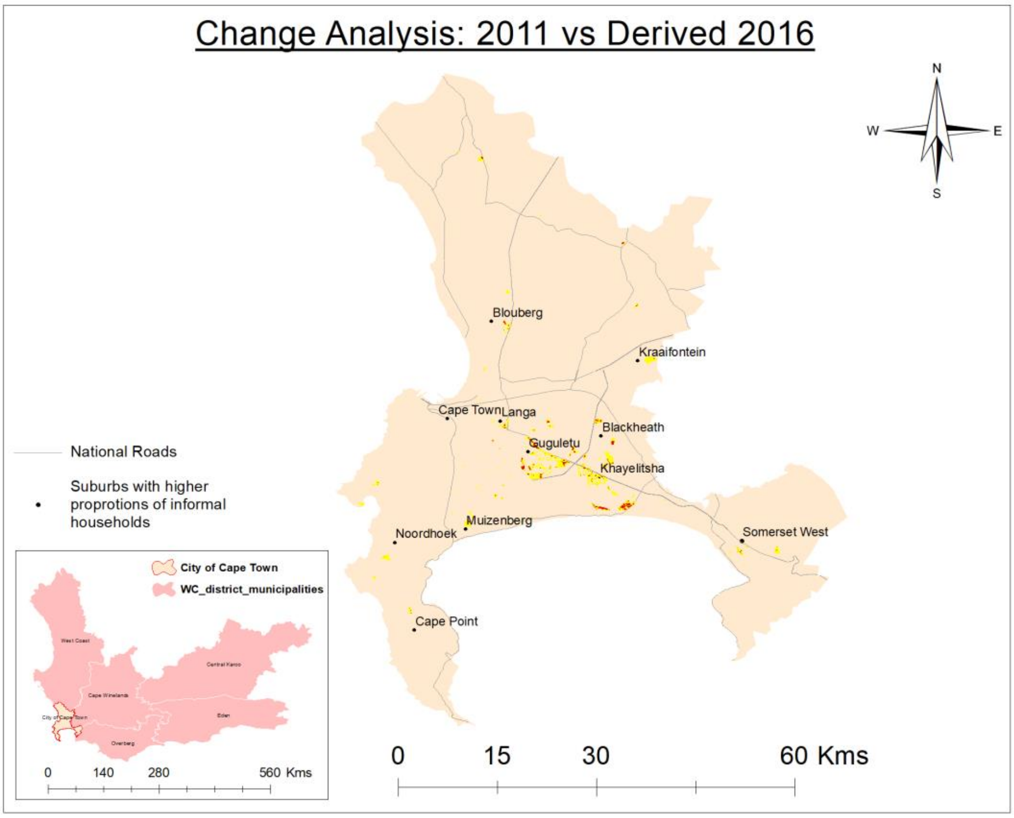


Figure 5.7 Map of Land-Cover Change (LCC) (DD4) of Informal Areas Generated Between The Reference 2011 (D1) and Derived 2016 (D3) Datasets.

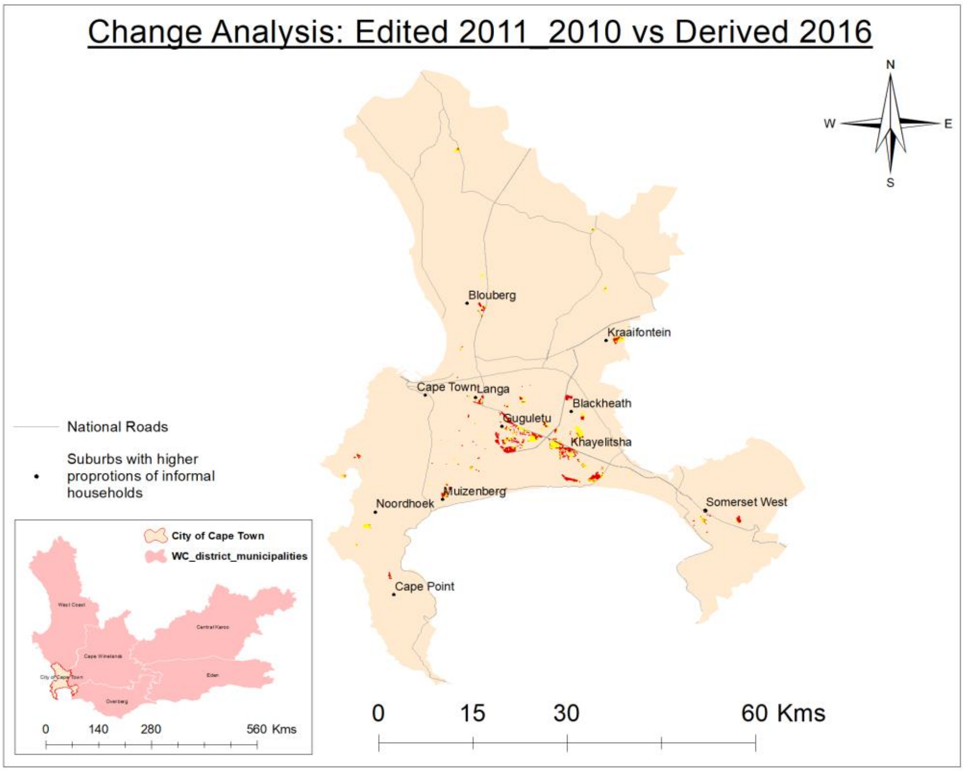


Figure 5.8 Map of Land-Cover Change (LCC) (DD5) of Informal Areas Generated Between the Edited 2011_2010 (D2) and Derived 2016 (D3) Datasets.

As shown in Figure 5.7, the DD4 data scope showed a highly significant change of informal areas' LC (red patches) to other land-cover (yellow patches) within the specified 4-year assessment period (2011 - 2016). The degree of change in DD4 is presumed to be highly exaggerated and non-representative of the actual LCC expected to occur in a 4-year interval. These exaggerated LCC, primarily, might be due to low data precision in D1 or different methods employed in classifying the underlying datasets (D1 and D3) in DD4. As shown in Figure 5.8, unlike DD4, the DD5 data scope revealed plausible LCC, representing the actual LCC of informal areas, expected to occur within the 4-year interval. Area conversions of informal areas (red patches) to other land-cover (yellow patches) were optimal within the assessment period. We recall that underlying datasets (D2 and D3) in DD5 were edited to improve the data precision to represent the actual LCC. As a result, DD5 provides higher accuracy in representing the actual LCC in informal areas in the City of Cape Town.

Table 5.7 Calculated Areas in Sampled LC Datasets and LCC Data Scopes

	Informal Land Cover (LC)	
Sampled Datasets	**Area (ha)**	**Percentage Change (%)**
2011 (Reference) (D1)	1319.00	-
Edited 2011_2010 (D2)	1448.16	-
Derived 2016 (D3)	1356.49	-
	Informal Land Cover Change (LCC)	
Reference 2011 vs Derived 2016 (DD4)	677.72	49.96
Edited 2011_2010 vs Derived 2016 (DD5)	379.05	27.94

The calculated areas for three sampled LC and two-data scopes of LCC datasets, and the percentage area change (%) between the two-data scopes are presented in Table 5.7. As represented in maps (Figure 5.4 - Figure 5.6) and presented in Table 5.7, calculated areas of informal areas varied between the three sampled LC datasets, with the least area (ha) in DI. During data processing, uncaptured informal areas in D1 were then captured in D2 and D2, hence increasing calculated informal areas in these datasets. Similarly, the two-data scopes shown in maps (Figure 5.7 - Figure 5.8) and presented in Table 5.7 differed in the percentage area change of informal areas. As observed in Figure 5.7, DD4 shows an exaggerated LCC, having about 50% of informal areas' conversions to other land-cover. Alternatively, as represented in the DD5 map (Figure 5.8), the data has about 28% of the total LCC. Just like in maps, the latter also reveals an optimal LCC in area-size, expected to occur within the assessment period, unlike the former. Consequently, only DD5 was used in assessing LC conversions of informal areas, as discussed in the subsection below.

5.2.3 Land-Cover (LC) conversions of informal areas

The conceptual schemas of LC conversions[52] and conversion labels[53] (subsection 1.7.3) were used in analyzing the LCC matrix and statistics in the study area. The schemas were used in assessing LC dynamics or conversions of informal areas using conversion classes or labels (Munch *et al*. 2017). While LC conversions describe trajectory and patterns in the LCC of informal areas to other land-cover areas, conversion classes simply assign labels to LC conversions between the two periods. As formerly mentioned (subsection 1.7.3), an indicator-based approach was employed in representing LC conversions and describing patterns and trajectories concerning development, environmental degradation, and sustainability. For this analysis, only the DD5 dataset was employed. Accordingly, the LC conversions in DD5 was carried out, and thematically represented in Figure 5.9.

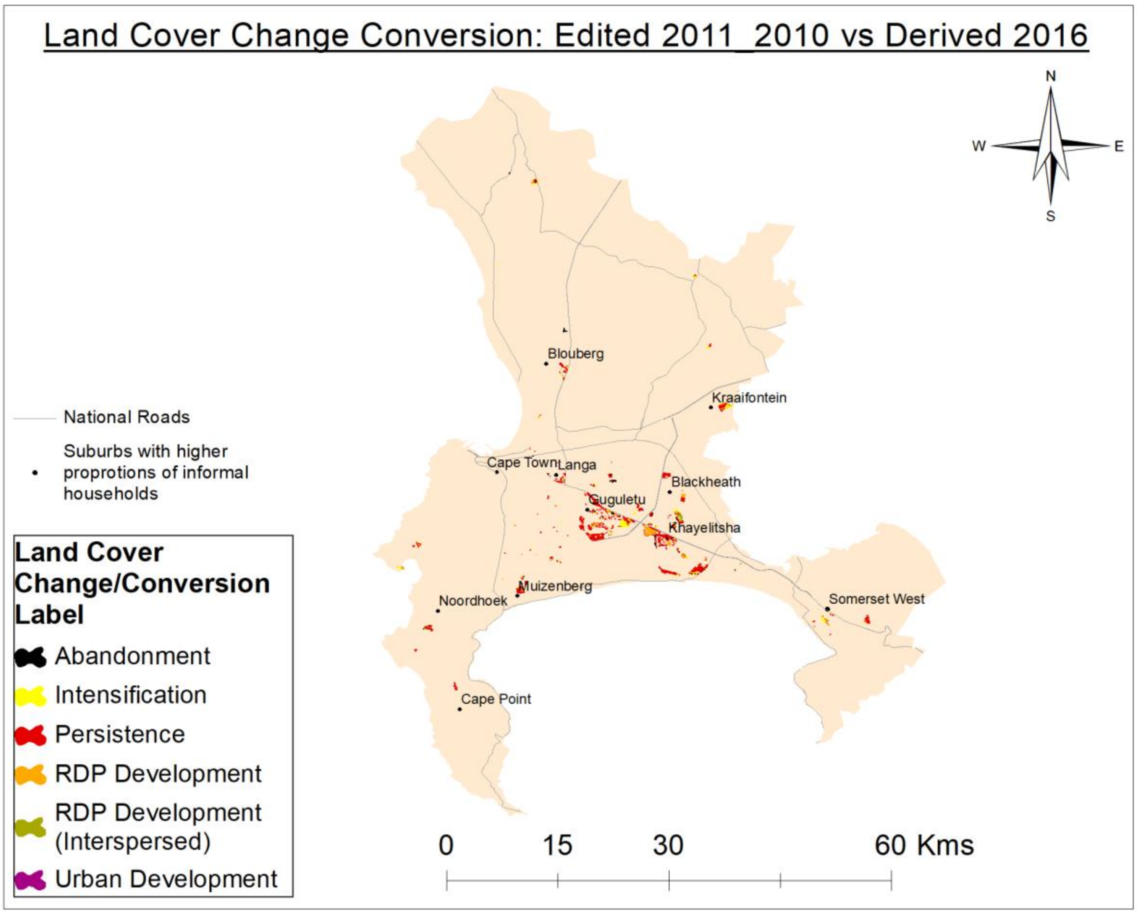


Figure 5.9 LC Conversions And Conversion Classes in the DD5 Data Scope Generated from the Change Analysis Between the Edited 2011_2010 (D2) and Derived 2016 (D3) Datasets.

52 Table 1.3 LC Conversions and Change Trajectories of Informal Areas to Other Land Covers From 2010 To 2016 and Conversion *Labels* Used. Adapted from: (Munch *et al.*, 2017)

53 Table 1.4 Descriptions of Conversion Classes (and Labels), Concerning Change Trajectories And Patterns In *Informal* Areas Adapted from: (Munch *et al.*, 2017).

As shown in Figure 5.9, six conversion classes were identified and assigned in the LC conversions of informal areas in the City of Cape Town. As represented in Table 5.8, the area-sizes of LC conversions were calculated for each conversion class. Generally, the map (Figure 5.9) and calculated areas (Table 5.8) reveal the trajectory and extent in LC conversions of informal areas. Two main landscape processes (or signals), including reclamation and degradation, were recognized in defining trajectory and patterns in LC conversions of informal areas. The reclamation process consists of conversion classes - *Abandonment*, *Urban Development*, and *RDP Development*, describing conversions where informal areas are substituted with bare soil (Ab) and housing structures (UD, RD, and RDi) (Table 5.8). The degradation process includes *Persistence* and *Intensification* that occur when informal areas persist (Pe) and intensify (In), over time, respectively (Table 5.8).

Table 5.8 Conversion classes and Calculated LC Conversion Areas in the DD5 Data Scope from 2010 to 2016

Informal Areas Conversion Labels	Class Description	DD5 - Edited 2011_2010 (D2) vs Derived 2016 (D3)	
		Area (ha)	% of Class
Ab - Abandonment	Areas where shacks are converted to bare soil	43.68	1.37
In - Intensification	Areas where shacks substitute bare soil	141.00	4.43
Pe - Persistence	Areas with no change in informal areas	2824.14	88.71
RD - RDP Development	Areas where shacks are replaced with RDP houses	103.80	3.26
RDi - RDP Development (Interspersed)	Areas intertwist with RDP houses and shacks	63.49	1.99
UD - Urban Development	Areas converted to urban houses and built-up structures	7.60	0.24
Total Change Conversion		**3183.69**	**100.00**

The reclamation process is a situation where informal areas decline in area-size, which is reducing in extent in 2016 from its relative extent in 2010. As presented in Table 5.8, this process accounts for about five percent of landscape processes. A conversion class where informal areas are removed or abandoned, thereby converting into bare soil is termed *Abandonment (Ab)*. This LC conversion occurs when a whole or parts of informal areas are moved to another area or removed for residential developments in the form of *Urban Development (UD)* and *RDP Development (RD)* (DHS and SANSA 2011). This class only accounts for less than one percent of the total conversion areas. A typical situation where an informal area has been abandoned and converted to bare soil is presented in Figure 5.10.

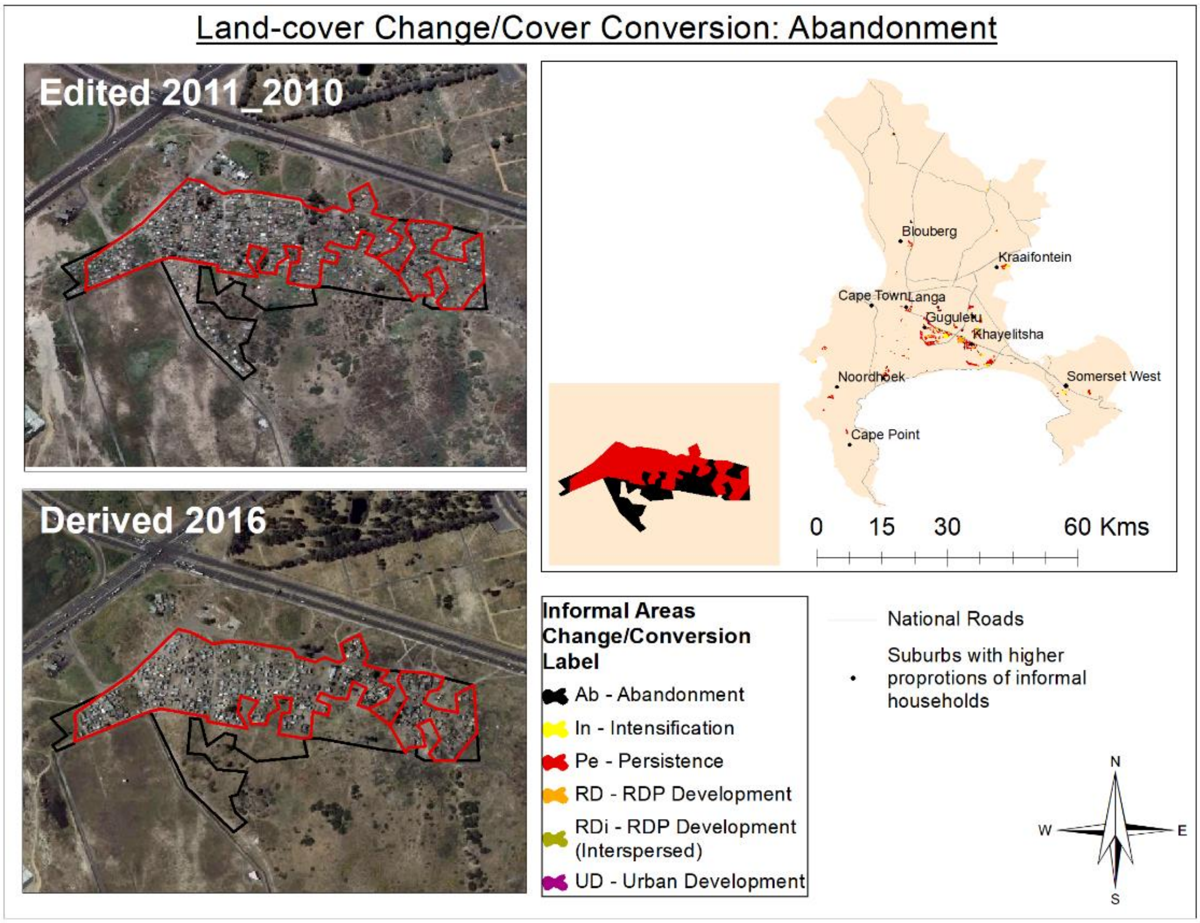


Figure 5.10 Conversion Class – Abandonment: Map and Aerial Photographs Showing LC conversions of Informal Areas to Bare Soil Within the Assessment Period.

Another reclamation process - *Urban Development,* is a situation where informal areas are converted to urban-built areas. This particular process contributed the least among other conversion classes, accounting for less than one percent (Table 5.8). The *RDP Development (interspersed)* (*RDi*) is a unique reclamation process pervaded by a degradation process and cannot be regarded as an absolute landscape reclamation signal. This conversion class occurs when parts of informal areas are replaced and interspersed with the *RDP Development,* accounting for about two percent of the total conversion areas (Table 5.8). The class - *RDP Development* occurs when informal areas are completely replaced with RDP houses and accounted for about three percent of the total (Table 5.8). A typical scenario of the *RDP Development,* replacing informal areas in the study area is shown in Figure 5.11.

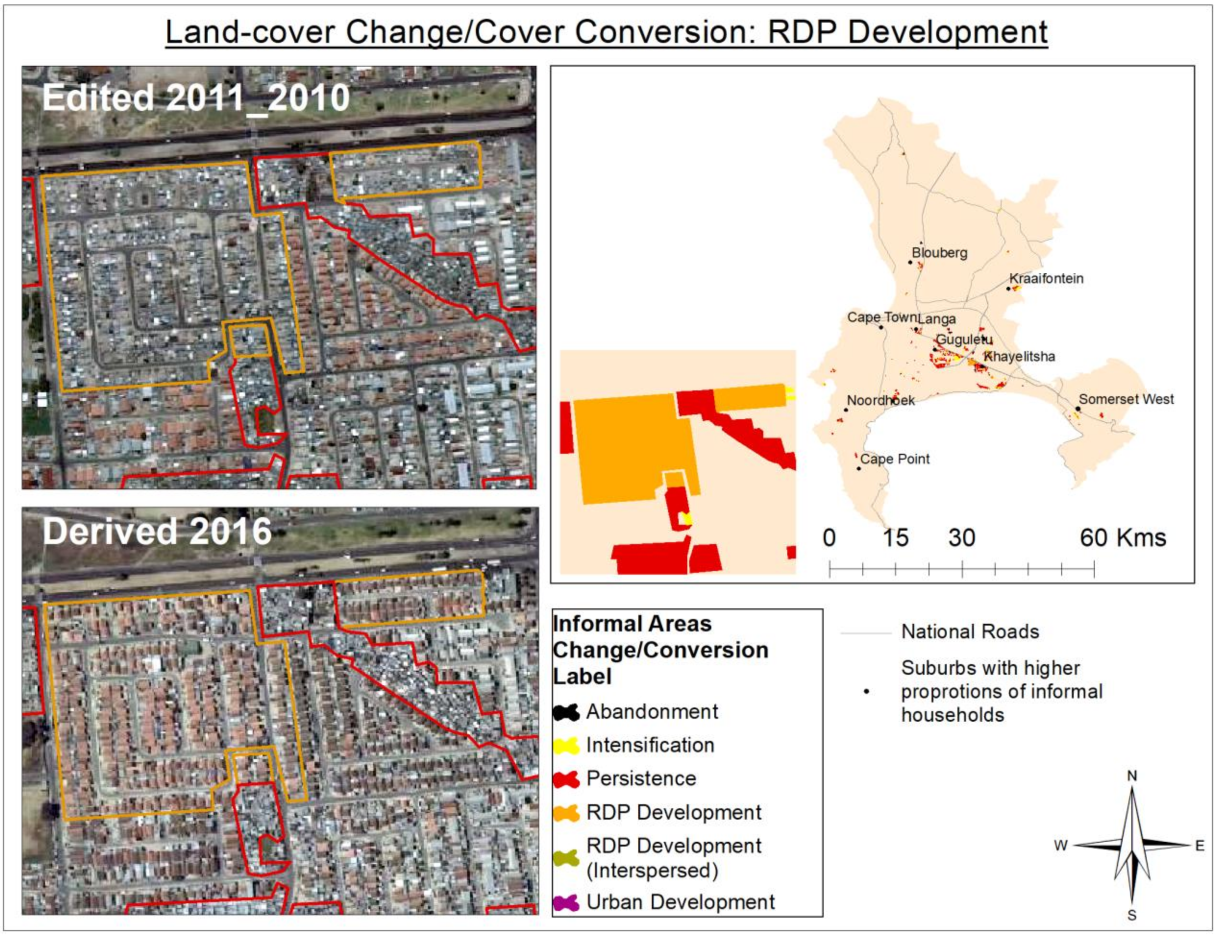


Figure 5.11 Conversion Class - RDP Development: Map and Aerial Photographs Showing LC conversions of Informal Areas to RDP houses Within the Assessment Period.

The LC conversion map in Figure 5.9 is mostly characterized by a degradation process - *Persistence*, making up more than 89% of the total conversion areas (Table 5.8). This class, *Persistence*, occurs when informal areas remained the same, with no change in extents of informal areas' boundaries throughout the specified period (2010 - 2016). As previously mentioned (subsection 1.7.3), the study did not assess population density such as counting informal households within informal areas. Yet, some informal areas were observed to be densely intensified, with no expansion, of any kind, in area-size. A typical example of such informal areas, where extents remained unchanged but densely intensified, over time, is presented in Figure 5.12.

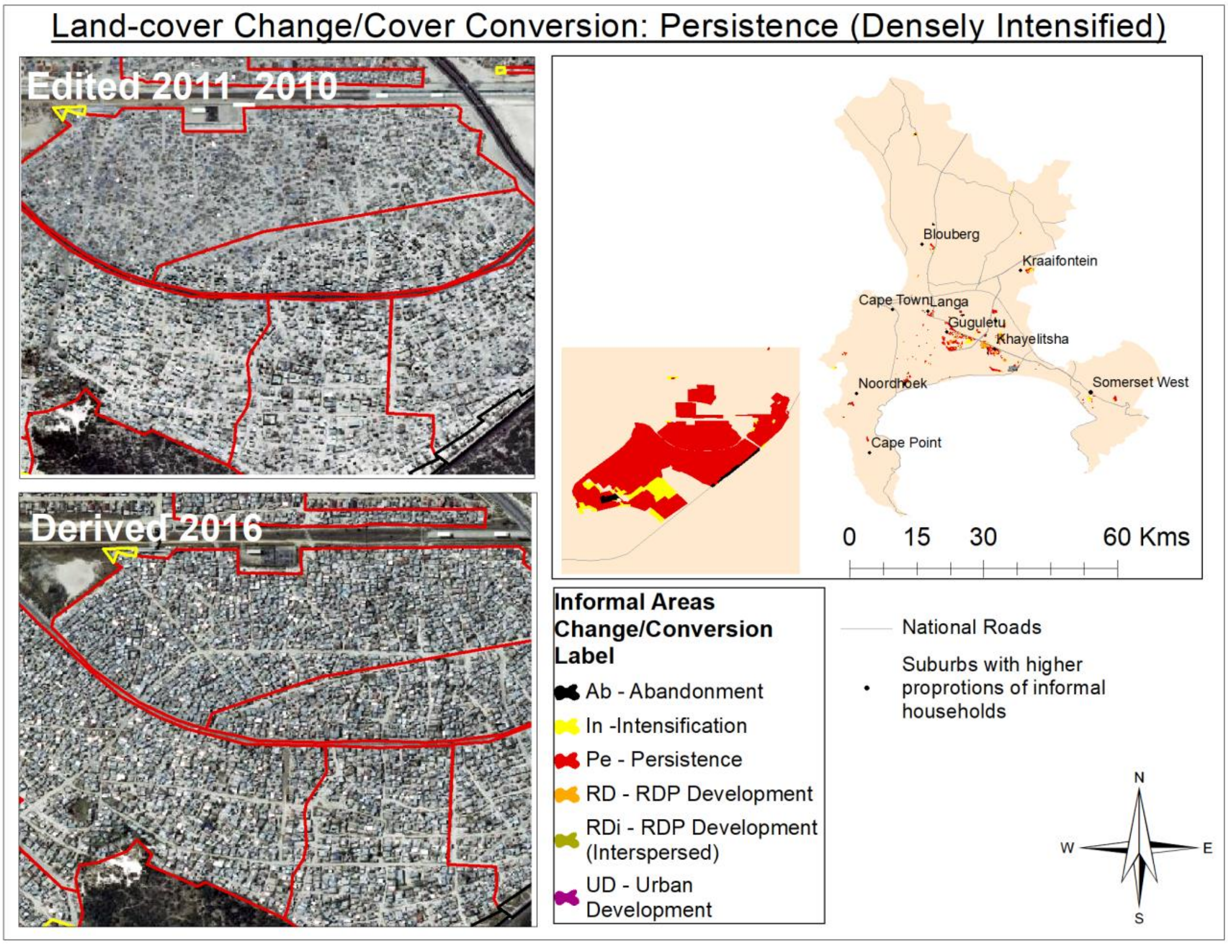


Figure 5.12 Conversion Class – Persistence: Map and Aerial Photographs Showing Persisted but Densely Intensified Informal Areas within the Assessment Period.

Another degradation process - *Intensification*, occurs when informal areas expand in area-size, over time. This change trajectory occurs when bare soil (or empty land) is invaded by the urban poor and converted into informal areas. This conversion class accounts for about 4% of conversion areas (Table 5.8). A typical scenario of *Intensification*, where vacant land surrounding an informal area is invaded by poor households and transformed into shack-clustered areas, is presented in Figure 5.13. Another typical example is visible in our primary case study area - the Sofia settlement, which also exemplifies an *Intensification* process occurring beyond the assessment period (Figure 5.14). As presented in Figure 5.14, *Intensification* was fairly marginal from 2010 to 2016 in the Sofia settlement. Within a 3-year interval, this process worsened in the settlement by over doubling in 2019 from its relative size in 2016, as formerly shown in Section 1.6[54] and again in Figure 5.14 below.

[54] Section 1.6: DESCRIPTION OF CASE STUDY AREAS

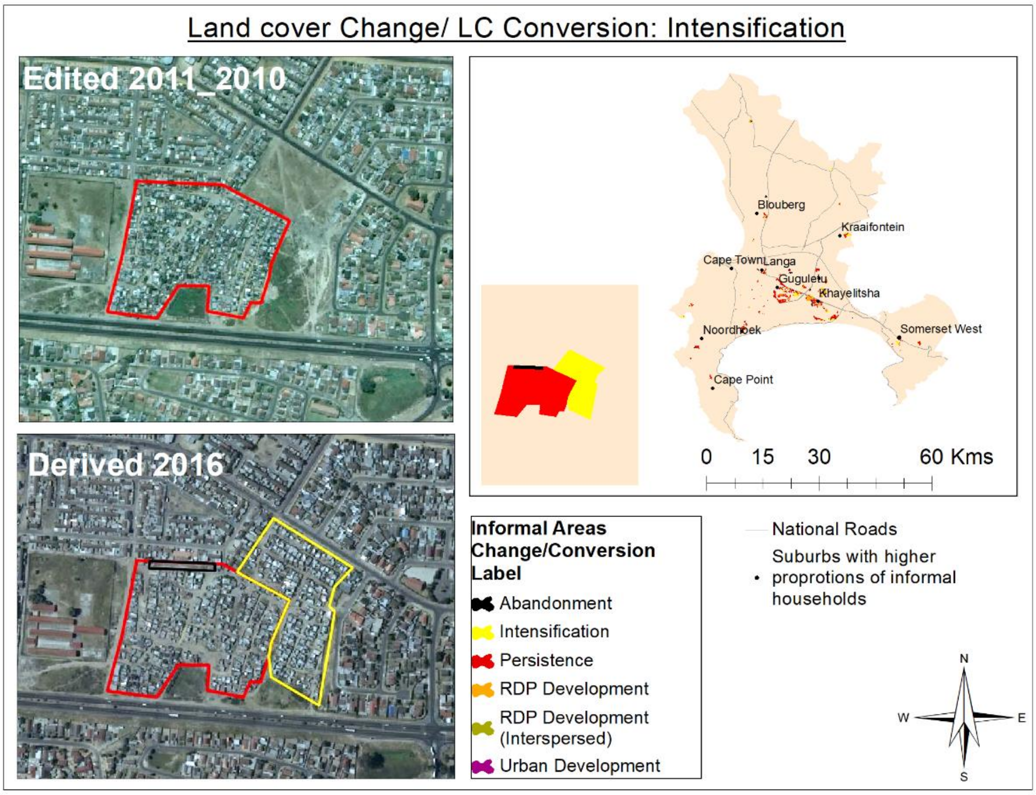


Figure 5.13 Conversion Class – *Intensification*: Map and Aerial Photographs Showing LC Conversions of Vacant Land into Informal Areas Within the Assessment Period.

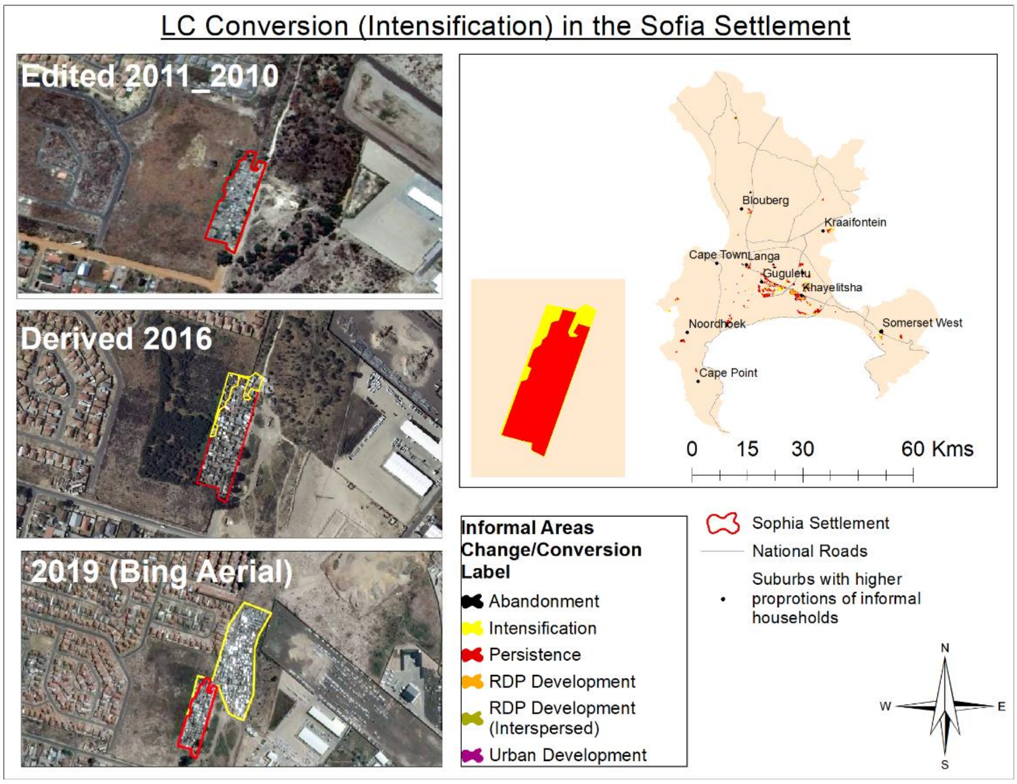


Figure 5.14 Map and Aerial Photographs Showing the *Intensification* Process in the Sofia Settlement Within the Assessment Period and Bing Aerial (2019) (Open Layers Plugin in QGIS) showing *Intensification* Beyond the Assessment Period.

5.2.4 Discussions: Land-cover change and conversions in informal areas

When D1 intersected with D3, the resultant DD4 data scope shows LCC that is non-representative of actual LC conversions of informal areas in the City of Cape Town. The resultant LCC was exaggerated, particularly in major townships such as Khayelitsha and Gugulethu, where a change in extents of informal areas is unexpected due to well-grounded infrastructural developments in these townships. Again, there is no immediate vacant land surrounding informal areas to promote land invasion and propagate shack-clustered areas in these townships. This study may not have assessed LCC per suburb but the maps have thematically shown spatial distributions of informal areas across suburbs. As well, LC conversions of informal areas within and in proximity to suburbs have been recognized. The study reworked the DI dataset and increased data accuracy in D2 and D3, which in turn, improved data accuracy in representing LCC and LC conversions in the DD5 data scope. The study's focus is not to compare or relegate the validity of the D1 dataset (reference data) but to explain the actions taken in updating data and increasing data validity for the benefit of policymakers.

Conversion classes were assigned in the DD5 data scope because of its higher precision in representing the actual LCC. There were slight anthropogenic transformations or rather a landscape reclamation process of informal areas in this data scope. The bare soil class – *Abandonment* seems to support poverty and energy poverty mitigation through the RDP programme (DME 1998). Although minuscule, this bare soil conversion can be converted to *RDP Development* or *Urban Development*. Development, as a product of civilization, is exploited in the form of *Urban Development* and *RDP Development* in the study area. These classes are also as slow-paced as *Abandonment*. Conversely, the *RDP Development (interspersed)* represents RDP houses interspersed in informal areas, regarded as a partial landscape reclamation process. This might have been promoted due to some conflicting legislation in the RDP programme (DME 1998) that permits erecting RDP houses in shack-clustered areas.

The *Persistence* of informal areas outweighs other conversion classes in the study area. In the DD5 data scope, informal areas persisted almost in all suburbs, particularly those with large populations of informal households, according to the literature[55]. Along with *Persistence*,

[55] Section 2.6: TRENDS IN ENERGY-USE PATTERNS AND RELATED MATTERS IN INFORMAL HOUSEHOLDS IN THE CITY OF CAPE TOWN

Intensification also promotes the landscape degradation process, where informal areas, not only persist and expand in extents but also intensify, densely. The dense *Intensification* can occur when poor migrants from rural villages to urban areas are coerced to settle in informal areas because they are poor (DHS and SANSA 2011). Or else, *Intensification* occurs when informal households decide to invade and erect shacks on vacant land surrounding them. This form of land overexploitation limits RDP efforts (DME 1998) and undertaken strategies to reduce informal areas' propagations in South Africa. This process, *Intensification*, also indicating an increase in population, in the same way, limits INEP's efforts (DoE 2015) in meeting the growing electrification demands in informal households in South Africa.

Assumptions made from the DD5 data scope confirms significant landscape degradation gradients in the City of Cape Town. It is important to note that informal areas have been persisting in the study area even before the assessment period. *Intensification* may have increased beyond the assessment period as was exemplified in the primary case study area, where the extent of the Sofia settlement over doubled in recent times. Then again, *RDP Development*, *Urban Development*, and *Abandonment* do not equal the *Persistence* and *Intensification* of informal areas in the City of Cape Town. A similar study reported a similar conversion trajectory including *Persistence*, *Intensification*, and *Abandonment* conversion classes, in informal areas across provinces in South Africa (DHS and SANSA 2011). As is, landscape reclamation is not as fast-paced as degradation processes of informal areas, which inexorably, are expected to worsen beyond the assessment period in the City of Cape Town.

By and large, this part of the research has engaged GIS intelligence in defining the state of poverty and energy poverty at the regional level. In addressing Research Question 3 [56], *Persistence* and *Intensification* reveal large expanses of informal areas, comprising large populations of informal households that are both poor and energy-poor and may require electricity access and RDP houses. These processes further frustrate RDP and INEP efforts (DME 1998; DoE 2015) but constant interventions are required in mitigating their impacts. *Urban Development* is one of the interventions supporting landscape reclamation. *RDP Development* has validated the RDP programme, concerning RDP housing delivery in South Africa (DME 1998). The class, *Abandonment*, may be marginal but has provided favourable prospects to expedite energy access and new policy formulations. It is critically important to understand other energy poverty situations to improve energy access in informal areas. As a

[56] Section 1.4: RESEARCH QUESTIONS. 3. Will mapping and monitoring informal areas define the state of (energy) poverty and development over time, at a regional scale?

result, energy-use patterns, as well as energy-related data, in the primary case study area, are analyzed and discussed in section 5.3 below.

5.3 ENERGY USE AND RELATED DATA, PATTERNS, AND RELATIONSHIPS

This section analyzes energy-use patterns and other energy-related matters in informal households in the primary case study area - the Sofia settlement[57]. By adopting the study methodology described in subsection 1.7.4, the section addresses Research Objective 4[58] and Research Question 4[59]. As earlier mentioned (in subsection 1.7.4), two primary surveys were used in investigating energy matters and supplies in the primary case study area. Data interpretations of these two surveys are analyzed in categories, under individual subsections below:

- Dwelling characteristics and household sizes
- Electricity access and other energy-use patterns
- Energy demand levels and energy-use behaviour
- Energy burden and costs on household income
- Expected benefits and productivity of energy sources
- Local energy supply and sustainability

We recall (subsection 1.7.4) that participants were not compelled to respond to any uncomfortable or personal questions, neither was any personal and identifying data captured. This ensured that the research study fully complied with the relevant ethical limitations and requirements (Appendix 7 and 8). As a result, respondents to specific questions were only considered in addressing them. For this part of the research study, analyzing parameter(s) or groups of parameters was not to focus on how large the sample sizes were. The purpose is to understand energy-use patterns and matters in the case study area, with the intent to map significant results using the proposed new SRM. This is a precondition to demonstrating the utility of the new SRM in mitigating energy poverty in a community, such as the Sofia settlement. Both primary surveys used were structured, purposely to address the model's purpose.

[57] Section 1.6: DESCRIPTION OF CASE STUDY AREAS

[58] Section 1.3: RESEARCH AIM AND OBJECTIVES. 4: Investigating energy-use patterns and other energy-related matters at the household level in a selected informal settlement called the Sofia settlement, used as a primary representative case study of an energy-poor community.

[59] Section 1.4: RESEARCH QUESTIONS. 4. What are the present energy-use patterns and behaviour in poor households in a typical informal settlement?

5.3.1 Dwellings types and household sizes

Dwelling types and household sizes[60] influence energy productivity and demand, as well as energy-use performance in households. As shown in Table 5.9, most households dwell in corrugated metal sheeting dwellings, rather than in mobile dwellings in the case study area. The majority of households built their own dwellings, whereas others were built by the local authority. Some households have occupied their dwellings for over a year, and others for less than a year. Most dwellings are non-insulated (n = 77) or poorly insulated (n = 19). Most households have not renovated their dwellings, while some were unsure of renovating them, since their occupation. Others have renovated their dwellings by either replacing the roof, a window, and/or a door, flooring, or levelling and rebuilding them. Some factors, such as fire outbreaks[61] from burning local traditional energy products (Walls, Olivier and Eksteen 2017), can result in a need to rebuild or renovate dwellings in the case study area.

Table 5.9 Dwelling Types and Relevant Components Describing Informal Households in the Case Study Area

House/household characteristics	Household proportion (%)	No of respondents (n)
Corrugated Metal Sheeting	98.51	
Mobile Home	1.49	117.00
Lived more than a year	79.49	
Lived less than a year.	20.51	117.00
Built by Self	73.68	
Built by Authority	26.32	114.00
Renovated	30.83	
Not renovated	63.33	
Not sure if renovated	5.83	120.00

As shown in Figure 5.15, the household size ranges from the household size of one to a household size of nine in the study area. All household sizes have at least one family member over 18 years. Households of four are the largest, making up about 25% of the total household sizes (n = 101), with two members over 18 years in 18 of them. This is followed by the household size of two (n = 22) and households of three (n = 18), having two members over 18 years, in 12 and 10 of these household sizes, respectively. The order of household sizes in the case study area generally corresponds to that of most informal settlements in the City of Cape Town[62]. The household size of one (n = 14) has all its members over 18 years. Although the

[60] CHAPTER 1: TRENDS IN ENERGY-USE PATTERNS AND RELATED MATTERS IN INFORMAL HOUSEHOLDS IN THE CITY OF CAPE TOWN. See Subheading – Household sizes
[61] During the field survey, a situation was witnessed where a paraffin heater used for space heating in a particular dwelling/household caused a fire outbreak that burnt down the dwelling in the case study area.
[62] Figure 2.8 Distributions of Household Sizes At A Temporal Stretch In Informal Households (Grouped) By Census Years in the City of Cape Town. (Source: StatsSA 2011

household size of five (n = 11) has three members over 18 years (n = 7), households of nine (0.99%) have four members over 18 years (n = 1).

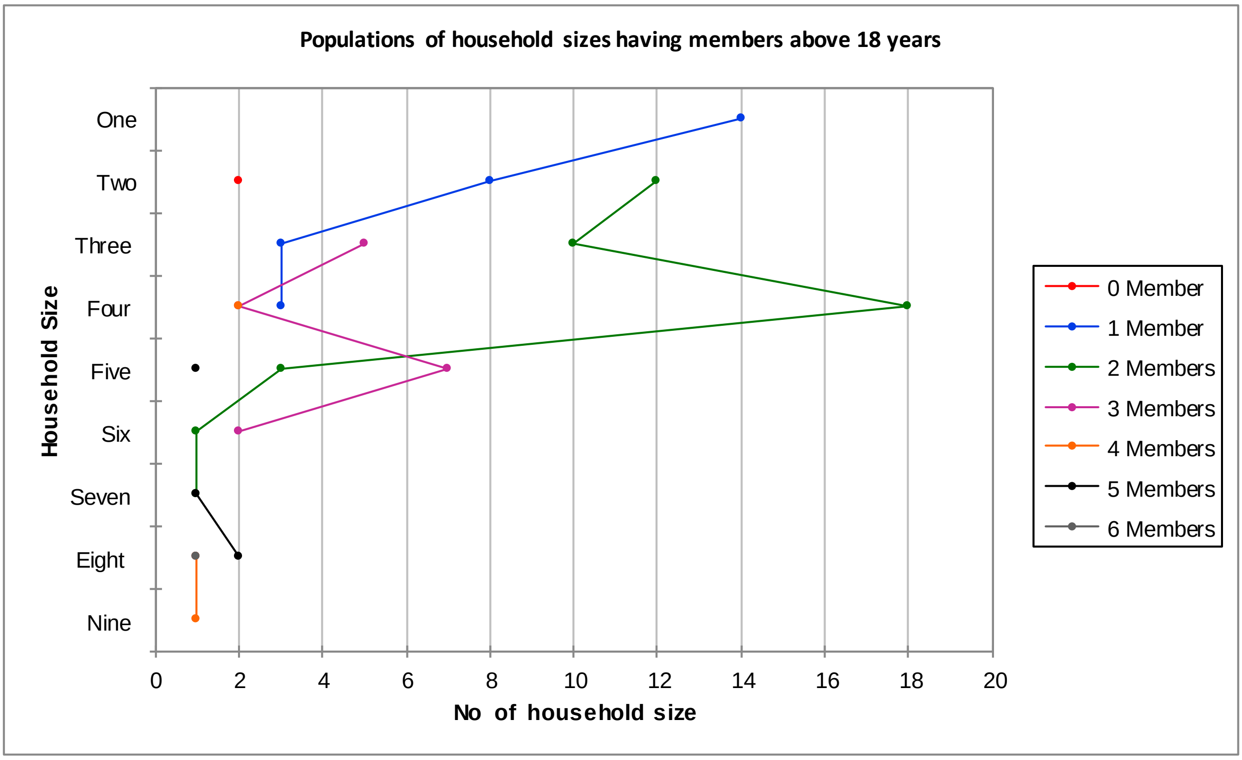


Figure 5.15 Distributions of Household Sizes and Household Members Over 18 Years of Age in the Case Study Area

5.3.2 Electricity access and energy-use patterns

There is no general electricity access (95.83%, n = 96) in the case study settlement, which explains the adoption of alternative energy sources, as presented in Table 5.10. The primary energy use in the settlement is paraffin, similar to the primary energy source in informal settlements in the City of Cape Town[63]. As shown in Table 5.10, following the use of paraffin for lighting, cooking, and heating, are candles used only for lighting; gas and fuelwood for cooking; and lastly, fuelwood and coal for heating. The household preference for paraffin use is due to product affordability (52.14%, n = 117), accessibility and availability (36.75%), convenience (7.69%), environmentally friendly (2.56%), and respect for tradition (0.85%). Most households (n = 97) obtain mainly paraffin and gas from area vendors, and some (about 63%) indicate occasional product scarcity by the vendors, while others (37.11%) indicate constant

[63] As discussed in Section 2.6CHAPTER 1: TRENDS IN ENERGY-USE PATTERNS AND RELATED MATTERS IN INFORMAL HOUSEHOLDS IN THE CITY OF CAPE TOWN; Refer to – Energy-use patterns

product availability. Most households walk less than 100 meters (48.96%, n=115) and others walk between 100 - 500 meters (31.25%) to area vendors to buy energy products. Very few households (n = 7) obtain other energy products, such as fuelwood and coal from woodlots and other outlets.

Table 5.10 Proportions (%) of available Energy Sources for Satisfying Minimum Energy Needs based on their Energy-use Efficiencies in households

Energy sources	Lighting	Cooking	Heating
Smart access			
Electricity	5.91	2.16	0.78
Transitional energy			
Paraffin	46.24	66.19	59.38
Gas	2.69	14.39	6.25
Traditional energy			
Candles	39.78	-	-
Coal	2.15	2.16	14.06
Fuelwood	3.23	12.23	17.97
Agric. residue	-	2.88	1.56
No of respondents (n)	**186.00**	**139.00**	**128.00**

As shown in Table 5.10, transitional energy fuels are cleaner alternative energy fuels than traditional energy fuels in terms of increased energy productivity and lesser health risks. According to Practical Action (2010), the minimum acceptable basic energy needs, including lighting, cooking, and heating, are set as baselines in the case study area. As previously indicated, paraffin is mainly used for lighting, cooking, and heating; followed by candles used for only lighting; gas and fuelwood used for cooking; and fuelwood and coal used for space heating; in the case study area. These largely conform to energy-use patterns in informal settlements, at large in the City of Cape Town[64]. The number of respondents for space heating dropped, indicating that most households do not meet this energy service in their homes. According to StatsSA (2011), a total of 39 767 informal households had no space heating service in 2011, which increased to 48 104 by 2016 (Stats SA 2016).

[64] As shown in Figure 2.13 Distributions of Informal Households Showing Available Energy Resources Including Electricity Access for Lighting, Cooking, Heating in 2011. (Source: StatsSA (2011)).

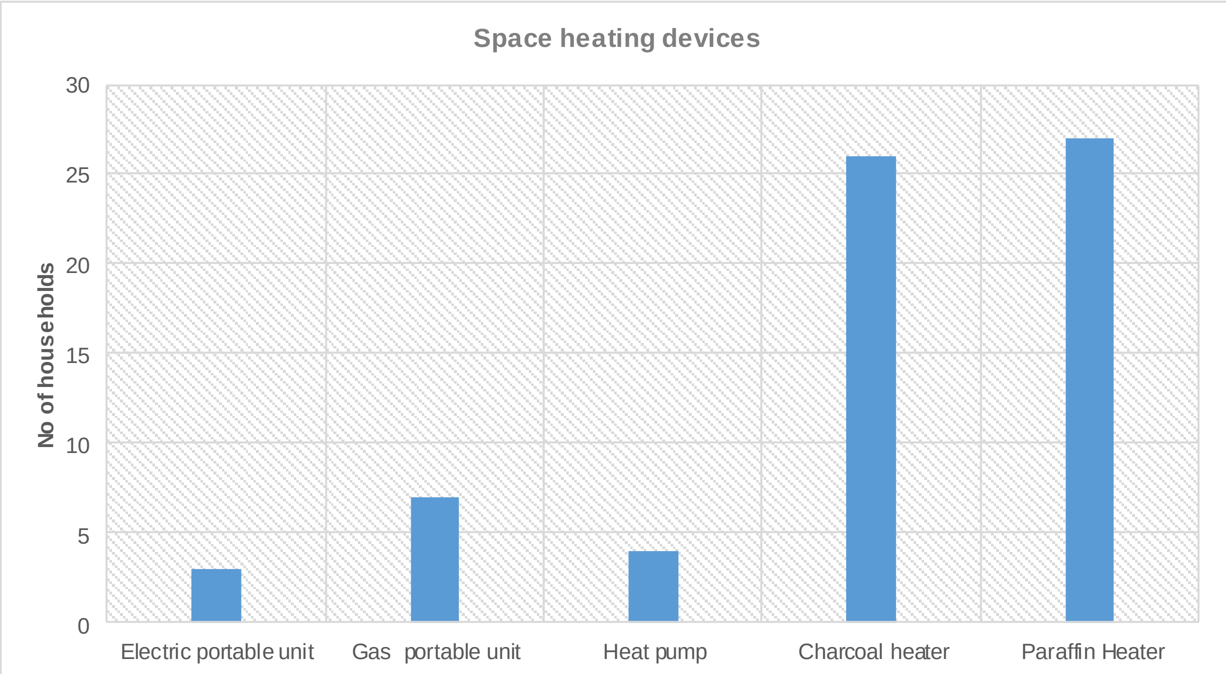


Figure 5.16 Distributions of Informal Households using Various Heating Devices for Space Heating in Winter in the Case Study Area.

As presented in Figure 5.16, most households use paraffin heaters, while some use charcoal heaters for space heating in winter. A very small proportion of households use electric portable units and the rest use either gas portable units and heat pumps. In the settlement, informal households practice multiple energy uses (or energy mix practices). Most households concurrently employ paraffin and candles for lighting (n = 45) and others use paraffin and fuelwood for cooking (n=10), and heating (n = 8), respectively. Likewise, households concurrently employ charcoal, and paraffin heaters (n = 14), gas portable units and paraffin heaters (n = 3), heat pumps, and paraffin heaters (n = 3), and electric portable units and paraffin heaters (n = 1). As cooling methods in summer, about 97% (n = 71) of households identify window and door units and about 3% identify electric fan and evaporative cooler.

As revealed in Table 5.10, 4% of households (n = 96) use electricity to meet energy needs, agreeing with SEA (2014) concerning ongoing illegal connections in informal settlements in South Africa. About 6% (n = 186) of households use electricity for lighting, about 2% for cooking (n = 139), and less than one percent for heating (n = 128). A total number of 39 traditional incandescent and LED light bulbs, coupled with 84 electrical appliances including refrigerator, freezer, microwave, television, and mobile phones are recorded in the case study area (Ye, Koch and Zhang 2018). These appliances are perhaps in storage or maybe in use through illegal connection access (SEA 2014) since there are no grid-connections, presently, in the case study area.

5.3.3 Energy demand and energy use behaviour

The average monthly energy demand assesses monthly energy consumption rates used in satisfying the minimum energy needs in households. As shown in Figure 5.17, most households consume <100l, between 100 - 250l, and >250l of paraffin in winter than in summer. Alternatively, some households consume 100 - 250l and >250l of paraffin in winter than in summer. Consumption rates for gas decreased from summer to winter, while fuelwood and charcoal slightly increased across seasons. As shown in Table 5.11, there are no significant differences ($p<0.05$) between the consumption rates of all the local energy fuels across the seasons, except for paraffin (X^2 = 0.03). Seasonal variations seem to contribute to higher demands for paraffin, which also promote this product availability, accessibility, and affordability in the case study area.

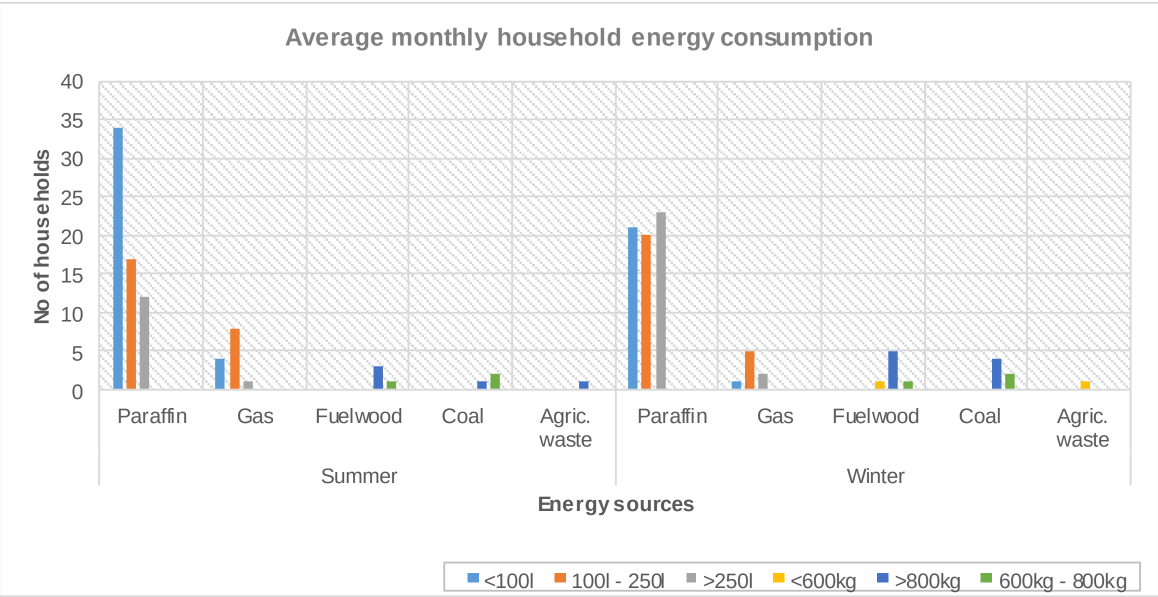


Figure 5.17 Distributions of Local Energy Sources and Average Monthly Consumption Rates in Households showing energy use in Summer and Winter Seasons in the Case Study Area

Table 5.11 Significance Relationship (Chi-test) Between the Average Monthly Consumption Rates (Grouped) of Energy Sources in Winter and Summer in the Case Study Area.

Local energy sources	**Average monthly consumption (grouped)**	**Significance (X^2) (P value = <0.05)**
Paraffin	<100l; 100-200l; >250l	**0.03**
Gas		0.42
Fuel wood	<600kg; 600-800kg; >800kg	0.13
Coal		0.23

Analyzing the relationships between energy demand and household sizes evaluates energy consumption rates in households based on household sizes. As shown in Figure 5.18, this analysis was only carried out between household sizes and average monthly consumption of paraffin (n = 61). The household size of four consumes 100l – 250l of paraffin in a month, similar to household sizes of three and two. The household size of four makes up the largest, consuming 250l of paraffin per month, just like the household size of one. The relationships between these two grouped parameters are considered null and void [X^2 = 0.68 (P>0.05)]. Whether large or small household sizes, there are no significant differences ($p > 0.05$) in consumption rates. In other words, monthly energy consumption rates are independent of household sizes but on other factors in the study area.

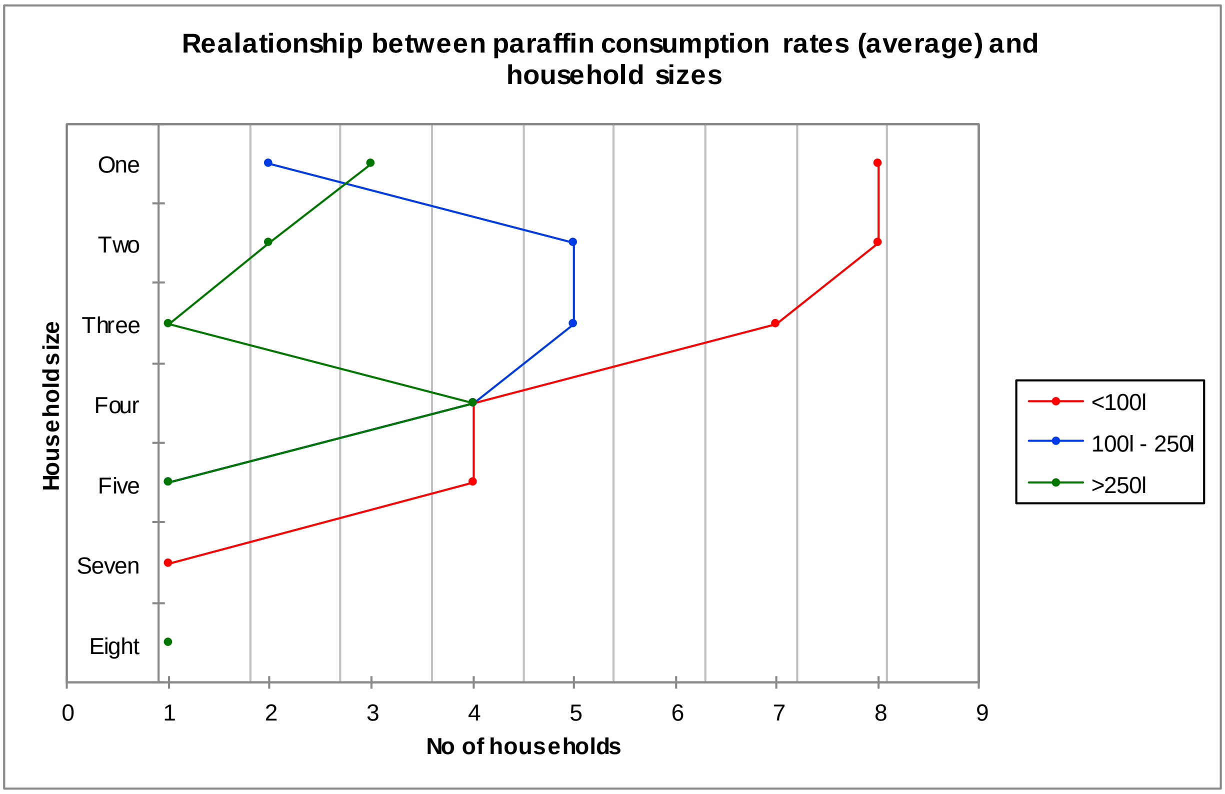


Figure 5.18 Distributions of Household Sizes Showing Average Monthly Consumption Rates Of Paraffin in the Case Study Area.

Energy-use behaviour is assessed to understand household behaviour to energy-use and other external factors affecting behaviour. This also analyzes positive behaviour in adopting cleaner energy practices in households. As shown in Table 5.12, over half the respondents agree to switch off, or down space heating devices, when going out, or sleeping at night. Some households show a willingness to turn off their heating devices, even though others are not willing to save energy, very often. As presented in Table 5.13, households are not concerned about saving energy, including households with no form of heating devices, and do not need to save energy. For lighting, cooking, and heating, the majority of households put much thought and action to save energy, while the rest have no action, whatsoever, to save energy. Most households worry about probable future hype in energy prices and worry about the impact of burning less efficient energy resources on climate.

Table 5.12 Energy-Use Behaviour to Space Heating in Households in the Case Study Area

How frequent are heating devices turned down or off?	Household proportion (%) (n = 97)
Almost always	56.70
Very often	13.40
Not very often	8.25
Never	21.65
Total	**100.00**

Table 5.13 Energy-Use Behaviour And Other Concerns about Energy Security And Climate Change In Households in the Case Study Area.

Energy use behaviour / Levels of concern	How much thought and action to save energy	How worried about the likely future energy price rises?	How worried about climate change?
A lot	65.09%	83.33%	90.57%
A fair amount	7.55%	3.92%	2.83%
Not very much	4.72%	1.96%	2.83%
None at all	22.64%	10.78%	3.77%
Total	**100.00**	**100.00**	**100.00**

5.3.4 Energy cost and energy burden

The average monthly energy cost assesses the average amount of household income spent in satisfying the minimum energy needs in households in a month. This also determines the affordability rates of energy products, which in turn, is indicative of energy burden levels (energy costs) in households. It goes further to explain the contribution of energy costs to household expenditure[65]. As presented in Figure 5.19, most households have energy costs of [50%] on household income, while others spend about [40%] and a lesser amount of [<5%] in a month. While some households have [20%] energy costs, monthly, others spend [10%]. Remarkably, most households spend [50%] and [40%] of their income on energy products, indicating higher levels of energy burden, which may be limiting satisfying modern energy services in the case study area.

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[65] As discussed in CHAPTER 1: TRENDS IN ENERGY-USE PATTERNS AND RELATED MATTERS IN INFORMAL HOUSEHOLDS IN THE CITY OF CAPE TOWN; Refer to subheading - Household monthly income

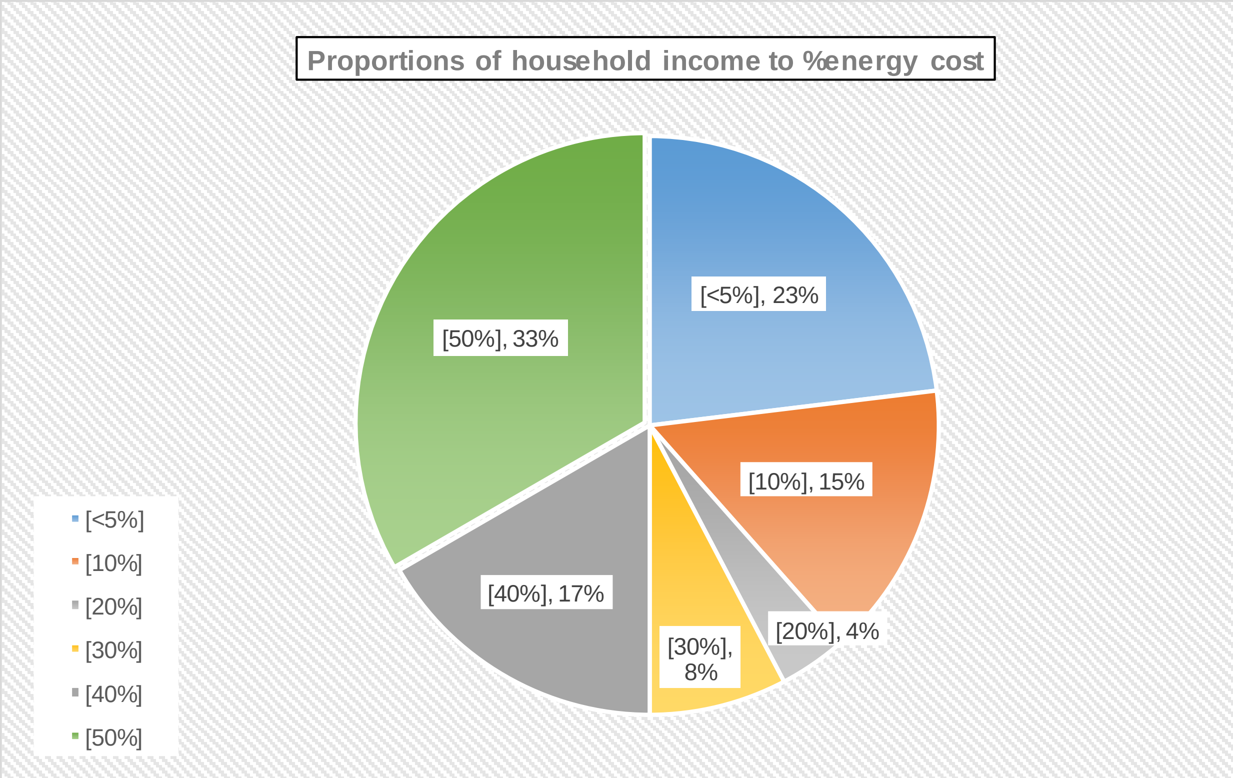


Figure 5.19 Distributions of Households Showing Percentage Proportions of Monthly Energy Costs in the Case Study Area.

Analyzing the relationships between monthly energy costs and household sizes determines whether the costs of energy products are dependent on household sizes. The majority of household sizes spend <R300 on energy products, while others spend between R301 - R999, as presented in Figure 5.20. All household sizes spend average amounts of <R300 and between R301 - R999 on energy, monthly except for an amount of <R300 not met in the household size of six. A few household sizes spend between R1000 - R1999, and >R1999. Energy costs between R1 000 – R1 999 are also consumed in household sizes of two and four. Small proportions of household sizes of one and four spend more than R1 999 on energy. This particular energy cost seems exaggerated considering that the highest household income most prevalent in informal settlements in Blackheath[66] - the suburb where the case study area is located, is mainly 'no income earners'. Just like energy consumption rates, monthly energy costs are also not influenced by household sizes in the case study area.

[66] As shown in Figure 2.12 A 2011 Survey showing Distributions of Informal Households According to Household Monthly Income and Employment Status in Some Selected Suburbs in the City Of Cape Town

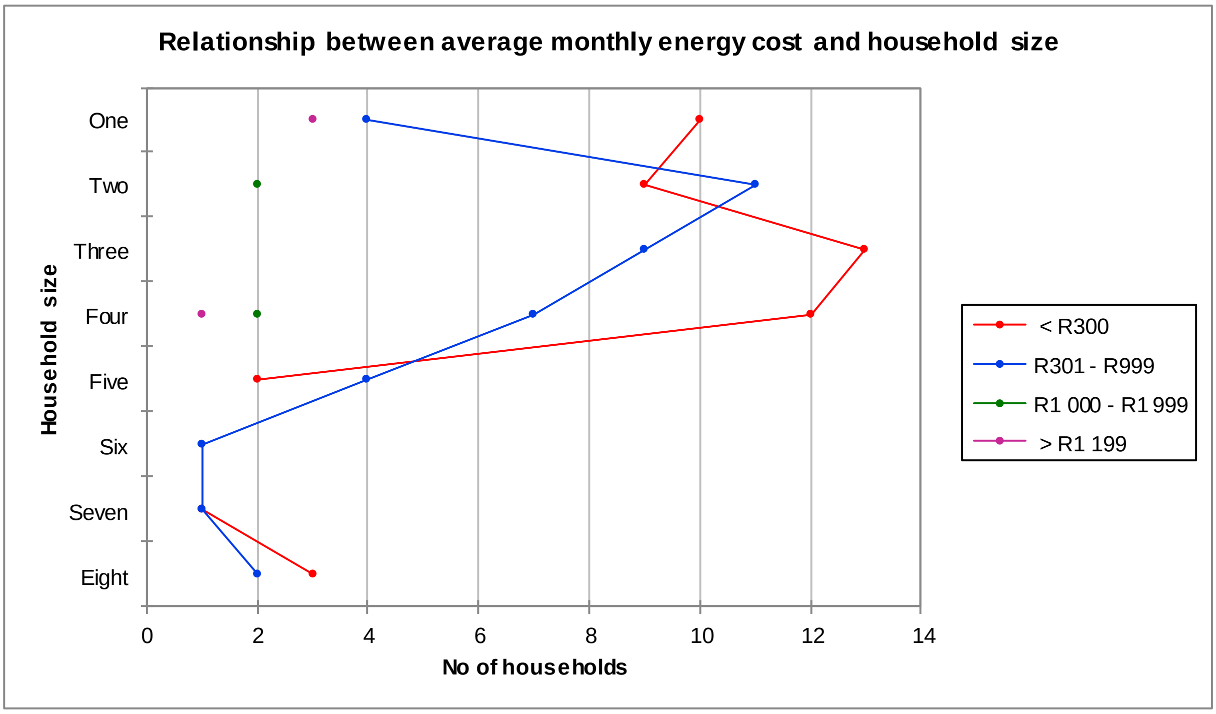


Figure 5.20 Distributions of Household Sizes Showing Average Energy Costs Per Month in the Case Study Area.

5.3.5 Energy productivity and expected benefits

Energy productivity and benefits assess the productivity and socio-economic benefits of available energy sources. For learning purposes, 49% (n= 119) of households use candles to study, while 51% use paraffin. The longest study time ranges from <2 hours to 2 – 6 hours. Around 68% (n = 98) of households have at least one family member with a high school certificate and nearly 22% have no education, similar to the literature[67]. Roughly 6% and 3% have a diploma and high degree certificates, correspondingly. While 93% (n = 100) of households have no kind of family business, about 5% run businesses such as fashion, food vending, and hair salons. As a means of conveyance, few households (n = 25) have cars and bicycles. Most commute to school (n = 74) and work (n = 75) by taxi, foot, and train, in that order. Respondents also indicate that transportation choices were based on availability, accessibility, and affordability.

[67] As discussed in Section 2.6: CHAPTER 1: TRENDS IN ENERGY-USE PATTERNS AND RELATED MATTERS IN INFORMAL HOUSEHOLDS IN THE CITY OF CAPE TOWN. Refer to Subheading – Education level; and shown in Figure 2.10 2011 Survey Showing Household Populations of Education Levels of in some selected Suburbs in the City of Cape Town. (Source: StatsSA 2011)

Table 5.14 Household Proportions Indicating Levels of Irritations (Eyes And Nose) and Breathing Difficulty from Burning Local Energy Sources in the Case Study Area

	Level of irritations (%)			
Frequency	**Yes, very much**	**Yes, not too much**	**Not at all**	**No of respondents (n)**
When using	80.00	17.50	2.50	**40**
Immediately after using	86.11	13.89	0.00	**36**
A long time after using	85.00	5.00	10.00	**20**
No of respondents (n)	**80.00**	**13.00**	**3.00**	**96.00**

For health benefits and risks, households indicate to have irritations during or after consuming local energy fuels, as shown in Table 5.14. Most households have irritations but not too much when burning local energy fuels. Some have irritations immediately when burning local energy fuels. Others have irritations a long time after burning local energy fuels. The rest have no irritations when burning local energy fuels. Households (n = 56) also respond that these irritations gradually fade away in few days (n = 27), weeks (n = 12) or months (n = 17). Some households (35%, n = 110) indicate visiting the hospital or clinic one or two times a month, others (about 47%) have zero visits to the clinic. Smaller proportions of households visit the hospital/clinic three to more than four times in a month.

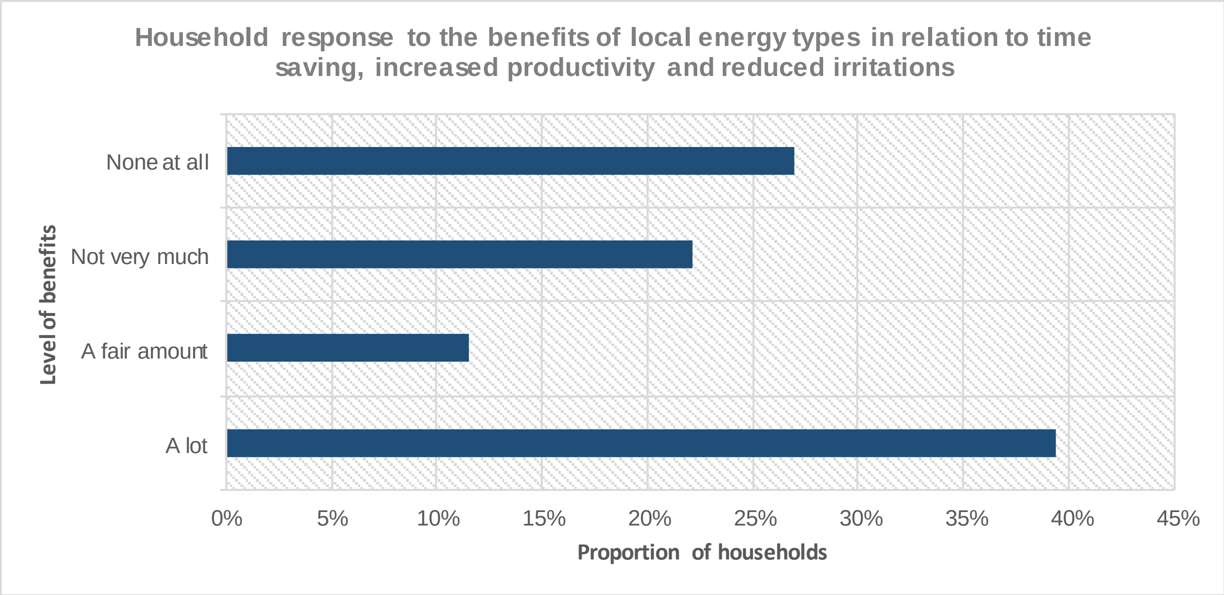


Figure 5.21 Distribution of Households showing Responses to Energy Benefits in terms of Saving Time, Better Productivity, and Reducing Irritations (Eyes, Nose And Throat) When Using Local Energy Resources in the Case Study Area.

For energy productivity in terms of saving time, increased productivity, and fewer irritations, households react, favorably to using local energy fuels, as shown in Figure 5.21. Some households indicate to benefit from burning local fuels and others indicate not much. Some households agree that consuming local energy fuels do not entirely save time, increase productivity, nor reduce irritations. For improved energy-use efficiency, most households (n = 104) suggest Solar PVC (n = 7). Some households indicate external (n =17) and internal insulations (n = 14), and replacements of windows, doors (n = 18), and roofs (n = 24). Other households (n = 24) implore the municipality to provide electricity through pre-paid meter installations in their homes. The rest indicate increasing the availability of paraffin, as well as provisions of RDP housing options.

5.3.6 Local energy supply and sustainability

There are two area vendors, peddling local energy fuels in the study area. While one vendor peddles gas, the other sells paraffin. Other local energy products used by households, such as firewood and charcoal, are obtained from woodlots and other sales outlets outside the target settlement. Area vendors indicated they purchase local energy products in bulk from small depots or mobile retailers, who supply directly to them. The price lists for these local energy products in the case study area is presented in Table 5.15. The price for paraffin is fixed in summer but falters between R13 and R15 in winter. There are fixed prices for different kilograms of gas, which are not affected by seasons. The area vendor for gas said that the regulation of gas prices is independent of seasonality but rather on bulk purchase costs. Both area vendors confirmed the affordability, availability, and sustainability of these local energy products, except in a few winters in some years when demand was very high.

Table 5.15 Price Lists of Two Main Local Energy Products, Peddled In The Case Study Area As Set By Area Vendors

Local energy types	Price (Summer)	Price (Winter)
Paraffin per litre	R13	R13 – R20
Gas (5kg)	R120	-
Gas (9kg)	R220	-
Gas (19kg)	R420	-

5.3.7 Discussions: Significant factors sustaining poor energy use in the study area

In the case study area, dwelling types are mainly made up of corrugated metal sheeting, commonly referred to as shacks in South Africa. As reported by literature[68], this type of dwellings is often poorly constructed, with no external or internal insulation to support energy-use efficiency. Currently, there is no electricity access in the study area and many recorded

[68] Section 2.4: INEQUALITY IN ENERGY DISTRIBUTION: PROFILING INFORMAL SETTLEMENTS

electrical appliances tend to support the verdict of wide-spread electricity theft in informal settlements in South Africa (SEA 2014). Energy-use sources primarily include paraffin (transitional) and candles (traditional), used for lighting only, in the settlement. Fuelwood and charcoal are mainly adopted for space heating and cooking in households. Households also practice multiple energy uses, particularly for space heating in winter, probably to circumvent energy insecurity, price hype, and product scarcity that occur, occasionally mainly due to seasonality. Local energy devices are mostly adopted for space heating in winter but natural methods are primarily used for space cooling in summer in the case study area.

As earlier mentioned, the target settlement consumes mainly local energy fuels, which have increased energy burden levels in households. Consumption analyses reveal that most households consume <100l of paraffin monthly in summer and 100-250l and >250l in winter. Gas consumption rates show to decline across seasons and other energy products such as fuelwood and charcoals increased in winter, but only slightly. Except for paraffin use, no significant relationships exist between, and within, the consumption rates of local energy products across the seasons. Energy cost analyses have revealed higher energy burden levels since most households spend between <R300 and R999, with about [50%] and [40%] energy costs on household income per month. The analyses also reveal lesser energy burden levels where informal households, for instance, have [5%] energy costs on household income in a month. Study analyses have shown that household sizes neither influence monthly energy consumption rates nor average monthly energy costs in the case study area.

To a significant extent, the target settlement reveals positive energy-use behaviour to saving energy that also encourages immediate energy transition or shift, once provided. Some households worry about price hypes for local energy products, while others worry about the health and ecological impacts of burning local energy fuels. Available local energy products seem to offer better energy productivity, save time, and have fewer impacts on health in households. Some households otherwise argue that these available energy products are not entirely productive and cause irritations during and after use. The analysis also shows that households visit the local clinic, typically a few times, monthly for various health issues. Currently, available local energy fuels in the case study area cannot achieve modern energy services[69] and associated benefits in households.

[69] Table 2.1 Modern Energy Services Contributing to Achieving Millennium Development Goals (MDGs)

At present, the Sofia settlement has few socio-economic activities except for a few small businesses. The highest educational qualifications amongst the inhabitants are mainly few with high school certificates and most with no form of education. Interviews with the area vendors reveal that local energy supplies can be sustainable, except on rare occasions in winter when energy demand is very high. The affordability of local energy products has been confirmed by both area vendors and households, which, somehow, contradicts the high energy burdens of consuming these local products on household income. Also, lack of electricity access in the settlement reinforces the availability and affordability of these local energy fuels, particularly paraffin.

Conclusively, energy-use patterns in the target settlement are mostly poor, mainly including transitional – paraffin and gas; traditional energy fuels - agricultural/animal wastes, fuelwood, and coal; and lastly, smart electricity, hence partly addressing Research Question 4[70]. While energy practices are mainly local energy devices, energy-use behaviour in households only shows the ability to save energy and recognize health concerns of poor energy use, hence addressing, completely Research Question 4[70]. There are other ways to effectively model significant factors propagating poor energy-use patterns in the case study area. The proposed new SRM has been identified as a practical tool that can give a clearer picture and quick representations of these diverse factors and their interactions, as well as promoting cleaner energy access and practices in the case study area; this is discussed in section 5.4 below.

[70] Section 1.4: RESEARCH QUESTIONS. 4. What are the present energy-use patterns and behaviour in informal households in a typical informal settlement?

5.4 APPLYING THE PROPOSED NEW SYSTEM REINFORCING (SRM) MODEL

This section addresses Research Objective 5[71] and Research Question 5[72] by applying the proposed new System Reinforcing Model (SRM)[73], formerly presented in Section 3.2, and shown again in Figure 5.22, in the interest of easy reference. The proposed new SRM acts as a management decision framework, agreeing with the perceptions of Stephenson *et al*. (2010) and Shrestha and Acharya (2015). The literature[74] has demonstrated the logical application of a systems approach - SE concepts with SsT principles, into developing the new SRM, agreeing with Tejeda and Ferreira (2014). Among its many features, the new SRM represents data quantifications into feedback loops, while defining interrelationships between data to solving system problems. Thus far, energy-use patterns and other matters have been analyzed[75] in a typical energy-poor informal settlement in South Africa, representative of a typical energy-poor community in sub-Saharan Africa. To demonstrate its utility, the new SRM was used to make quick demonstrations of significant outcomes of analyses in the case study area – the Sofia settlement, and probable solutions to improve clean energy access.

We logically describe the model application, first by assessing systems of energy poverty also known as design decisions to assess levels of energy poverty, followed by triggering system designs to enable and promote energy access. The proposed new SRM model is applied, iteratively, to guarantee a high-quality model development with behaviour and structure that can equal reality. The model application begins with:

- ✓ First, plotting the historical reference modes of key elements, defining energy-use patterns in informal settlements regionally - in this case, the City of Cape Town - to support the overall model's purpose (Pejic-Bach and Ceric 2007).

[71] Section 1.3: RESEARCH AIM AND OBJECTIVES. 5. Developing a proposed new SRM, a model that prioritizes best strategies and options in improving energy access, useful in addressing energy poverty at a community level. Significant outcomes of Objectives 1 to 4 are incorporated into the new model as options to facilitate Energy Access Sustainability (EAS) in the primary case study.

[72] Section 1.4: RESEARCH QUESTIONS. Will the proposed model serve as a suitable framework to support modelling of key drivers of energy-use patterns and behaviour and EAS, as well as external factors affecting processes in an energy-poor community? Can the new SRM help to mitigate energy poverty and improve energy access in such a community?

[73] Figure 3.2 Proposed New System Reinforcing Model (SRM) for Energy Access Sustainability (EAS)

[74] As discussed in CHAPTER 3: APPLYING A SYSTEMS APPROACH TO MITIGATING ENERGY POVERTY

[75] Section 5.3: ENERGY USE AND RELATED DATA, PATTERNS, AND RELATIONSHIPS

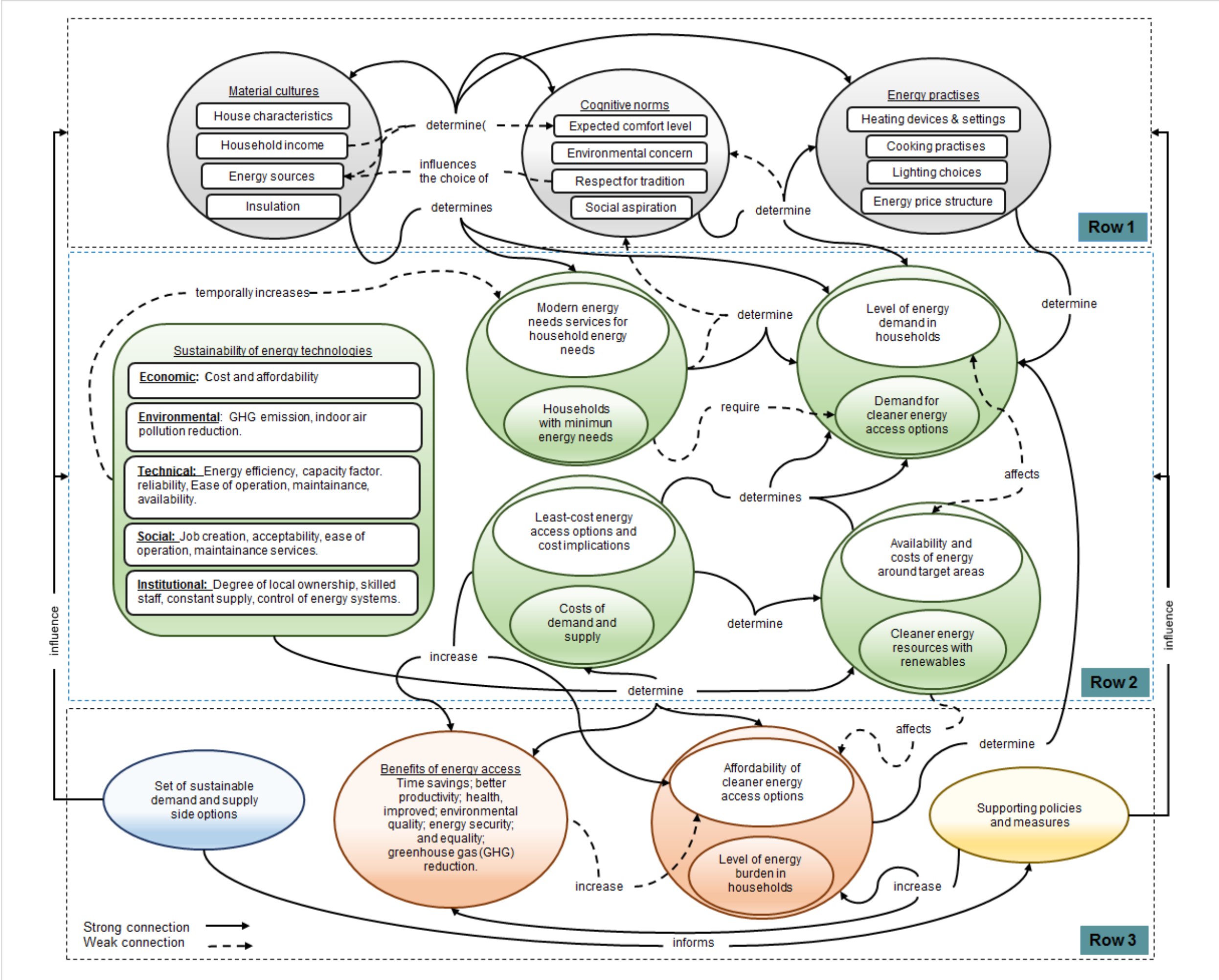


Figure 5.22 Proposed New System Reinforcing Model (SRM) for Energy Access Sustainability (EAS), Implementable at the Sub-Regional Level.

- ✓ Then, the first step in the model application – developing the first design decision – *material cultures*, with a simple stock and flow structure, built on feedback loops analyzing interrelationships (Figure 5.22).

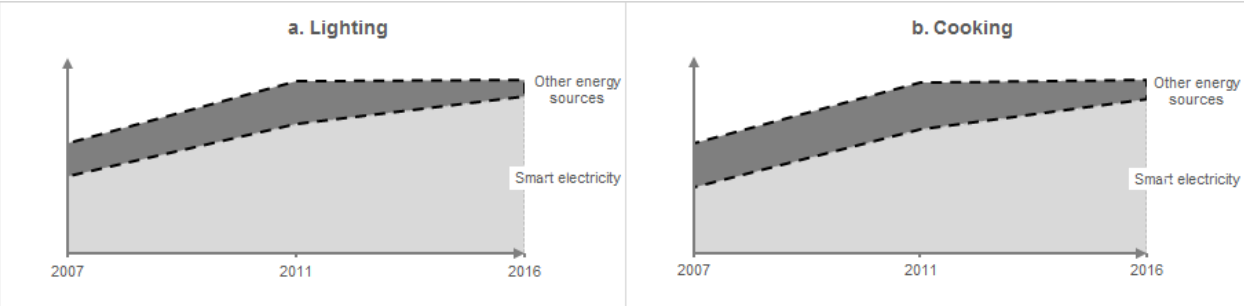
- ✓ The second and third steps - addressing the first system interface in the new SRM by including the other design decisions - first, *cognitive norms*, followed by *energy practices*, generating more feedback loops analyzing interrelationships (Figure 5.22).

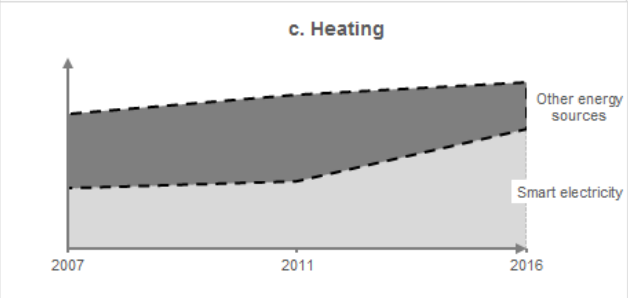
- ✓ The fourth step - addressing the second system interface by integrating the first system designs in Row 2 and also those in blue and yellow circles in Row 3, to assess the performance of design decisions and enable energy access, hence generating more feedback loops (Figure 5.22)

- ✓ The last step and the last system interface incorporates the last two system designs in orange circles in Row 3, whose elements and interconnections either encourage or relegate EAS (Figure 5.22). At this stage, significant outcomes of the whole study investigations are considered and objectively integrated.

5.4.1 Historical reference modes of key elements

Before the SRM model application, historical reference modes of the key elements worth modelling, succinctly analyzing energy-use patterns in informal settlements, over time, are explored. These key elements are crucial in addressing the model’s purpose, which is to understand energy poverty levels with the intent of promoting energy access in informal settlements in South Africa, as well as energy-poor communities in sub-Saharan Africa. The model’s purpose is condensed into the behavioural curves between using *smart electricity* and *other energy sources* (gas, paraffin, fuelwood, charcoal, and animal dung) in satisfying the minimum basic energy needs - *lighting*, *cooking*, and *heating* - in informal settlements in the City of Cape Town. These key elements are plotted as historical reference modes at constant periods and represented in multiple graphs and time plots, as shown in Figure 5.23. The time plots (1) provide historical data in theory, (2) act as a mental guide to the new SRM model application, and (3) validate the plausibility of the new SRM model after completion.





	Lighting (%)		
	2007	2011	2016
Electricity	70	75	90
Other energy	30	25	10
	Cooking (%)		
	2007	2011	2016
Electricity	60	72	88
Other energy	40	28	12
	Heating (%)		
	2007	2011	2016
Electricity	44	44	71
Other energy	56	56	29

Figure 5.23 Historical Reference Modes of Key Elements, Showing the Adoption Gaps (Dark-Grey Shaded) generated Between the Use of Smart Electricity and Other Energy Sources for a. Lighting, b. Cooking and c. Heating in Informal Settlements in the City of Cape Town. (Source: Superweb (StatsSA 2011;2016))

As shown in Figure 5.23, some data selected from Stats SA (2011; 2016) were employed in plotting the historical reference modes but the values are non-consequential at this point. Considerable emphasis is placed on the behavioural curves between the adoption of *smart* *electricity* and *other energy sources* in meeting *lighting*, *cooking*, and *heating*, and most importantly, the adoption gaps between them. The use of *smart electricity* and *other energy sources* increased (from 2007 to 2011), over time, but the latter decreased, subsequently (from 2011 to 2016). The adoption gaps support the understanding of energy-use patterns and energy poverty levels in informal settlements, over time. The adoption gaps generated for *lighting* (Figure 5.23a) and *cooking* (Figure 5.23Figure 5.23b) are relatively small and stagnant, over time, compared to that of *heating* (Figure 5.23c). There is a wider adoption gap for *heating* (Figure 5.23c) because most informal households employ multiple energy uses for space heating in winter (Vermaak, Kohler and Rhodes Bruce, 2013). Notably, the adoption gaps generated by *other energy sources* are to be bridged by providing access to *smart electricity* or other available cleaner access options to improve clean energy access in informal settlements.

Literature[76] and data analyses[77] have shown myriads of elements, promoting poor energy-use patterns, and widening the adoption gaps in informal settlements. The new SRM has been proposed as a multi-criteria tool in modelling these elements and various sustainable access solutions in bridging the adoption gaps. The core concept of the new SRM depends on developing basic mechanisms represented in feedback loops, capable of understanding the adoption gaps in achieving the model's purpose. Significant outcomes of data analyses in Section 5.5 are treated as step inputs in the SRM model application. As earlier indicated, the model application began by developing basic mechanisms of, firstly, each design decision, and then, system designs, as analyzed step-by-step in the subsections below.

5.4.2 The productivity of material cultures

The first step of basic mechanisms, a simple system stock with its subsystems and elements, comprising of the design decision - *Material Cultures* (*MCs*), is developed. Generally, the system performance is significant when a series of strong connections in feedback loops flow between elements. Weak feedback loops may not strongly drive system performance but are treated as step inputs to broaden the understanding of supplementary elements that perhaps influence system purpose.

[76] Section 2.6: TRENDS IN ENERGY-USE PATTERNS AND RELATED MATTERS IN INFORMAL HOUSEHOLDS IN THE CITY OF CAPE TOWN
[77] Section 5.3: ENERGY USE AND RELATED DATA, PATTERNS, AND RELATIONSHIPS

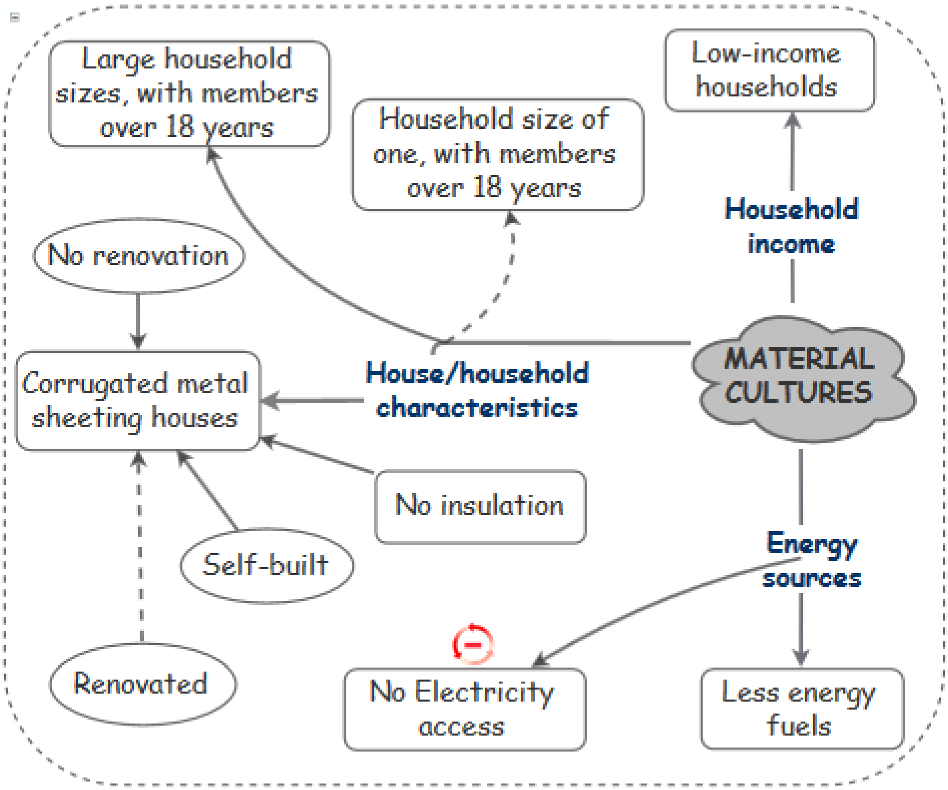


Figure 5.24 The First Step of Basic Mechanisms: The Design Decision - *Material Cultures*, Illustrating the Interrelationships Between Elements using Data Scope Analyses in the Case Study Area. Bold Lines Represent Strong Connections, while Dotted Lines Represent Weak Connections. Both are Equally Important to Model Behaviour.

As shown in Figure 5.24, the three subsystems in *MCs - household low-income*, *house characteristics*, and *energy sources*, are flowing as strong and weak loops to other system elements. Fundamentally, the *MCs* decision is strongly defined by *low-income households* in *self-built* and *corrugated metal-sheeting houses*, having *no insulation* and *renovation*, *large household sizes with economically active individuals over 18 years*, *no electricity access*, and use mainly *less clean energy fuels*. System elements, such as the *household size of one*, and *renovated houses*, do not strongly drive the system behaviour. Moreover, *non-insulated and corrugated metal sheeting houses* are of poor construction to maintain optimal warm temperatures in households, particularly in winter. Overall, the *MCs* decision shows low levels of productivity in its subsystems and elements, disproving energy access and energy-use efficiency in the case study area, and conceivably, widened the adoption gaps[78] in the historical reference modes.

[78] Figure 5.23 Historical Reference Modes of Key Elements, Showing the Adoption Gaps (Dark-Grey Shaded) generated Between the Use of Smart Electricity and Other Energy Sources for a. Lighting, b. Cooking and c. Heating in Informal Settlements in the City of Cape Town. (Source: Superweb (StatsSA 2011;2016))

5.4.3 Contributions of cognitive norms

In the second step, a new set of feedback loops are added to understand why households use energy the way they do (Stephenson *et al.* 2010). *Cognitive Norms* (*CNs*) analyze energy choices, characterized by values, such as *social aspirations*, *the expected level of comfort*, *traditional beliefs*, and *environmental and health concerns*, which in part, determine the *MCs* decision and in part, by such as determine *Energy Practices (EPs) and appliances*. The interactions between these elements in the *CNs* decision contribute to the understanding of households' inclination to particular *MCs* and *EPs*.

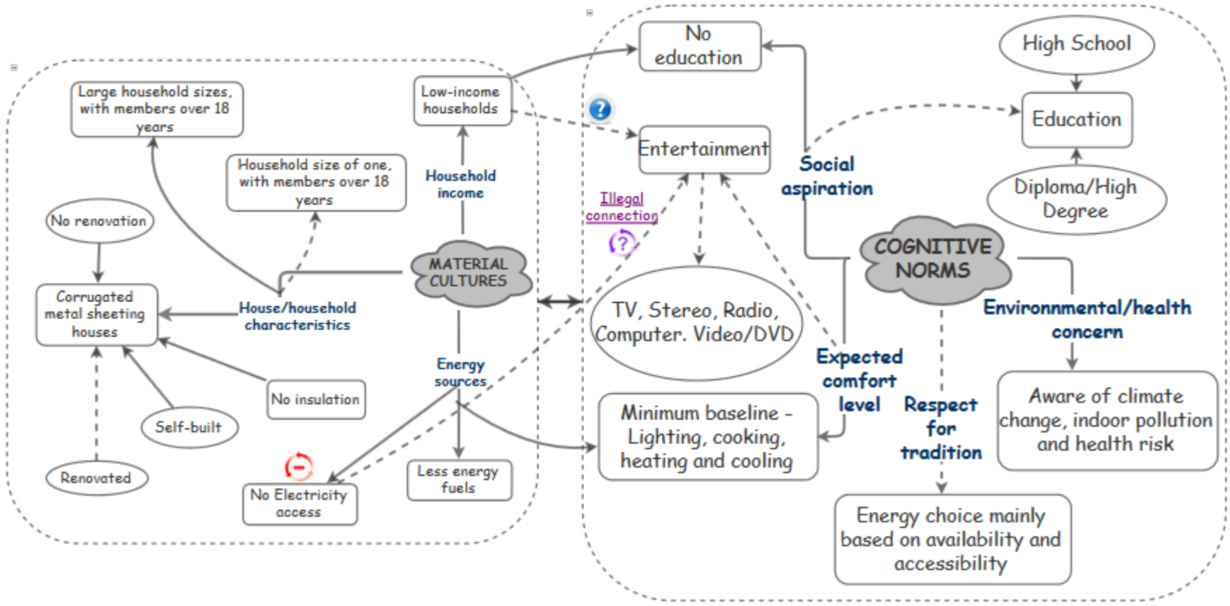


Figure 5.25 The Second Step: The Inclusion Of Design Decision - *Cognitive Norms*, Illustrating the Interrelationships Between Elements Using Data Scope Analyses in the Case Study Area. Bold Lines Represent Strong Connections, while Dotted Lines Represent Weak Connections. Both are Equally Important to Model Behaviour.

As presented in Figure 5.25, energy choices are not driven by *respect for tradition* but by the *expected comfort level*, regarding the *minimum energy needs baseline* in the *CNs* decision. Regardless of the *awareness of environmental and health concerns* of poor energy use within the *CNs* decision, system elements such as *low-income households, poor energy sources*, and *corrugated metal sheeting houses* in *MCs* discourage preferences to cleaner energy access in households. Interestingly, households have some level of *entertainment*, thus questioning the likelihood of illegal connections (SEA 2014), and *household low-income* status. These are weak loops and do not strongly contribute to defining the belief system and values of people. *No education* and the *minimum energy needs baseline* also, are strongly determined by such things as *low-income households* and *less clean energy fuels* in *MCs.* Generally, the *CNs* decision demonstrates poor values and belief systems of people, contributing to poor energy choices in the case study area. Eventually, low productive *MCs* led to poor contributions of *CNs,* and vice versa, in widening the adoption gaps[78] in informal settlements.

5.4.4 Preferences of energy practices

In the third step, another set of basic mechanisms involving the last design decision – *Energy Practices* (*EPs*) is integrated to assess energy-use practices, appliances, and energy price structure in the case study area. The *EPs* decision is strongly determined by *MCs* and *CNs*, which, in turn, partly influence *CNs* and does not determine *MCs*. At this stage in the model application, the first system interface in energy poverty and access processes, comprising only design decisions, has been addressed.

As shown in Figure 5.26, system elements such as *lighting*, *cooking*, *heating*, *cooling*, and *energy price structure* in arrays of feedback loops are endogenous to the *EPs* decision. The system behaviour is not exclusively dependent on its system elements but determined by elements in *MCs* and *CNs*. *EPs* include mainly traditional energy devices and few electrical appliances. The *energy price structure* of paraffin is said to be affordable, irrespective of seasonality, *household sizes*, and *low-income*. The *EPs* decision is strongly defined by the driving behaviour of *MCs* and *CNs*; with product *availability* strengthening *energy prices* to be affordable. Even with the *awareness of climate change and indoor air pollution* in the *CNs* decision, *EPs* are influenced by more resilient elements in the *MCs* decision such as *no electricity access* and available *less clean energy fuels*, among others. Consequently, unproductive *MCs* and poorly contributed *CNs* led to poor *EPs* in the study area. Largely, constant arrays of strong connections flowing in design decisions led to poor systems' performances, and as a consequence, widened the adoption gaps[78] in informal settlements, at large.

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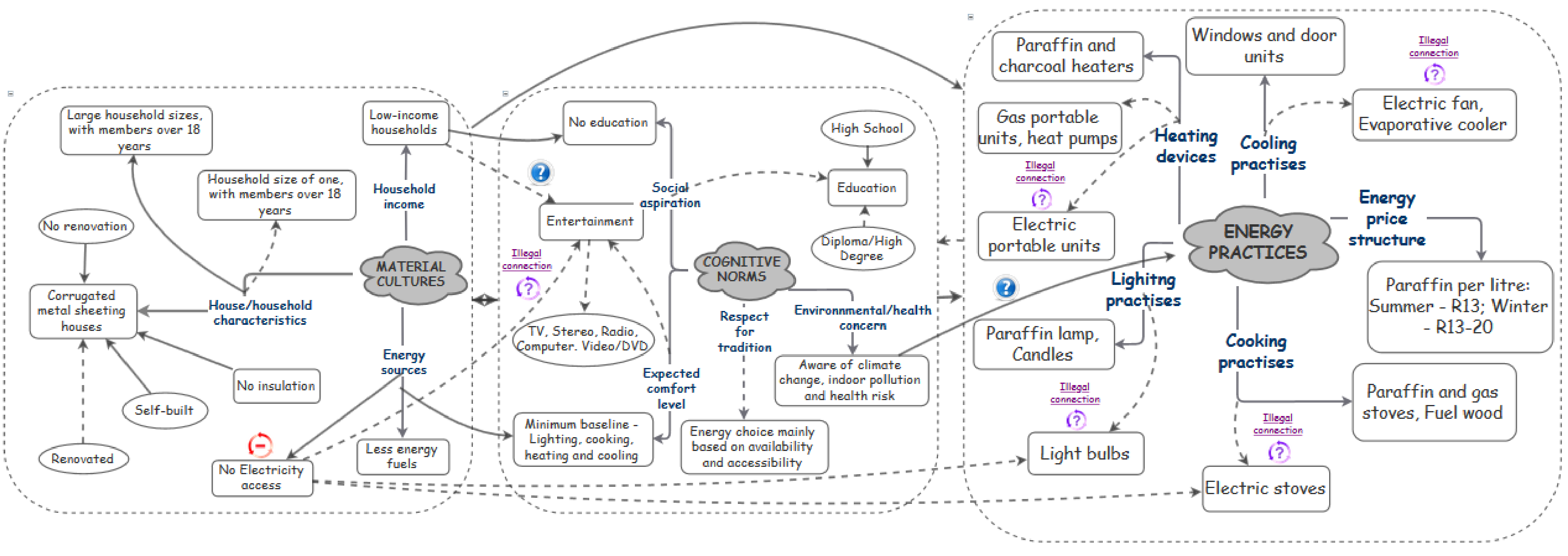

Figure 5.26 The Third step: The Inclusion of The Design Decision - *Energy Practices*, Illustrating The Interrelationships Between Elements Using Data Scope Analyses In The Case Study Area. Bold Lines Represent Strong Connections, while Dotted Lines Represent Weak Connections. Both are Equally Important to Model Behaviour.

5.4.5 Enabling energy access and sustainability

In the fourth step addressing the second system interface, design decisions are checked by integrating system designs to enable cleaner and sustainable access options. These system designs check design decisions by assessing the *minimum energy needs* in *modern energy services* and the *energy demand level*, which are in turn, determined by *availability*, *cost*, *affordability*, and the *benefits* of energy types; while at the same time, identifying *least-cost cleaner energy access options* and *sustainability of energy technologies* to enabling energy access in bridging the adoption gaps[78]. From here on, only key elements defining system behaviour in design decisions are considered during the rest of the model application.

As shown in Figure 5.27, *modern energy services* are influenced by design decisions. For instance, *less clean energy fuels* and *household low-income* in *MCs* can satisfy the *minimum energy needs*. Among *modern energy services*[79], households need to satisfy, at least, these *minimum energy needs* including *lighting, cooking, and heating* (Practical Action 2010). *Transitional and traditional energy fuels* are currently employed in satisfying the *minimum energy needs* in the study area. Moreover, poorly structured elements within *CNs and EPs* decisions are interactively acting against achieving *modern energy services* in the case study area.

Design decisions also influence the *energy demand level*, determining the *acceptable energy consumption level* in households as shown in Figure 5.27. For example, the relationships between using *transitional and traditional energy fuels* to satisfy the *minimum energy needs baseline* through *poor energy-use practices* in design decisions strongly influence the *energy demand level*. Among available local energy fuels, *paraffin* and *candles* are higher in *energy demand levels* than those of *gas*, *fuelwood*, and *coal*. There is a higher *demand* for candles among *traditional energy fuels*. The *demand level* for *<100l of paraffin* outweighs other *transitional energy fuels* for lighting, cooking, and heating, individually. As previously described[79], the *energy demand level* evaluates total energy demands for available resources, required to meet the *minimum energy needs*. For this study, the *acceptable level of energy consumption* is reached when households can satisfy the *minimum energy needs* in the study area.

[79] As shown in Figure 3.3 Modern Energy needs showing Minimum Acceptable Threshold levels and a Top-Down Approach (Centre Column) describing the Energy Demand Level in Households. (Modified from Practical Action 2010 and Shrestha and Acharya 2015).

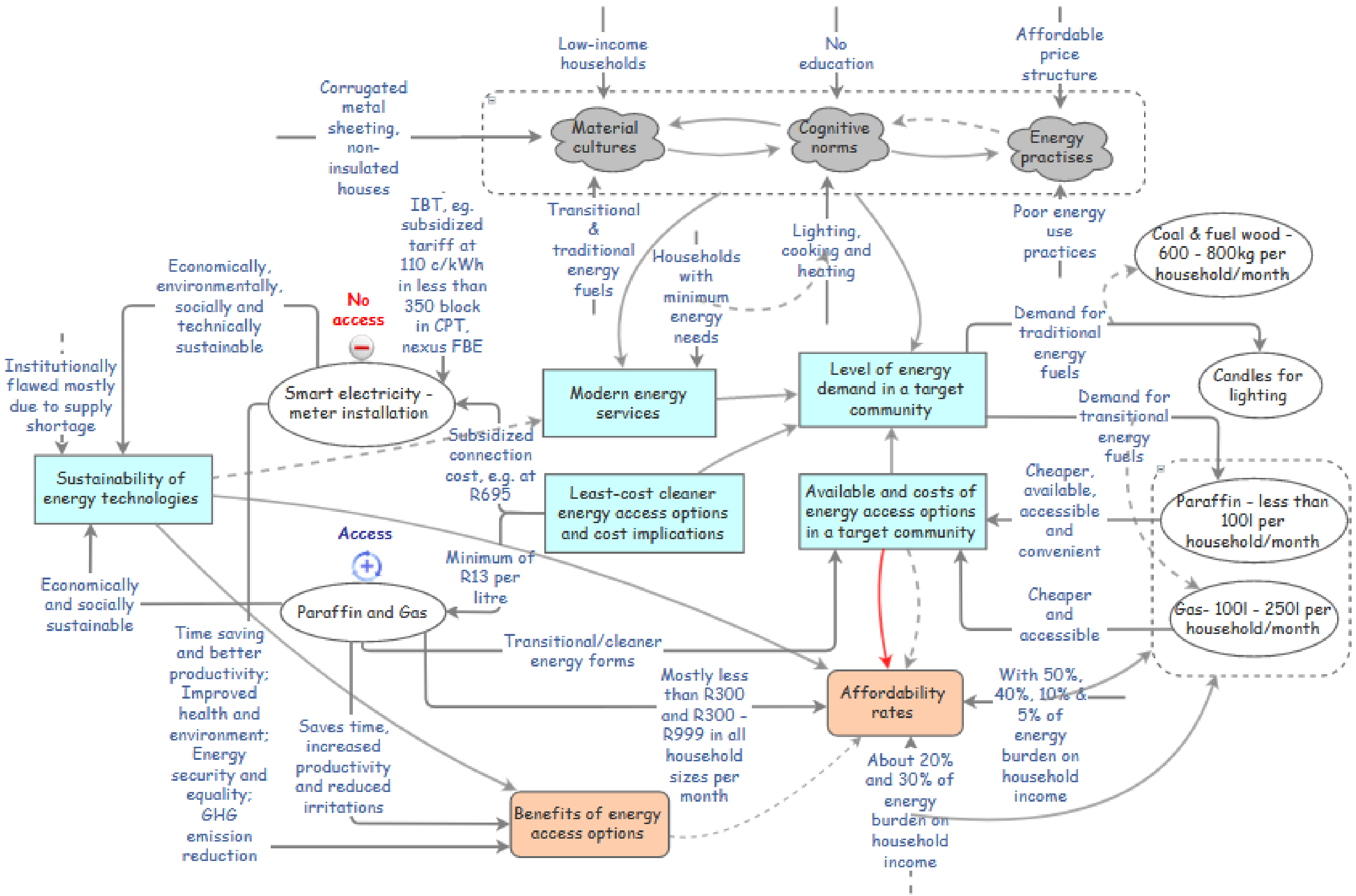

Figure 5.27 The Fourth Step: The Inclusion of System Designs (green and orange boxes) Describing Design Decisions and Enabling Energy Access, Illustrating the Interrelationships Within and Outside the Systems. Bold Lines Represent Strong Connections, while Dotted Lines Represent Weak Connections. Both are Equally Important to Model Behaviour.

Then again, the *energy demand level* is driven by option *availability and costs*, along with *accessibility* and *convenience*[80], as shown in Figure 5.27. *Availability* influences the *energy demand level* but does not strongly influence *affordability;* since *availability* does not equal *affordability*. In the study area, product *availability* in itself promotes *affordability*, thus generating another feedback loop (red) between these system designs. The red feedback loop indicates that *availability* promotes *affordability*, which is largely influenced by a lack of electricity access in the study area.

Even with product *affordability*, *levels of energy burden* are higher of such available energy products on household income, as shown in Figure 5.27. Most households spend <R300 and between *R300 – R999* on local energy products per month. As reported by StatsSA (2011)[81], majorities of informal households earn between R1 601 - R3 200, and 'no income earners', monthly, in the City of Cape Town. Evaluating *affordability rates* while levelling on *energy burdens* of these available energy products, energy costs take away mostly *50% and 40%* large fractions of household income, with no exacerbating impact from household sizes[82]. Small fractions of *5% and 10%* energy costs on household income are also recorded. It is therefore important to identify other available *least-cost cleaner access options* to achieve positive *affordability rates.*

Presently, available *least-cost cleaner access options* are mainly *transitional energy* such as *paraffin* and *gas*, having strong *economic and social sustainability* (Figure 5.27). The *institutional sustainability* is partially flawed due to periodic product scarcity and price oscillations. These *energy fuels* are *affordable* but, at the same time, produce high *energy burdens* and *fewer energy benefits*. The reasons being that of product *availability* and *accessibility*, in which *energy benefits* are perceived in the capacity of such available local *energy fuels* to *save time, improve productivity, and reduce irritations*. Another available *least-cost cleaner access option* is access to *smart electricity through meter installations*, and the study area is close to the grid to receive electricity.

Electricity access can be more cost-effective than using *transitional energy fuels* (DoE 2016; SEA 2014a). The costs of *electricity* consumption, for example, *<350 kWh at the subsidized*

[80]As demonstrated in Figure 3.4 Some System Designs in the proposed New SRM, as well as their Attributes, Profiles, And relevant Methodologies.
[81] As shown in Figure 2.11 Temporal Stretch of Household Monthly Income in Informal Households (Grouped) by Census Years in the City Of Cape Town. (Source: StatsSA 2011).
[82] As analyzed in Subsection 5.3.4: Energy cost and energy burden

(FBE) tariff of R110[83], monthly, in recent times, perhaps are quite cheaper than the structured prices of available local energy products in the study area. Only *energy benefits of grid-connections,* for example*, at the subsidized cost of R695*[84]*,* exceed the monthly cost of using available local *energy fuels* and its expected *energy benefits* in the study area.

5.4.6 Promoting energy access sustainability: Policy interventions and implications

In the fifth step and the last system interface, strategies, and interventions are integrated to resolve system parts propagating model problems. To this point, the model application has shown problem systems and a guide to discover plans and policy instruments, targeting the socio-economic and cultural conditions in the case study area. Energy pro-poor policies expressed in the 1998 Energy White Paper[85] (DME 1998) have been recognized as policy instruments that can eliminate model barriers to changing model behaviour. These policy interventions can improve on key system elements to changing the model behaviour. The last two system designs - *supporting policies and measures* and *a set of sustainable options,* are set aside to changing the model behaviour and promoting EAS in the study area.

To recap the model application thus far, the model reveals low productive elements in *MCs,* defined by poor contributions of *CNs,* and translated into poor preferences of *EPs*. There are certain conditions where *CNs* are favourable but are compromised by unproductive *MCs,* or another situation where *CNs* favour energy-efficient *MCs* but are weakened by poor *EPs* (Stephenson *et al.* 2010). Addressing model lop-sided components through specific interventions, targeting socio-economic states in the case study area, can shift energy-use patterns and behaviour in households. The shift can be substantially disadvantaged by wider scales of socio-technical and supply systems. Resolving problem systems requires revoking certain mechanisms to improve interventions and strategies. With the prime understanding of system forces prolonging model problems, system designs (in yellow boxes), promoting EAS, and bridging the adoption gaps[78], are grounded in policies and measures, along with stakeholders' specifications, as presented in Figure 5.28.

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[83] As shown in Table 5.5 Historical Events of Subsidized IBT Structure Designed for Low-Energy Users (Supplies = 20 Amps), Imbued with FBE Allocations in the City of Cape Town.
[84] As shown in Table 5.3 Table showing Access Rates (Meters Installed) and Access Costs (SCC), Significance of Relationships between them, and Annual Percentage Increase in SCC. (Source: EGD 2018)
[85] As reviewed in CHAPTER 4: POLICY REVIEW: ENERGY PRO-POOR POLICIES

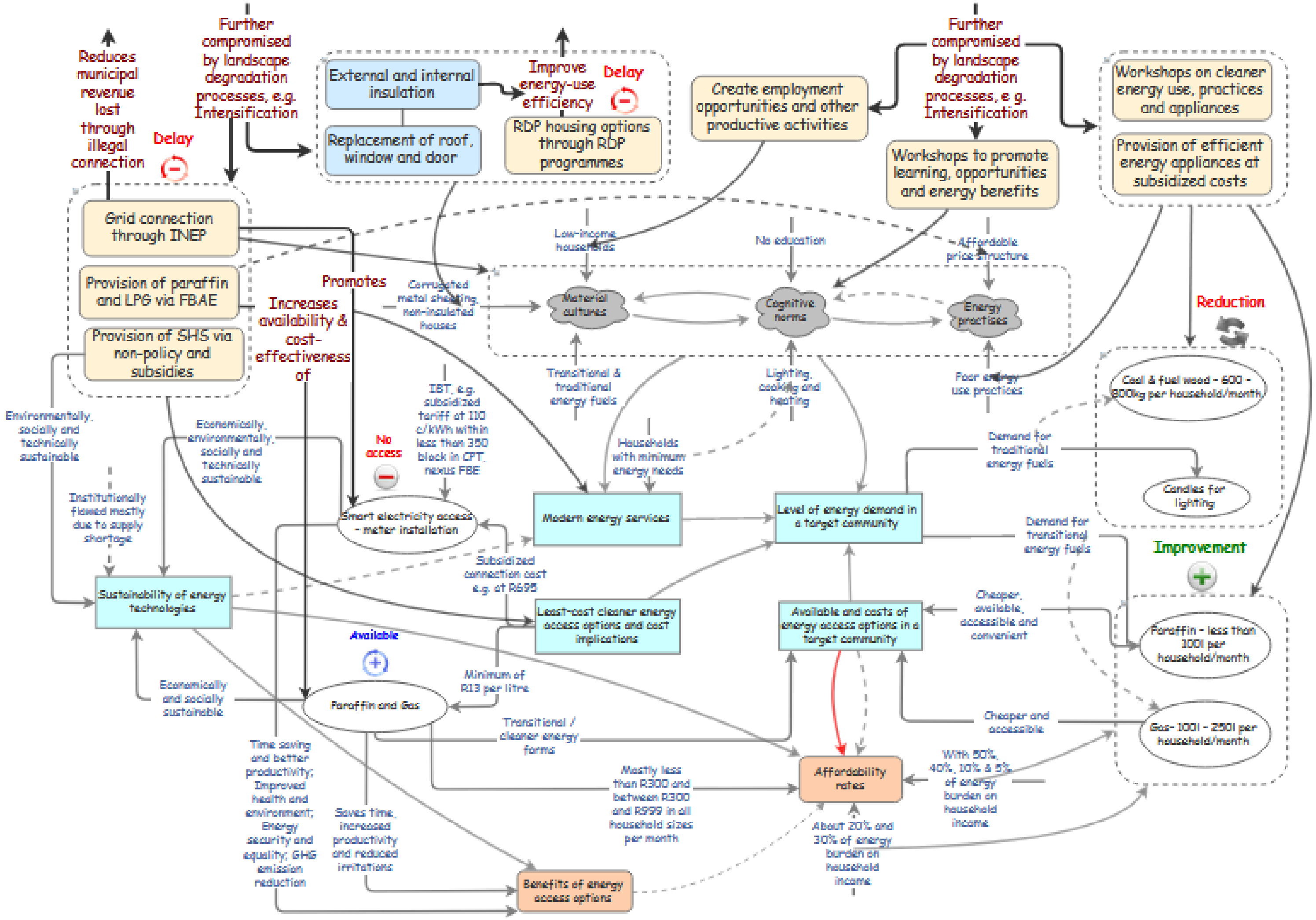

Figure 5.28 The Fifth Step: The Inclusion Of System Designs (yellow boxes) Promoting EAS Through Policies and Other Interventions, Illustrating the Interrelationships Between the Systems. Bold Lines Represent Strong Connections, while Dotted Lines Represent Weak Connections. Both are Equally Important to Model Behaviour.

As shown in Figure 5.28, valued strategies such as w*orkshops on cleaner energy use and practices* and *subsidizing efficient energy-use appliances* can improve *EPs* based on device performance, operability, and time-saving. *No education* and *baseline energy needs* in *CNs*, determined by *MCs*, also translate to limiting cleaner *EPs* and the use of the finest energy devices. *Promoting learning opportunities and its benefits* can redefine the socio-cultural behaviour by influencing *CNs*, which influence *EPs*, *MCs*, and whole model behaviour. *Employment prospects* and *entrepreneurial and productive activities* can improve *household low-income*. *Non-insulated corrugated metal sheeting houses* limit energy-use efficiency and device performance (Muringathuparambil *et al.* 2017). The *RDP programme* [86] delivers subsidized/free houses to low-income households (DME 1998) but is somewhat delayed at present. Challenges are mainly of financial constraints in clearing backlogs and meeting new housing demands within this programme. Some *sets of demand-side options*, such as *house insulation*, and *replacement of roof and orifices*, among others, are identified through stakeholders' participation, which can increase energy-use efficiency in households, to some large extents.

The most reliable solution to energy poverty is access to *smart electricity*, which can competently bridge the adoption gaps[78] in informal settlements. At the moment, there is no electricity access, and perhaps, illegal connections (SEA 2014) in the case study area, as demonstrated in Figure 5.28. Presently, the *INEP programme*[87] (DoE 2015) battles with large connection backlogs, particularly in informal households. *Smart electricity through meter installations* can discourage *municipal revenue lost* through illegal connections (SEA 2014). With *FBE benefits* [88] (DME 2003) entrenched in the *IBT pricing structure* [89] (SEA 2014),

[86] As reviewed in Subsection 4.1.1 Reconstruction and Development Programme (RDP). The RDP policy (DME 1998) was initiated in 1994. The key objective is to build thermally efficient low-cost houses, as an opportunity to promote energy access, efficiency, and conservation in poor households. Another objective is to reduce poor practices of using local fuels and appliances for water and space heating in winter in energy-poor homes (Walsh, Wesselink and Janisch 2011).

[87] As reviewed in Subsection 4.1.2 Integrated National Electrification Programme (INEP). The Integrated National Electrification Programme (INEP) (DoE 2015) was commissioned in 2001 as a strategy to achieve universal energy access by 2012. Presently, there are limited funds (DoE 2015) to carry out electrifications, particularly in informal households. The INEP (DoE 2015) is also faced with addressing backlogs, and electrifying newly built houses. Rising electrification costs further frustrate INEP efforts (DoE 2015) in addressing these challenges. Refer to Section 4.3 DRAWBACKS IN POLICY IMPLEMENTATIONs

[88] As reviewed in Subsection 4.1.4 Free Basic Electricity (FBE) Policy. The Free Basic Energy (FBE) Policy (DME 2003) was commissioned in 2003 to promote electricity use in poor households, once connected; fixed at a monthly allocation of 50kWh per household (DME 2003).

[89]As reviewed in Subsection 4.1.6 Inclining Block Tariff (IBT) Policy. The National Energy Regulator of South Africa (NERSA) introduced the Inclining Block Tariff (IBT) in 2010 into the electricity regulatory framework (SEA 2014). The IBT policy allows an increasing electricity use to be billed on a sliding scale (SEA 2014), cross-

providing access to *smart electricity* will benefit households. *Smart electricity* and other proposed solutions such as *RDP housing* (DME, 1998) and *income-yielding initiatives*, will eventually improve *MCs*, which, in turn, favour some parts of *CNs* and *EPs*, and the overall model behaviour to achieving EAS in the study area.

As shown in Figure 5.28, relying solely on *smart electricity* cannot improve energy access immediately in the study area because of INEP drawbacks in grid-connecting informal households (DoE 2011). With *smart electricity* intended, other cleaner energy sources are considered. *Paraffin* is among the available *least-cost cleaner access options* adopted in the study area. Although it widens the adoption gaps[78], *transitional energy*, such as *paraffin*, can gain acceptance through the *FBAE policy*[90] (DME 2007) to discourage the use of *traditional energy fuels*. Another viable solution is the *non-grid SHS policy*[91] (DoE 2012), likely a convenient option because of the volatile nature of informal settlements. These energy policies can act as a stop-gap until a more sustainable solution is provided in households. There are delays[92] in currently implementing these policies, mainly cutting across institutional, technical, economic, and socio-cultural systems (DoE 2012; DME 2007). By way of policy reforms, proposed policies can lessen *energy burdens* and promote EAS in the study area. Despite drawbacks, these interventions are further compromised by increasing *landscape degradation*

subsidizing low-energy consumers. IBT cushions the poor from rising electricity costs while encouraging efficient electricity use in high-energy users (Adam 2010; Njekelana 2013).

[90] As reviewed in Subsection 4.1.5 Free Basic Alternative Energy (FBAE) Policy. The Free Basic Alternative Energy Policy (FBAE) (DME 2007) (DME, 2007) was introduced in 2007, in rural areas and low-income households where INEP (DoE 2015) and FBE (DME 2003) rollouts are impossible to penetrate due to infrastructural shortages. Policy objectives are to address socio-economic issues arising from insufficient energy supply and to reduce health risks by promoting safe energy alternatives (DME 2007). The FBAE (DME 2007) embraces FBE equivalence of R56.29 in providing poor households with alternative energy forms. Selected energy carriers within the FBAE policy include paraffin, LPG, coal, and Bio-Ethanol gel.

[91] As reviewed in Subsection 4.1.3 Non-Grid (and Mini-Grid) Electrification Policy. As part of the INEP programme, the Energy White Paper on non-grid was introduced in 2002. This policy centered on the financial investments of developing renewable energy technologies in rural areas since it is almost difficult to electrify most areas by 2025 (Ogunlade *et al.*, 2007). Non-grid renewables are provisional alternatives to electricity and low-cost energy options for poor households (DoE 2012). The non-grid is temporary for remote rural communities until grid connection is possible. Without the non-grid, most households in rural areas would continue to use less clean energy forms (Brent and Rogers 2010; Patel and Chowdhury 2018). The Solar Home System (SHS) was identified as one of the many renewable ways to improve energy access in poor rural homes. SHS is a small 50W Photovoltaic PV panel, equivalent to about 250Wh use per day, designed per individual households (DoE 2012).

[92] Refer to Section 4.3 DRAWBACKS IN POLICY IMPLEMENTATIONs

processes[93] in informal areas, particularly rapid *intensification processes*, as exemplified in the case study area[94].

5.4.7 Discussions: Multi-criteria System Reinforcing Model (SRM) and core attributes

A valuable aspect in the SRM model development are arrays of reinforcing feedback loops between, and within, system interfaces. Weak connections in such loops show low-level system dependency, which indicates the impact of a change in a system produces a change in another system, although not strongly. Alternatively, strong connections in loops have a high-level dependency, indicating the impact of a change in a system produces an equivalent change in another system in the same direction. Strong connections in such reinforcing loops can be direct in curbing impact and improving behaviour. For instance, *supporting laws and policies* can directly improve *modern energy* services. Also, it can be indirect, in which *supporting laws and policies* indirectly improve design decisions to then encourage *modern energy services*. Another model valuable aspect is the trade-off between *availability* and *affordability*. Typically, *availability* does not promote *affordability*. Based on the case study scenario, the model reveals the strong connection between these two system designs in a red feedback loop, as product *availability* propels product *affordability* in the study area.

Besides acting as the finest *least-cost clean access option* with improved *energy benefits*, providing access to *smart electricity* also discourages *municipal revenue lost* through illegal connections in informal settlements (SEA 2014). With access to *smart electricity*, free *FBE allocations* (DME 2003), *connection costs,* and *electricity subsidies* within *IBT pricing structures* (SEA, 2014), can be accessible by informal households. When grid-connections are not delayed in households, access to *smart electricity* eventually increases *modern energy services* and *energy benefits*. A part of the research also projected that clearing electrification backlogs in informal households in the City of Cape Town can be achieved by 2034 based on a BAU scenario[95]. *Smart electricity* access can transform the model behaviour to mitigating energy poverty, improving EAS, and bridging the adoption gaps[78] in informal settlements. Due to

[93]As analyzed in Subsection 5.2.3 Land-Cover (LC) conversions of informal areas.
[94] As shown in Figure 5.14 Map and Aerial Photographs Showing the *Intensification* Process in the Sofia Settlement Within the Assessment Period and Bing Aerial (2019) (Open Layers Plugin in QGIS) showing *Intensification* Beyond the Assessment Period.
[95] As shown in Table 5.2 Predictions and Scenarios of Access Rates in Reaching Total Electricity Access by 2030, Benchmarked Against the Total Household Population Without Electricity Access in the Base Year (2016) in City Of Cape Town.

various drawbacks in the *INEP programme* (DoE 2015), *transitional energy fuels*, such as *paraffin*, become valuable access options to improve energy access. These options may widen the adoption gaps[78] but will certainly improve cleaner energy use, particularly in winter when multiple energy uses are practiced and energy consumptions are high.

The energy access process expects households to use cleaner energy sources, once provided (Bahadur Rahut *et al.* 2017). This process disregards factors acting singly, or in groups in opposing behaviour to sustainably adopting new technologies. The model has revealed, and extensively so, a complex set of socioeconomic and cultural elements that can delay such an immediate energy shift in a target group. For *space heating* in winter, such delay in an immediate shift can occur due to *households' low-income* status, or electricity cost rises, in trying to keep a warm temperature in *low-efficient metal-corrugated sheeting dwellings* in the study area. Then again, in the study area[96], most informal households show no interest in applying for *RDP housing options* because of the long waiting time, before approval (DME 1998). There is no electricity access to encourage an immediate energy shift in the case study area. The proposed new SRM model, constructively, has provided practical solutions, targeting factors opposing positive energy-use behaviour in energy-poor groups. Even with intended policy reforms, *education* and *workshops* are equally as important to changing perceptions to embracing policies and new energy technologies in informal households, once provided.

Up to now, this research study has demonstrated the value of using systems thinking in improving energy access through an actionable model and a case study scenario of a typical energy-poor settlement. The model's purpose has been to assess energy poverty levels and promote cleaner energy access in energy-poor communities such as informal settlements in South Africa. The model has been applied in an energy-poor community whilst revealing important model attributes improving energy access. The model application revealed poor system performances in design decisions, indicating a high energy poverty level, in the case study area. The integrated system designs, after checking the design decisions' performance, enabled and promoted energy access solutions. New access options and their sustainability recognized both technical and non-technical aspects. Many drawbacks in supply systems, policies, and other interventions, as well as landscape degradation processes, have shown to

[96] During the field survey, the focus group was asked about requesting for RDP houses. While some households said to have applied for the past 10 years and counting, others decided not to apply because of the long wait of other households in the community.

significantly restrict EAS in the study area. By and large, the model robustness supported sustainable energy supply and demand-side options, which will eventually promote EAS in the long run. The above narrative addresses the model's purpose while responding to Research Question 5[97].

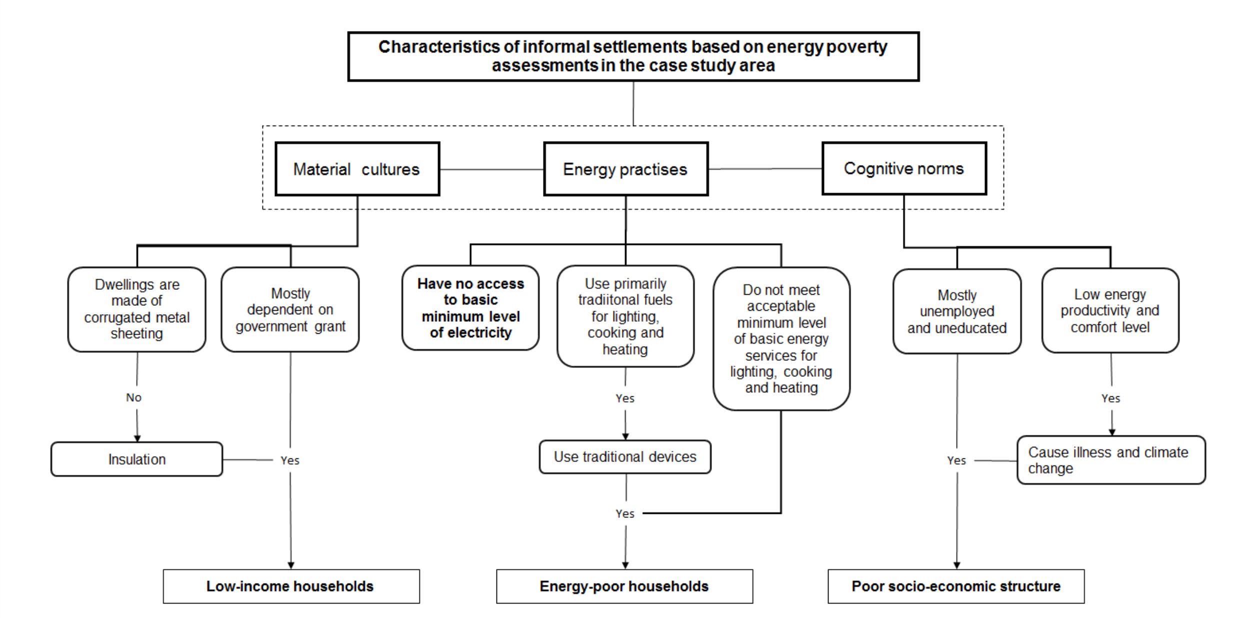

Figure 5.29 Concise Characteristics of Informal Settlements, at large, based on the Assessments of Design Decisions in the new SRM Model, when applied in the Case Study Area.

For the most part, operating systems in the study area are, presumably, the same systems propagating regimes of poor patterns of energy-use in informal settlements, at large, in South Africa (Mdluli and Vogel 2010; SEA 2014). As shown in Figure 5.29, informal settlements in South Africa are typically characterized by low-income, energy-poor households, with poor socio-economic and productive conditions. Today, energy access considers technologies that recognize the preferences of a target community. Also, mitigating energy poverty is effective when new technologies and economic indicators demonstrate positive impacts on the performance of priority indicators, such as design decisions in SRM, in a target community (Cherni *et al.* 2007). The magnitude to which these complex energy poverty systems can be improved, to bridge the adoption gaps in informal settlements, has been comprehensively demonstrated through the methodical application of the proposed new SRM in the case study area.

[97] Section 1.4: RESEARCH QUESTIONS. Will the proposed model serve as a suitable framework to support modelling of key drivers of energy-use patterns and behaviour and EAS, as well as external factors affecting processes in an energy-poor community? Can the new SRM help to mitigate energy poverty and improve energy access in such a community?

5.4.8 Further discussions: Importance of the new System Reinforcing Model (SRM)

Despite the extensive electrification in urban cities in South Africa, millions of urban poor households, currently, lack access to electricity networks and modern energy services. The reliable opportunity to bridge the social gaps between urban and urban poor areas is by expanding electricity access through decentralized systems (Cherni *et al.* 2007). Until now, the capacity of the South African government to expand the grid, or off-grid access options, is widely limited. This is worsened by slow progress in planning proper assessments and development frameworks, coupled with the actual implementation of identifiable access solutions. As a multi-criteria planning tool, the new SRM framework can effectively conceptualize normative decision into a functional management scheme that supports energy access planning and implementations of strategies and actions in a targeted energy-poor community.

The core advantage of the SRM method is the multi-criteria decision approach in integrating large quantities of data, and establishing the interrelationships to solving energy access problems. This approach allows for different but integrative methodologies in determining energy poverty issues. The new SRM multi-criteria method, allowing flexible methodologies, provides a dependable and integrated structure for managing energy poverty and access processes and should be employed as a best practice. The model incorporates favourable solutions in producing change by allowing quantitative and qualitative inputs. The model prioritizes the target group by building on their design decisions. The design decisions assess energy-use patterns and encourage energy access when effectively integrated with system designs in the new SRM. As it stands, the proposed new SRM method provides multiple dimensions to replace or expand energy access, while curbing ecological footprints and health risks in a target group.

By identifying the strengths and weaknesses of a target group from design decisions, the new SRM builds energy access plans to influence resources in different ways. The new SRM has shown to provide a set of systemic access solutions for such a design decision identified as a problem. The model has also shown to represent trade-offs between, and within the design decisions. These trade-offs led to designing the right energy access plans since most access solutions are based on stakeholders' specifications. Access solutions have been to address problem systems through policies and other actions, and furnish them with a new set of sustainable access options. In a different way, the new SRM can allow policymakers to investigate new access plans by evaluating subsequent states of a problem system, in an ideal condition where such a system has been improved on.

An active energy access process is, every now and then, limited due to failure to identify the needs and strengths of a target group. Experts in energy poverty have realized that, from the beginning, energy access projects must involve the target group by prioritizing their inputs, interests, and investments (Cherni *et al.* 2007). As a result, planning access projects must encourage stakeholders' participation in improving energy access. Informal households in the case study area were engaged to identify alternative ways of improving their energy-use experience. The new SRM provides such an enabling platform to learn from a target group, concerning the present conditions and ways of improvements through external supports. Unfortunately, technical decisions are often unavailable before involving a target group in energy access methods. But, the new SRM approach has demonstrated the participatory sensitivity in understanding relevant problems of energy poverty and solutions addressing problems in a target group.

As a people-centric model, the new SRM approach has shown to engage stakeholders and as well, considered external events. The model can be valuable to energy providers and policymakers to understand, in advance, the impact of their decisions in a very structured management process. The model shows how and where decisions are influencing positive outcomes in mitigating energy poverty and promoting institutional efficiency. The new SRM model also provides a holistic overview of providing clean energy access but allows policymakers a comprehension of a system-level impact in formulating decisions. This means that the SRM model allows addressing a specific system since each system is treatable as a whole but interdependent entity. As is, the new SRM model can support a decision-making process in targeting particular poor energy-use patterns or behaviour with appropriate access solutions in a target group.

Lastly, new SRM approaches, with its complete assessment and planning systems, prove to policymakers, beneficial impacts of new technologies on certain assets, while impacting negatively on other assets. New energy technologies, with different sustainability pillars or dimensions, can be assessed separately, and later, as a whole into a management design framework. Even when these energy technologies impact on sustainability dimensions, positively or negatively, certain extrapolations are deductible from such impacts. When policymakers also struggle with selecting suitable energy technologies, regarding local requirements and investment capacity, the new SRM can decrypt complexity and identify options suitable to meet the needs of the target community. The new SRM has shown that baseline factors are alterable and adaptable according to prevailing conditions and available resources in a target group. Generally, the new SRM is shown to be a valuable tool for developing a tailored energy access management scheme in an energy-poor group in South Africa and sub-Saharan Africa, at large.

CHAPTER 6: FINAL DISCUSSIONS: ENERGY ACCESS SUSTAINABILITY – RECAPPING CRITICAL ISSUES AND RECOMMENDATIONS

We need innovation to transform policies that drive approaches to adoption and actual implementation. According to Broto *et al*. (2017), a research agenda recognizes the needs of urban users, provides both context-specificity and disaggregated data of a target group, and promotes energy distribution and urban governance. The research agenda also highlights multiple concepts of energy access, and superior options, in developing well-planned management strategies that can benefit all. Electrification, without understanding the needs of end-users, obscures complex limitations on improving energy access in energy-poor communities. As a result, energy access cannot rely on electricity or fuel supply but must extensively consider factors limiting energy-use efficiency. The study has revealed the importance of stakeholders' participation in promoting energy access but prominently, undetectable factors limiting energy access through the new SRM application. It is also important to incorporate urban development in the policy agenda since urbanization breeds investment opportunities and improved service delivery. As discussed in subsection 5.4.8, recognizing specific contexts and environmentally-friendly access options using the SRM participatory tool, along with good urban governance[98] and working policies, will result in achieving sustainable energy access (or EAS) in any target community (Broto *et al*. 2017).

The core objective of sustainability stresses that available (energy) resources should meet the needs of the present generation, whilst also maintaining socio-economic stability and environmental integrity without compromising the needs of future generations. Sustaining energy access can be very challenging, particularly in informal settlements, where many conflicting issues limit government efforts. A part of the study[99] established landscape degradation processes, such as *Persistence* and *Intensification*, in informal areas. These processes are constantly occurring and delimit EAS, government efforts, and policy effectiveness. The policy progress, in the form of the *RDP Development* – a landscape

[98] As discussed in Section 2.9 UNDERPINNING SUSTAINABLE ENERGY ACCESS . In brief, energy potential is an asset within the scope of good governance to infrastructural developments and sustainable growth. With infrastructural developments, access to social services, and more importantly, to modern energy services can increase.
[99] Section 5.2.1: Land-Cover (LC) mapping of informal areas: From 2010 to 2016

reclamation process, has shown to be unparalleled to landscape degradation[100]. For more effective operation of the RDP programme (DME 1998), new and targeting strategies[101] are perhaps required. Whether the focus is on residential, commercial, or industrial sectors, improving energy-use efficiency requires a working institutional system, equipped with functional internal and external measures. As anticipated, the combined efforts of all service providers will go a long way to improve energy access and energy-use performance in households that contribute to the growth of the national economy. Then again, SRM sustainability assessments can model interrelated evidence and elucidate the most sustainable energy technologies and dimensions, aiming to promote EAS.

The lack of electricity access is typical in rural and urban poor households, which also has received attention but with inadequate solutions, in South Africa. Recently, Energy Access Sustainability (EAS) compels the use of clean energy fuels while developing technological innovations to improve electricity access. Due to the financial costs of grid-electrification, policies, such as non-grid SHS (DoE 2012) and off-grid FBAE (DME 2007) policies, are nurtured and promoted in energy-poor households. The study reviewed these policies, ascertaining policy usefulness, and also constraints in policy execution. These policies are subsidized with the financial weight on the government to sustain policy effectiveness. Currently, subsidized low-smoke cooking stoves and cleaner energy fuels are distributed in energy-poor households across the municipalities. According to Ogunlade *et al.* (2007), subsidizing the capital and maintenance costs of policies is a huge financial burden on government and service providers. As previously suggested[102], policy attention and future reforms that embrace private investments would ensure the off- and non-grid option sustainability. The SRM can also monitor the impact of policy reforms when applied at a temporal stretch. As typified and proposed using SRM, improved actions of FBAE implementations (DME 2007) would increase the availability of cleaner energy fuels to discourage the use of traditional energy fuels in the case study area.

[100] As analyzed in Section 5.2.3: Land-Cover (LC) conversions of informal areas
[101] As discussed in Section 4.4: RETHINKING POLICIES AND RECOMMENDATIONS; Refer to recommendations for the RDP programme, within.
[102] As discussed in Section 4.4: RETHINKING POLICIES AND RECOMMENDATIONS

To date, electricity costs have been rising as reported by electricity forecast analyses [103] conducted in this study. Most poor households cannot afford connection costs and most connected poor households cannot afford electricity tariffs. Thus far, the IBT sliding scale integrated with free FBE allocations has been trying to promote electricity use in these households. The fixed free FBE allocation is, again, insufficient to meet the minimum basic energy needs in households (Adam 2010). Another concern is that majorities of informal households lack electricity access and may not be grid-connected by 2030 (United Nations 2014). Very remote rural areas are off-grid as a result of the weak rural economy to cost recovery. As reported by Ogunlade *et al*. (2007), a new policy that contemplates moving electricity to the people, or vice versa, can be explored for rural households. As indicated[104], policy interventions, particularly where connection costs can be free, the same, or perhaps, further subsidized, should be considered for informal households to achieve total electricity access by 2030. Regardless, the SRM also offers a system-level impact where policy interventions can be monitored, over time, to guarantee successful management of targeted system parts, while correspondingly, acknowledging their relevant impacts influencing other system parts.

The success of EAS depends on the sustainability of the energy system. According to the literature[105], the energy sector produces large emissions of PM and GHG as one of the major ecological setbacks in South Africa (Vanhoren *et al.* 1993; World Bank 2016). The energy sector [106] also implements occasional load shedding events due to coal shortages and to circumvent the system breakdown (Vanhoren *et al.* 1993). The government aims to provide electricity access to those without it, whether residential or commercial sectors, to build economic cohesion and sustainability. This is often critical since electrification is usually required to comply with local and international environmental legislation, also taking into account energy policies and integration, as well as energy security in Africa, as a whole (Ogunlade *et al.* 2007). In South Africa, the major shortfall of electrification is rooted in the institutional system complexity, breeding ambiguities in technical, socio-economic, and environmental sub-systems (Brent and Rogers 2010). Energy access contributes to socio-

[103] As analyzed in Section 5.1: HISTORICAL TRENDS and FORECASTS: ELECTRICITY ACCESS RATES, CONNECTION COSTS, and TARIFFS
[104] As discussed in Section 4.4: RETHINKING POLICIES AND RECOMMENDATIONS; Refer to recommendations for the INEP programme
[105] As discussed in Section 2.7: IMPACT OF ENERGY POVERTY
[106] As reviewed in Section 2.3: ENERGY DISTRIBUTION AND CHALLENGES PARTICULAR TO SOUTH AFRICA

economic development and has to be accessible and affordable. The national economy also depends on the energy system since a large amount of energy produces every unit of fiscal output in South Africa. It is crucial to research more information on how to effectively drive energy supply and circulation in the market. More so, the SRM institutional sustainability assessment can decrypt institutional aspects prolonging energy poverty and also provides pragmatic actions to solving them. The way it is, sustainable energy development, which involves clear assessments of socio-economic development paths, accurate information, and labour force, can, to a certain degree, evolve and thrive the South African energy system (Ogunlade *et al*. 2007).

One way to promote affordable energy use is to recognize the externality costs of electricity generation. In South Africa, the central costs of electricity generation neglect the costs of externalities, stemming from air pollution and ecological footprints. The externality costs estimate the costs of the ecological impacts of electricity generation and provide a basis for recompensing end-users. Spalding-Fecher and Matibe (2003) at one time evaluated the total externality costs to a value of more than ZAR7 billion in South Africa. The supply and externality costs give the actual costs of energy use. In other words, the more affordable the actual costs, the more the competitiveness among energy service providers. As a national obligation, and to maintain sustainable energy supply and consumption, accounting for the externality costs and developing long-term energy planning schemes [107], can produce a cost-effective economy and a good basis for sound policy formulations. Integrating ecological impacts into energy restructuring schemes will reduce externality costs and develop socio-economic and human operational systems. Alternatively, an SRM system design - *energy benefits* – can provide comprehensive energy benefits, motivating the use of clean energy resources in the energy sector. The SRM also provides green solutions to curb ecological setbacks, translating into, and increasing, the externality costs. Notwithstanding, the SRM solutions influence other system parts and must be viewed, holistically.

[107] As discussed in Section 2.9 UNDERPINNING SUSTAINABLE ENERGY ACCESS . Energy planning reflects factors acting within and against energy access. With the planning capacity set at the national level, the ease of adapting energy access programs develops domestic schemes to improve energy access. The domestic energy planning schemes, consider energy-related policies and investment decisions that gratify supply and demand-side options to sustainable development, worldwide (Bazilian *et al.*, 2012). Flawed energy planning by poor policies and decisions produce unrelated phases of energy access lack at different locations (Bazilian *et al.*, 2012). Nonetheless, energy planning, using wide-ranging energy frameworks and policies central on subsidy reformations, aims to accomplish the UN MDGs within national boundaries (Rehman *et al.*, 2012).

Electricity forecast [108] is another reliable way of ensuring energy security, wider energy redistribution, and understanding the future and probable risks in electricity expansion. Typifying future scenarios of energy access helps to simplify the short-term and long-term impact on the economy, resources, and the environment, and also provides significant information to policy formulation and investment growth. With clear-defined assessments of future electricity access rates [109], investment growth will definitely improve, along with the confidence to achieve energy security, nationally. The new SRM has a dynamic modelling potential that can determine progress in improving electricity access but has not been demonstrated, at least not yet. With this SRM attribute, policymakers can analyze chains of impacts, likely to influence future electricity access rates and account for them in policies. Economics of energy supply and demand influence future electricity access rates, mostly resulting in increased electricity costs. Perhaps, channelling public finance and recognizing renewable options may facilitate innovations in the energy sector but may require recommendations in policies. Without added resource investments and improved network competence, electricity supply deficits are bound to occur and will interfere with satisfying household energy needs and growing the economy. Improvising resources to counter network expenditures is pro-poor and will go a long way to improve electricity access and revert electricity cost upswings in poor households.

The majority of informal households without electricity access is not because of the non-proximity to the grid as these transverses across the terrains in South African cities. Major concerns limiting electricity access are the infrastructural dichotomy [110] between urban and urban-poor areas, the volatile nature of informal areas, and institutional, financial, and investment constraints in expanding electricity access. Apparently, the best solution is optimizing available access options, concerning the key factors limiting energy access, as exemplified through the SRM application. The SRM was used to collate diverse but key elements propagating energy poverty, establishing their interrelationships, and determining solutions in the target settlement. Basically, the SRM acted as a useful tool for designing a tailored EAS management framework in the case study area. This indicates that SRM can be

[108] Section 5.1: HISTORICAL TRENDS and FORECASTS: ELECTRICITY ACCESS RATES, CONNECTION COSTS, and TARIFFS

[109] As demonstrated in Subsection 5.1.1Trends in access rates (meter installed) and forecasts

[110] As discussed in Section 2.9 UNDERPINNING SUSTAINABLE ENERGY ACCESS . Energy potential is an asset within the scope of good governance to infrastructural development and sustainable growth. Infrastructural development, not only increases access to social services but also increases access to modern energy services.

applied in any energy-poor community in South Africa, and sub-Saharan Africa, at large. (Kambule *et al.* 2019).

To conclude, this research study has investigated energy poverty problems in sub-Saharan Africa, with the main focus on South Africa, regarding energy policies in the old document; electricity access forecasting and historical rates and other related matters; energy-poor communities, such as informal settlements, and landscape processes occurring within; and energy-use patterns, and other matters in informal households. The main part of this study designed an EAS model, called the new SRM, as a tool for solving energy poverty. The SRM model has shown to have the conceptual and flexible structure to improve energy poverty situations in sub-Saharan Africa and across the globe. Likewise, other study concepts have produced significant results and outcomes, addressing research study questions and sub-questions. This thesis closed the loops by competently addressing the research aim and objectives, through multidisciplinary assessments, while focusing on SE and SsT concept analyses in the new SRM background.

CHAPTER 7: CONTRIBUTIONS OF THE RESEARCH STUDY

The research aim (Section 1.3) has been to investigate (energy) poverty scenarios through multidisciplinary assessments of energy matters and methodologies using a novel systems approach. Energy poverty in itself is a socio-economic problem that requires insightful approaches to reducing its impacts in energy-poor groups. The very first challenge in this research was the difficulty of understanding unrelated study concepts of energy poverty assessments and integrating these multifaceted concepts, using complex SE with SsT approaches, as a novel solution to energy poverty mitigation. The thesis researched design concepts and the developments of engineering ideas into solving energy poverty situations through the understanding of the existing problem, complex environments, and operational dynamics. Through literature reviews and expert consultations, the required knowledge on energy poverty matters was developed. These also supported the understanding of structural and behavioural patterns of human, concrete and non-concrete environments, institutions, management strategies, and technologies, concerning the study concepts. Real-world observations also result in developing representative secondary case studies that are characteristics of primary case studies in this thesis. However, detailed contributions of each study concept are logically described in the subsections below:

7.1 First study part – Review of energy pro-poor policies

Some relevant energy pro-poor policies (Chapter 4) in the 1998 Energy White Paper (DME 1998) have not been previously reviewed, all together, as was determined from the extensive literature review in this thesis. The research study demonstrated the ability to, collectively but singly, review these relevant policies, to a point where study outcomes were sufficient and beneficial to future policy reformations. The methodology[111] adopted is flexible enough to include quantitative and qualitative shreds of evidence, supporting policy review and implementation progress in both formal, and informal households. These shreds of evidence have to also cope with data shortages for empirical investigations of some of the policies. Meanwhile, the methodology adopted will be useful to policymakers, researchers, and institutions, involved in technology management, policymaking, and policy management. Specific contributions of this study are summarized below:

[111] Subsection 1.7.1: Policy Review: Energy Pro-Poor Policies

1. This study demonstrated a policy-review methodology, assessing complex policy concepts, objectives, progress, setbacks, whilst providing recommendations for future policy reforms. The methodology was further validated with representative case studies of rural and informal households in real operational contexts, thus contributing to knowledge on levels of policy effectiveness among energy-poor households in South Africa.

2. Using target groups in the research study was important for capturing relevant information and as a mental guide to addressing the research aim. This approach has shown its usefulness in assessing policy effectiveness and should be considered frequently in policymaking processes.

3. Reviewing energy pro-poor policies, hierarchically, based on the earliest years of commissioning enhances understanding of the progression in policy formulations, improving energy access. This also supports the understanding of South African government efforts in mitigating energy poverty, over time, from the earliest commissioned RDP programme to the most recently introduced IBT policy. This approach has not been applied in the past but this thesis, iteratively, demonstrates such progression in policy patterns and progress, over time, in South Africa.

4. The difficult part of this study review was proposing policy recommendations since literature has at one point provided specific recommendations for some policies, reviewed, especially when the review lacked some empirical data investigations. The thesis contributes to knowledge by emphasizing ways of solving imperceptible challenges in policies often neglected in policy reforms.

5. The research study initiated a comparative analysis to validate policy competence as effective instruments for energy poverty mitigation. Many authors have compared policies, not particularly energy pro-poor policies, only to appraise government performance and efforts. Rather, this thesis contributes to knowledge by providing a clear-cut edge of energy pro-poor policies against similar policies in a few selected countries, albeit within the sub-Saharan African context.

7.2 Second study part - Historical trends and electricity forecasting

The methodology[112] developed and investigated for this research study in Section 5.1 has perhaps been published. No research has shown to adopt this methodology to describe specifically electricity-related parameters influencing electricity access in a representative secondary case study. The thesis demonstrated the ability of this methodology in predicting future rates of electricity access from historical precedents. The methodology was very integrative, supporting trend analyses of access rates and costs, and electricity tariffs, and the relationships within, in operational environments. The methodology will benefit experts in energy sectors, energy authorities, policymakers, and researchers, involved in electricity distribution and management. Specific contributions of this particular study are summarized below:

1. The study developed and demonstrated a novel procedure by assessing historical electricity access rates with corresponding analyses of historical access costs using statistical extrapolations. The procedure is tested with a representative secondary case study and contributing to knowledge, concerning the probability of achieving total electricity access, regionally in South Africa, based on the designed structures of SCC and NSCC.

2. Target groups were also used in this study to obtain the necessary information in addressing the research objective and aim. Formal and informal households were considered and targeted to enable comparative assessments between parameters. This approach should be considered more in improving electricity access, particularly in electricity-deprived households.

3. The research study used the forecasting methodology to elucidate future rates of electricity access. This approach was difficult in dissimilar environments, where improving future electricity access in a target group was benchmarked against the base year (2016) and achieving total electricity access by 2030 as set by the UN. This approach is novel and has not been applied but this thesis demonstrates its success in grouping contexts, despite fundamental variances.

[112] Subsection 1.7.2: Historical Trends and Forecasts: Electricity Access Rates, Access Costs, and Tariffs

4. The research study developed and investigated BAU patterns to assess institutional operations and strategies influencing gaining total electricity access by 2030. The approach has been published previously but this thesis demonstrates the use of this approach in reaching total electricity access at different periods, different future scenarios, and among various target groups, benchmarked against the base year (2016) and the UN set year (2030). This contributes to the understanding of the present institutional operations and strengths in improving electricity access based on BAU scenarios and required institutional modifications that enable gaining total electricity access by 2030.

5. The research study also provides a better understanding of the historical increases in access costs and electricity tariffs and their impressions on future electricity access among sampled target groups. The forecast trend analyses contribute to knowledge, concerning relationships between electricity price hypes and continuous lack of electricity access in informal households, in particular.

6. The comparative approach carried out between SCC and NSCC historical outputs supports the understanding of the SCC's practicality in improving electricity access among a sampled target group. Maybe, this approach is non-consequential but will benefit energy providers in understanding that the SCC structure may not be that affordable for the target group, whom these subsidies are aimed at.

7. Finally, the study presented generic IBT-designed structures integrated with FBE allocations and allowed comparative analyses between electricity tariffs for low- and high-energy users. This thesis further contributes to knowledge by creating more awareness about the IBT structure, as well as consumption blocks where free FBE allocations are applicable.

7.3 Third study part – LC classification and change of informal areas

The problem addressed in this part of the research study in Section 5.2 is the difficulty of merging its uniqueness to fit with the rest of the research design. The study explored and developed complex concepts of geospatial techniques and infrastructure, operative in earth observation of informal areas. Developing methodologies (in subsection 1.7.3) from the literature and subject matters enhances the comprehension of complex physiognomies of informal areas in validating accuracies of both acquired and generated datasets. The thesis combines different methodologies and demonstrates its applications in spatially analyzing informal areas. These methodologies will support the monitoring of formal, commercial, and industrial areas but may contend with constraints in resolution scales, satellite imagery to be used, and data acquisitions. The methodologies will be beneficial for spatial analysts, remote sensing and GIS experts, Geo-informatics, researchers, and policymakers, undertaking infrastructural management, urban (land use) and, urban energy planning. Specific study contributions of this part are further explained below:

1. The study developed and demonstrated a well-structured step-by-step procedural methodology [113] in data processing for spatial analysis of informal areas. This methodology is tested in analyzing boundaries or polygons of informal areas (or households) in a representative secondary study area. This contributes most recent updates to the national database on LC and LCC of informal areas, over time, at a regional level.

2. Then again, a target group was introduced to acquire relevant information in the demonstration of the procedural methodology, addressing the research aim. This approach in this study is commonly applied in literature but often differs in the area studied, the assessment period, and the area coverage. The thesis contributes to the database new shreds of evidence on LC classifications of informal areas, in time and space that have not been surveyed, previously.

3. Applying the procedural methodology for the LCC analysis of informal areas demonstrates the ability to merge different change detection techniques. The LCC analysis is particularly difficult in highly heterogeneous built environments, where the target feature class appears smaller than the rest of the land-cover classes. However, monitoring LCC will support the understanding of the anthropogenic impacts at the barest minimum, influencing decisions deriving human behaviour change at the maximum level. Much research on LCC analysis and various techniques has been published before but the thesis demonstrates using multiple techniques in providing improved data accuracy in the DD5 data scope.

[113] Figure 1.7 Flow Chart of Procedures for Land-Cover (LC) Classification and Land-Cover Change (LCC) processing of Informal Areas in the City of Cape Town, Showing the Key Steps in the Central Column.

4. One of the challenging aspects of the study was the analysis of LCC dynamisms by developing LC conversions, conversion classes, and labels. Although advocated in the literature, the thesis demonstrates the use of an indicator-based detection method in describing trajectories of LC conversions and other landscape processes of informal areas.

5. Another challenging part was categorizing these landscape processes or signals in describing patterns of LC conversions. Although common in literature, the thesis demonstrates the robustness of this approach by developing two landscape gradients, namely degradation and reclamation processes. The usefulness of this concept is in describing states of environmental health, as well as urban (energy) planning and developments to the benefits of policymakers and infrastructural management.

6. From this research study, landscape degradation processes in informal areas were considerably revealed, which will be useful for developing effective management strategies for landscape reclamation, particularly through the RDP programme (DME 1998). The challenge has been that the volatile nature of informal areas can be highly fast-paced and can undermine landscape processes in input datasets. Through logical analyses, mapped LC changes, reflecting landscape degradation gradients, at any time, can benefit future strategies for sustainable landscape reclamation of informal areas, particularly in the City of Cape Town, as well as future researches.

7.4 Fourth study part – Analyzing energy-use patterns and related matters

This part of the research study (Section 5.3) struggled with developing the householder questionnaire (Appendix 4) in tune with updating SRM systems. The thesis designed a householder questionnaire and sampling methods that worked well in the primary case study area. Social studies are often challenging but can be successful with an understanding of the existing problem and complex environments. Testing the developed sub-questions in the questionnaire enhances the understanding of energy-use patterns, concerning humans, organizations, operational processes, and energy technologies, in sync with the SRM background. The methodology[114] adopted has been applied in the literature[115]. The thesis demonstrates this methodology by also considering the adoption of a systems approach to

[114] Subsection 1.7.4: Energy Use and Related Data, Patterns, and Relationships
[115] Section 2.5: EARTH OBSERVATION OF INFORMAL AREAS

solving a real-world problem. The methodology will be useful in electricity management and energy access programmes and for energy authorities, policymakers, and researchers. Some study contributions are summarized below:

1. The study demonstrated a sampling method, convenient in investigating matters of energy-use patterns and behaviour. This method was proven with a representative primary case study in an operational context, where a focus group was formed and households showed a willingness to participate. The method has been previously published but the thesis further corroborates the resourcefulness of primary data collection.

2. Target groups were used, which centred on acquiring relevant data to update SRM systems in addressing the research aim. This particularly proved relevance at the local scale since most literature assesses patterns of energy-use mainly on large-scale dimensions.

3. The difficult part was the ability to group some of the sampled parameters and understand their relationships in describing energy-use patterns and behaviour to updating SRM systems. This protocol, however, involves analytical techniques by demonstrating the important aspect of human knowledge in interpreting results.

4. Interpreting study results in a way that is demonstrative of SRM systems and its application enhances the understanding of the field of complex data modelling and simulation. As formerly mentioned, the sampling methodology has been applied in the past but the thesis demonstrates its reciprocity with system modelling concepts, regardless of their varying theories.

5. Finally, this part of the research study offers an enhanced context and a better understanding of diverse matters of energy consumption and related matters, based on design theory in SRM contexts. Aside from energy poverty, this research study also creates a roadmap to investigate similar study concepts, particularly in non-concrete environments, using engineering and system approaches.

7.5 Fifth study part - Applying a new System Reinforcing Model (SRM)

There are few challenges encountered in this study (Section 5.4), particularly that of developing and describing problem and solution frontiers of the new SRM, using SE/SsT concept analyses. The thesis investigated the design and development of SRM complex systems, operational in complex environments. A system has shown to be defined by its elements, purpose, and interconnection [116]. Successful system modelling requires an understanding of these complex elements and purposes, including technical and non-technical aspects, and their interrelationships represented in feedback loops. The literature review on this study provides the required knowledge on system modelling and model building and the understanding of the synergisms between stakeholders, organizations, energy access and technologies, and energy poverty mitigation.

The methodology [117] adopted and investigated has not been considered before in the literature. The thesis demonstrates the ability to develop this novel methodology adopted, through a logical application of SE and SsT. The methodology has shown flexibility in supporting other necessary methodologies for modelling energy poverty problems, and access solutions, in an actual environment. The methodology will be useful to experts in energy systems, systems engineers, model builders, and researchers that aim to improve energy distribution and technology management. This part of the research study is the highpoint of this thesis, and also falls within the domain of requirement engineering (Oosthuizen and Pretorius 2016). Specific study contributions of this part are explained below:

1. The novelty of this study is using a systems approach – SE with SsT, to perform research in an abstract (or non-concrete) environment. Authors may have argued on the difficulty in discovering and eliciting engineering systems, aiming to include stakeholders' specifications (Oosthuizen and Pretorius 2016). This domain of requirement engineering, mainly employed in discovering and eliciting complex socio-technical systems, are now directed to mitigating energy poverty situations,

[116] Section 2.10: A SYSTEMS APPROACH – SYSTEMS ENGINEERING AND SYSTEMS THINKING; See Paragraph 4
[117] CHAPTER 3: APPLYING A SYSTEMS APPROACH TO MITIGATING ENERGY POVERTY

strongly defined by multiple and complex socio-economic, cultural, technical, and institutional systems, in this thesis.

2. Another novel contribution is adopting the study methodology[118], established on design synthesis and system modelling, in integrating systems and subsystems working cyclically in energy poverty and access processes. This methodology contributes to knowledge of SE with SsT concepts and its wider applications in variously ranged perspectives.

3. The first step in solving the model's problem was to identify operating system interfaces. The challenging part was in defining functions of these interfaces, determining systems and subsystems within, and categorizing them as design decisions and system designs, during the model development. This is useful in managing energy poverty and access processes and should be used often in SE projects.

4. Applying SsT after system identification and connection using SE elucidates complex SRM modelling and the interrelationships between, and within, SRM systems. The study demonstrates the use of feedback loops in describing and interpreting the model interrelationships influencing possible outcomes. This significantly contributes to the field of SsT applications and aspects of human thinking.

5. The structure of feedback loops defines SRM interrelationships in strong and weak connections. The structure describes strong connections in feedback loops as more reinforcing and influencing to model outcomes. This, however, contributes to literature, where multiple dimensions, rather than a singular option, are sought to addressing problems defined by multifaceted systems.

6. Another real-world insight led to developing historical reference modes of key elements with a representative secondary case study to addressing the model's purpose. The approach placed more emphasis on the adoption gaps between key elements assessing energy-use patterns on a larger scale of operation. This

[118] CHAPTER 3: APPLYING A SYSTEMS APPROACH TO MITIGATING ENERGY POVERTY

significantly contributes to the SRM focus as a universal tool for energy poverty mitigation, implementable in any targeted energy-poor communities.

7. The logical SRM application in the primary case study area, from assessments of design decisions to those of system designs, led to the development of a model structure and quality that equal reality. SRM methods demonstrate to model and assess relationships between systems of energy poverty (design decisions) and sustainable energy access (system designs). The ability of the new SRM to model energy poverty and access processes, validated in a representative energy-poor community, is in itself, a novel contribution.

8. The study developed and investigated SRM sustainability dimensions to assess technical and non-technical access options. Literature may have applied SsT principles in sustainability assessments of engineering projects. This thesis demonstrates sustainability assessments and enhanced its benefits through SsT principles, and thus contributes to knowledge of EAS and other sustainability schemes. Broad assessments of sustainability in the new SRM has not yet been carried out.

9. The beneficial contribution of this study is the SRM participatory sensitivity to identify stakeholders' requirements, institutional efficiency, and other external consultations in updating systems. This demonstrates the change management characteristic of SRM by allowing stakeholders' interventions when institutional efficiency and other strategies are limited; whilst simultaneously, developing a tailored SRM framework suitable for energy access management in a target community.

10. Lastly, the thesis provides a superior understanding of energy poverty and access processes, based on frameworks of SE and SsT within the context of a systems approach, system modelling, and design science. Furthermore, the research study design [119] serves as an agenda that contributes more to using multidisciplinary approaches in solving real-world problems.

[119] Section 1.8: THESIS LAYOUT; See Figure 1.6 Flow chart of Methodologies Adopted for Research Objectives.

CHAPTER 8: LIMITATIONS AND RECOMMENDATIONS FOR FURTHER WORK

We recognized commendable efforts and progress in adopting cleaner energy access and practices in energy-poor households through the operational frameworks of energy pro-poor policies commissioned by the South African government, as discussed in Chapter 4. We also recognized some limited empirical investigations of these policies, such as the FBAE policy (DME 2007), due to poor data records within service providers. By acknowledging this limitation in this thesis, proper documentation and monitoring will be facilitated within the service authorities to the benefit of future researches and events. Due to the limited study duration, the study review was strictly centered on secondary data obtained from respective service authorities, along with desktop studies. For the first part of this study, some issues need to be considered in future research, mainly for institutional upgrading and to authenticate or rather expand on this study review. These mainly include;

1. Conducting primary data investigations, targeting a comprehensive survey for each policy. This approach will identify drawbacks, not provided in this study review, to advance policy expediency in future reforms.

By executing policies and programmes, electricity access has been remarkably expanded in South Africa but with slower progress of such electricity access in informal households, as analyzed in Section 5.1. There are no pending limitations in the second part of this research study, except that;

1. Due to the limited study duration, this study did not monitor the correspondence of forecasted events of electricity parameters, in reality, in households. Future researches may need to consider follow-up investigations to determine the impact of these parameters, particularly projected events of access rates and access costs in informal households.

The literature has revealed the rapid growth of informal settlements, over time, across the provinces in South Africa (Section 2.6) and the purposefulness of engaging geographical intelligence in classifying and monitoring informal areas at the regional level (Section 5.2). Future research may be required to acknowledge and focus their efforts on addressing some limitations encountered in this research study. The study limitations are succinctly described below;

1. The LC classification of D1 is fraught with uncertainty. A deliberate report on this uncertainty is essential if distributions of informal settlements are to be properly monitored and well-quantified in the future in South Africa.

2. Complete accuracy in capturing informal areas is very unlikely because of spatial limitations in mapping informal areas, particularly shacks in backyards and those interspersed in built-up areas. Therefore, some degrees of uncertainty must be acknowledged in the LC classifications and LC change analysis results of this research study.

Similar energy-use patterns and behaviour established in the secondary case study area (in Section 2.6) was demonstrated in the primary case study area (in Section 5.3). There are no obvious limitations in this research study.

1. The only limitation that perhaps occurred during the primary data survey in the Sofia settlement, which was target households trying to be thrifty with the truth to gain empathy, was tackled using techniques of content analysis in the course of data processing and manipulation.

The SE concept has been useful in identifying and connecting systems and SsT principles, through human thinking, enhances the understanding of system purposes (functions), and interconnections to solving problems (Section 2.10). The SRM, at this stage, was used to demonstrate concepts, which serve as a platform for deliberation by stakeholders in understanding the problem and the impact of different variables. As a real-world problem, energy poverty will continue to grow, so long as people are living below the poverty line, especially in sub-Saharan Africa. (World Bank 2016). There is a crucial need for advanced innovations in SRM conceptualizations that recognize model limitations in future research works, as summarized below;

1. First, the methodology adopted focused on qualitative assessments with fewer data quantifications in the SRM validation phase. Much of the limitation stem from not integrating large quantifications and criteria in the model, such as quantitative

assessments of the sustainability of energy technologies, particularly in a large-scale operation, among many others. The model thus far has demonstrated qualitative sustainability assessments, to provide a simple understanding of how effective are available technologies in improving energy access. Future research will improve the model utility in quantifying sustainability pillars, as well as other model components influencing energy access.

2. The addition of new systems or unknown factors in the SRM model may generate different feedback responses to addressing problems. There are parts of factors in any societal design, or perhaps emergent properties of the ecosystem or larger system in which understudy cases do belong. An example of such emergencies can include disruptive technologies or similar aspects of such sudden or slow changes in societal factors, not limited to but including, cultural inclinations or collective traits. Such inclusion will not change the proposed framework, drastically but makes it more inclusive and closer to perfection. These unknown factors should be filtered and integrated into developing new versions of the SRM model in future works.

3. This thesis does not focus on the SRM capability for dynamic modelling due to time restraints. Basic model development, verification, and validation are, however, demonstrated, so also the SRM systems and elements demonstrate to support such dynamic modelling and simulations. As it is, SRM methods are yet to model future energy access scenarios over the long term, after modifications based on the proposed model solutions, and should be considered in future research.

4. Rather than multiple case validation, the model can also be tested through Subject Matters Experts' validation or finding relevant literature, simply for triangulation purposes. Again, this approach was not demonstrated in this research due to time constraints but can be explored in similar research in the future.

5. Another limitation is not demonstrating the cost of the ineffectiveness of the model application. Speculations of such cost of ineffectiveness could be defined as a lack of feedback loops within the applied policies in the model, which may lead to misrepresentation of progress and continuation of such policies. Besides the cost assessment, other innovative ways can be used in quantifying metrics, for example, quantifications of such societal impacts after the model application, are an important

aspect that need be explored in the future. Also, the possibility of quantifying the ineffectiveness of other similar models may strengthen the support of the proposed hypotheses of this thesis and also should be explored.

6. In a case-to-case scenario, the model may display some levels of complexities in achieving absolute EAS. The initial stage in solving complex systems is to recognize them as one and modify system requirements and feedback mechanisms to improve behaviour. The SRM may require further research in decrypting complexities to achieving absolute sustainability.

7. Another limitation is whether the final SRM solutions will be acceptable by all stakeholders involved. The model application has only been performed once by the researcher in a single energy-poor community; thus further applications should be considered in future research. In reality, the SRM has to be applied by professional experts many times, and over longer periods, to improve confidence in outcomes, acceptable by all stakeholders involved.

8. At this point, the SRM is only suitable in a small-scale operation where operating variables are less and definite. The SRM has demonstrated its value in identifying system-level impact, implementation results, and prospects in behaviour change when deleting and adding new variables. As perceived, the new SRM has the conceptual flexibility but perhaps requires advancements in technical processes and dynamic patterns to be fitted on large-scale operations and at temporal stretches, respectively. These should be considered in future research works and purposes.

CHAPTER 9: CONCLUSIONS

The first part of the study (covered in Chapter 4) has reviewed energy pro-poor policies, improving energy access in South Africa (SEA 2014). The review established progress, drawbacks, and policy expediency to mitigating household energy poverty, even when benchmarked against such similar policies in sub-Saharan Africa. Policy drawbacks were observed to limit policy effectiveness but can improve if proposed recommendations are considered in policy reforms. In other words, comprehensive but targeting interventions, grounded on each policy context, were also recommended. These proposed policy recommendations, also, have been projected as functional platforms, enabling strategic policymaking and effective policy implementations in South Africa.

The second part of the study (covered in Section 5.1) analyzed trends in electricity-related matters in the City of Cape Town, to validate the historical and future electricity access scenarios. The historical analyses (2010 – 2018) established increasing trends in sampled parameters, such as access rates and access costs, which might have discouraged improved electricity access in informal households. The forecast (2019 - 2030) relationships showed similar trends in these parameters, demanding a shift away from the usual BAU pattern to promote electricity access. Future scenarios for reaching certain electricity access rates at different periods in households were established. Likewise, IBT-regulated tariffs increased across the period and consumption blocks. Subsidized IBT/FBE integrated structures were revealed to cross-subsidize low-energy users against non-subsidized structures, designed for high-energy users. Study outcomes aim to gain total electricity access, when integrated into policymaking, in the City of Cape Town.

A unique, and the third part of the study (covered in Section 5.2), described the use of independently generated Land Cover (LC) maps for Land Cover Change (LCC) analyses in informal areas in the City of Cape Town. The low data accuracy in the reference dataset [national LC (2011_D1)] resulted in manual edits and generations of higher precision LC datasets (2010_D2 and 2016_D3). The LCC analyses have shown that the DD4 dataset (generated between 2010_D1 and 2016_D3), inaccurately represented LC conversions of informal areas within the specified assessment period (2010 – 2016). However, the LCC analyses in DD5 (generated between 2010_D2 and 2016_D3), as expected, revealed higher landscape degradation processes, such as *Persistence* and *Intensification* of informal areas, within the period. The *RDP development* conversion class in DD5, however, validated government efforts and progress through the RDP programme (DME 1998). While some approximate states of reclamation processes have been visible, the degradation process - *Intensification* was more visible and increasing, even beyond the assessment period, as exemplified in the primary case study area. This study has demonstrated that actual LC conversions have higher accuracy in DD5 and should be employed for future researches and purposes.

The fourth part of this study (covered in Section 5.3) has analyzed energy-use patterns and energy-related matters, and its relationships, in a typical case of an energy-poor community, called the Sofia settlement, in South Africa. Study analyses revealed poor energy use and practices in the case study area. Paraffin was the primary energy use, with certain levels of energy productivity and benefits. There was no electricity, yet electrical appliances were recorded. The adopted local energy sources were shown to be available, affordable, and accessible but produced high levels of household energy burden, independent of household income and sizes. Study analyses quite corresponded with similar analyses in informal settlements in the City of Cape Town and also, further represented using the new SRM framework.

The fifth part of the study (covered in Section 5.4) validated the new SRM application, using data scope analyses (in Section 5.3), in the primary case study area The SRM model also incorporated other relevant research outcomes in representing energy poverty and access processes. For instance, energy policies (reviewed in Chapter 4), targeting model behaviour change, were used in updating SRM systems. The SRM participatory sensitivity was quintessential and was put into use, whilst simultaneously consulting external sources in updating SRM system performances. The model application produced a tailored SRM framework, specific to mitigating energy poverty in the study area. Generally, the proposed model solutions strongly demand consultations of funding authorities, policymakers, and stakeholders to achieve the model's purpose.

The SRM model was designed in such a way to provide new outlooks of energy poverty mitigation, dependent on the nature and complexity of energy poverty and access processes defining a typical energy-poor community. At this stage, the new SRM model is only implementable on a local scale, where solutions are sought to mitigate energy poverty. Policymakers may not consider the importance of a system-level impact in achieving a successful energy poverty mitigation but elements in system interfaces have shown interrelationships that can influence future energy access rebranding through policies and strategies. In other words, the cyclical nature of energy poverty and access processes suggestively require wide-ranged system elements to be wholly considered in policymaking. Whether the new SRM scheme portends as a tool, or the best practice, to be adopted is a key issue and one without recognition yet, at the policy level. However, this study has broadly described energy consumption patterns, probable access solutions, and expected outcomes through the new SRM application. As part of improving the national energy database, study outcomes have also demonstrated to be cohesive in expediting schemes of energy access planning and policymaking decisions and bridging social gaps and inequality in energy distribution, in South Africa.

In conclusion, the thesis has demonstrated a multidisciplinary approach in providing multi-criteria decision methods for advancements in energy poverty mitigation and energy access. Normally, solutions to human problems demand assessments of complex socioeconomic, technical, and cultural systems, as well as system interrelationships and dynamic changes occurring within. This notion led to designing a novel approach and other new methods, addressing the study concepts. Each study concept has produced significantly sufficient outcomes on energy poverty and also demonstrated the implications of complex data assessments in real operational environments. Independently, the study concepts have demonstrated ways of improving energy access, yet were consolidated and well-represented using the new SRM.

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APPENDICES

Appendix 1 Electricity Data On Meters Installed (From 2009 To 2019) In The City Of Cape Town, Obtained From Electricity Generation and Distribution (EGD), EGD Head Quarters, Cape Town.

Meters installed in CoC from Electricity Generation & Distribution (EGD), EGD Head Quarters

Year	Meters Installed
2018	797
2017	1915
2016	2436
2015	3910
2014	5783
2013	1731
2012	506
2011	77
2010	2

Appendix 2 Electricity Data On Connection Costs (From 2009 To 2019) In The City Of Cape Town, Obtained From Electricity Generation and Distribution (EGD), EGD Head Quarters, Cape Town.

All prices exclude VAT	
Subsidised Connections	
For single phase connections to applicable customers	
2018/19	R733.39
2017/18	R695.18
2016/17	R657.72
2015/16	R621.05
2014/15	R587.72
2013/14	R555.26
2012/13	R221.93
2011/12	R210.53
2010/11	R197.37
2009/10	R179.82
New Residential Supplies	
60A single phase	
2018/19	R2,432.00
2017/18	R2,305.26
2016/17	R1,611.40
2015/16	R1,905.26
2014/15	R1,698.25
2013/14	R1,741.23
2012/13	R1,672.81
2011/12	R1,752.63
2010/11	R1,545.61
2009/10	R953.51

Appendix 3 Electricity Data On Electricity Tariffs (From 2009 To 2019) In The City Of Cape Town Obtained From Electricity Generation and Distribution (EGD), EGD Head Quarters, Cape Town.

SCHEDULE OF ELECTRICITY TARIFFS EFFECTIVE FROM 1 JULY 2009

Note: All figures exclude VAT

1 The following tariffs are applicable to Domestic Customers

Domestic Customers are customers in private residential establishments including houses, blocks of flats and town house complexes. Domestic premises with supplies of 100 Amps or more connected after 30 June 2009 will be treated as Commercial Customers.

Residential establishments where a business licence exists such as hotels, bed and breakfast premises, hostels, retirement homes etc. will be regarded as Commercial Customers except where the total connected load of the business portion of a residential property does not exceed 15 kVA, the supply may be taken at the Domestic Tariff at the discretion of the Director: Electricity Services or an authorised representative.

Bona fide residential establishments registered by the Welfare Department will be regarded as Domestic Customers.

Consumers charged at the Lifeline Tariff and purchasing less than 400 kWh per month on average over the 12 months up to May / June 2009 will receive 50 free kilowatt hours per month as provided for in the Electricity Tariff Policy.

NOTE: Qualifying domestic consumers using pre-payment meters will not receive the free basic supply of electricity for months in which no energy is purchased unless this is specifically claimed at a vending outlet in each such month.

Qualifying domestic customers using credit meters will be credited with as much of the free basic supply of electricity as is used during the metering period.

1.1	**Domestic High** (> 800 kWh per month)		
	Daily Service Charge	(R)	3.40
	Energy Charge	(c/kWh)	64.44
1.2	**Domestic Low** (400 to 800 kWh per month)		
	Energy Charge	(c/kWh)	77.37
	Lifeline (< 400 kWh per month purchased)		
	Energy Charge	(c/kWh)	53.90

SCHEDULE OF ELECTRICITY TARIFFS EFFECTIVE FROM 1 JULY 2010

Note: All figures exclude VAT

1. Domestic Tariffs

Domestic customers are defined as natural persons purchasing electricity in private residential establishments including houses, blocks of flats and town house complexes and including bona fide residential establishments registered by the Welfare Department.

Where electricity purchased does not exceed 400 kWh per month (on average), customers will receive a free basic allocation of up to 50 kWh, bringing the total electricity received up to a maximum of 450 kWh per month. Should electricity purchased exceed 400 kWh per month (on average), then the free electricity portion will no longer be made available to the household.

The average of 400 kWh per month is an average measured over any consecutive twelve month period.

Qualifying domestic customers on prepaid meters will not receive the free basic allocation in months in which no electricity is purchased unless this is specifically claimed at a vending outlet in each such month. Qualifying customers on credit meters will be credited with as much of the free basic allocation as is used during the metering period.

1.1	***Domestic High (>1500 kWh average per month)***		
	Service Charge (Rand per day)		6.58
	Energy Charge (c/kWh)		79.97
1.2	***Domestic Low (<1500 kWh average per month)***		
	Energy Charge (c/kWh)		93.31
1.3	***LifeLine (<450 kWh average received)***		
	Energy Charge (c/kWh)	Block 1 (0 – 50 kWh)	0.00
		Block 2 (50.1 – 150 kWh)	58.11
		Block 3 (150.1 – 450 kWh)	70.47

SCHEDULE OF ELECTRICITY TARIFFS EFFECTIVE FROM 1 JULY 2011

Note: All figures exclude VAT

1. Domestic Tariffs

Domestic customers are defined as juristic or natural persons purchasing electricity in private residential establishments where electricity is used primarily for residential use including, but not limited to, houses, blocks of flats, town house complexes, bed and breakfast establishments, second dwellings and bona fide residential establishments registered by the Welfare Department.

Where electricity received does not exceed 450 kWh per month (on average, including any free portion received), consumers will receive a free basic allocation of up to 50 kWh. Should electricity received exceed 450 kWh per month (on average, including any free portion), then the free electricity portion will no longer be made available to the household.

The average receipt of 450 kWh per month is an average measured over a period of twelve consecutive months, and includes any Free Basic Electricity that may have been received.

Where Free Basic Electricity is received, this forms part of the LifeLine Block 1 allocation of energy, so only a maximum of 100kWh of the 150kWh is paid for by these consumers, the other 50kWh is paid for by the City.

Qualifying domestic consumers on prepayment meters will not receive the free basic allocation in months in which no electricity is purchased unless this is specifically claimed at a vending outlet in each such month. Qualifying consumers on credit meters will be credited with as much of the free basic allocation as is used during the metering period.

1.1	***Domestic (>450 kWh received per month)***		
	Energy Charge (c/kWh)	Block 1 (<= 600kWh)	107.43
		Block 2 (> 600kWh)	118.06
1.2	***LifeLine (<450 kWh average received)***		
	Energy Charge (c/kWh)	Block 1 (0 – 150 kWh)	61.60
	(Any FBE received forms part	Block 2 (150.1 – 350 kWh)	81.04
	of the Block 1 receipt)	Block 3 (350.1 – 600 kWh)	107.43
		Block 4 (> 600 kWh)	118.06

SCHEDULE OF ELECTRICITY TARIFFS EFFECTIVE FROM 1 JULY 2012

(Note: Prices quoted exclude VAT - prices in brackets include VAT)

1. Domestic Tariffs

Domestic customers are defined as juristic or natural persons purchasing electricity in private residential establishments where electricity is used primarily for residential use including, but not limited to, houses, blocks of flats, town house complexes, bed and breakfast establishments, second dwellings and bona fide residential establishments registered by the Welfare Department.

Where electricity received does not exceed 450 kWh per month (on average, including any free portion received), consumers will receive a free basic allocation of up to 50 kWh. Should electricity received exceed 450 kWh per month (on average, including any free portion), then the free electricity portion will no longer be made available to the household.

The average receipt of 450 kWh per month is an average measured over any period of twelve consecutive months, and includes any Free Basic Electricity that may have been received.

Where Free Basic Electricity is received, this forms part of the LifeLine Block 1 allocation of energy, so only a maximum of 100kWh of the 150kWh is paid for by these consumers, the other 50kWh is paid for by the City.

Qualifying domestic consumers on prepayment meters will not receive the free basic allocation in months in which no electricity is purchased unless this is specifically claimed at a vending outlet in each such month. Qualifying consumers on credit meters will be credited with as much of the free basic allocation as is used during the metering period.

The Net Metered Domestic tariff is available only for approved Net Metered Connections, where the Consumers offset their small scale generation against their purchases from the Municipality, provided that their purchases exceed their generation.

1.1	***Domestic (>450 kWh received per month)***			
	Energy Charge (c/kWh)	Block 1 (0 – 150 kWh)	113.20	*(129.05)*
		Block 2 (150.1 – 350 kWh)	118.11	*(134.65)*
		Block 3 (350.1 – 600 kWh)	118.11	*(134.65)*
		Block 4 (> 600 kWh)	140.18	*(159.81)*
1.2	***LifeLine (<450 kWh average received)***			
	Energy Charge (c/kWh)	Block 1 (0 – 150 kWh)	64.93	*(74.02)*
	(Any FBE received forms part	Block 2 (150.1 – 350 kWh)	89.95	*(102.54)*
	of the Block 1 receipt)	Block 3 (350.1 – 600 kWh)	118.11	*(134.65)*
		Block 4 (> 600 kWh)	140.18	*(159.81)*

SERVICES RENDERED		UNIT	REMARKS	2013/14 R excl. VAT	2013/14 R incl. VAT
RESIDENTIAL CONSUMERS					
Consumers receiving less than 250 kWh/month on average and charged at the Lifeline Tariff and will receive a free basic supply of up to 60 kWh per month. Consumers receiving between 250 kWh and 450 kWh per month on average will receive a free basic supply of 25 kWh per month NOTE: Qualifying residential consumers using pre-payment meters will not receive the free basic service of electricity for months in which no energy is purchased unless this is specifically claimed at a vending outlet in each such month.					
The free 60 or 25 kWh forms part of the first block of 350 kWh for Lifeline consumers (e.g. first 60 kWh are free, the next 190 kWh are at the appropriate rate, or the first 25 are free, with the next 325 at the appropriate rate.)					
Qualifying residential consumers using credit meters will be credited with as much of the free basic service of electricity as is used during the metering period.					
New residential consumers (supplies <= 100 Amps) will be charged at the Domestic rate unless they are subsidised connections in which case they will be charged the Lifeline tariff.					
DOMESTIC (> 450 kWh received/month) *No free basic service*					
Energy charge	Block 1	c/kWh	0-600kWh	125.00	142.50
	Block 2	c/kWh	600.1+kWh	152.00	173.28
LIFELINE (for qualifying customers only) *Free basic service*					
Energy charge	Block 1	c/kWh	0-350kWh	79.70	90.86
	Block 2	c/kWh	350.1+kWh	185.00	210.90

SERVICES RENDERED		UNIT	REMARKS	2014/15 excl. VAT	2014/15 incl. VAT
RESIDENTIAL CONSUMERS					
Consumers receiving less than 250 kWh/month on average and charged at the Lifeline Tariff and will receive a free basic supply of up to 60 kWh per month. Consumers receiving between 250 kWh and 450 kWh per month on average will receive a free basic supply of 25 kWh per month NOTE: Qualifying residential consumers using pre-payment meters will not receive the free basic service of electricity for months in which no energy is purchased unless this is specifically claimed at a vending outlet in each such month.					
The free 60 or 25 kWh forms part of the first block of 350 kWh for Lifeline consumers (e.g. first 60 kWh are free, the next 190 kWh are at the appropriate rate, or the first 25 are free, with the next 325 at the appropriate rate.)					
New residential consumers (supplies <= 100 Amps) will be charged at the Domestic rate unless they are subsidised connections in which case they will be charged the Lifeline tariff.					
DOMESTIC *No free basic service*					
Energy charge	Block 1	c/kWh	0-600kWh	134.76	153.63
	Block 2	c/kWh	600.1+kWh	163.87	186.81
LIFELINE (for qualifying customers only - see Tariff Policy for details) *Free basic service*					
Energy charge	Block 1	c/kWh	0-350kWh	84.31	96.12
	Block 2	c/kWh	350.1+kWh	204.65	233.30

SERVICES RENDERED		UNIT	REMARKS	2015/16 excl. VAT	2015/16 incl. VAT
RESIDENTIAL CUSTOMERS					
DOMESTIC *No free basic service*					
Energy charge	Block 1	c/kWh	0-600kWh	154.30	175.90
	Block 2	c/kWh	600.1+kWh	187.63	213.90
LIFELINE (for qualifying customers only - see Tariff Policy for details) *Free basic service may apply as per the Tariff Policy*					
Energy charge	Block 1	c/kWh	0-350kWh	91.06	103.81
	Block 2	c/kWh	350.1+kWh	252.12	287.42

SERVICES RENDERED		UNIT	REMARKS	2016/17 excl. VAT	2016/17 incl. VAT
RESIDENTIAL CUSTOMERS					
DOMESTIC *No free basic service*					
Energy charge	Block 1	c/kWh	0-600kWh	164.51	187.54
	Block 2	c/kWh	600.1+kWh	200.05	228.06
LIFELINE (for qualifying customers only - see Tariff Policy for details) *Free basic service may apply as per the Tariff Policy*					
Energy charge	Block 1	c/kWh	0-350kWh	97.09	110.68
	Block 2	c/kWh	350.1+kWh	268.81	306.44
HOME USER *(Not implemented in 2016/17 - envisaged for implementation 1 July 2017 as a part replacement for Domestic)*					
Network Access and Administration Charge		R/month		212.92	242.73
Energy Charge	Block 1	c/kWh	0-600kWh	129.02	147.08
	Block 2	c/kWh	600.1+kWh	200.05	228.06

SERVICES RENDERED		UNIT	REMARKS	2017/18 excl. VAT	2017/18 incl. VAT
RESIDENTIAL CUSTOMERS					
DOMESTIC *No free basic service*					
Energy charge	Block 1	c/kWh	0-600kWh	169.12	192.80
	Block 2	c/kWh	600.1+kWh	205.65	234.44
LIFELINE (for qualifying customers only - see Tariff Policy for details) *Free basic service may apply as per the Tariff Policy*					
Energy charge	Block 1	c/kWh	0-350kWh	102.00	116.28
	Block 2	c/kWh	350.1+kWh	205.65	234.44
HOME USER *(Not implemented in 2017/18 - delayed until at least 2017/18 for further consultation as a result of feedback received during the Public Participation Process)*					
Network Access and Administration Charge		R/month		7.20	8.21
Energy Charge	Block 1	c/kWh	0-600kWh	132.63	151.20
	Block 2	c/kWh	600.1+kWh	205.65	234.44

SERVICES RENDERED		UNIT	REMARKS	2018/19 Regulated	2018/19 Unregulated	2018/19 excl. VAT	2018/19 incl. VAT
RESIDENTIAL CUSTOMERS							
DOMESTIC *For prepayment customers with a municipal property valuation of between R400k and R1m.*							
Energy charge	Block 1	c/kWh	0-600kWh	158.35	24.54	182.89	210.32
	Block 2	c/kWh	600.1+kWh	197.85	24.54	222.39	255.75
LIFELINE (for qualifying customers only - see Tariff Policy for details) *Free basic service may apply as per the Tariff Policy*							
Energy charge	Block 1	c/kWh	0-350kWh	104.58	5.72	110.30	126.85
	Block 2	c/kWh	350.1+kWh	197.85	24.54	222.39	255.75
HOME USER For all credit meters and all properties with a prepayment meter and a municipal property value of R1m and more.							
Home User Charge		R/month		130.44	0.00	130.44	150.00
Energy Charge	Block 1	c/kWh	0-600kWh	136.61	24.54	161.15	185.32
	Block 2	c/kWh	600.1+kWh	197.85	24.54	222.39	255.75

Appendix 4 Householder Questionnaire Used For Primary Data Collection On Energy-Use Patterns And Related Matters In The Case Study Area

QUESTIONNAIRE / SURVEY QUESTIONS

Let's start by enquiring about your household

1. i) How many members are living in your home? ii) How many members are above 18 years?
   i. ________________
   ii. ________________

2. How long have you and your household members been living in this dwelling?
   i. ☐ More than a year (provide the number of years _______)
   ii. ☐ Less than a year.
   iii. ☐ This is a weekend or holiday apartment.

3. What type of material was used in building your home?
   i. ☐ Wood Frame/Corrugated Metal Sheeting
   ii. ☐ Brick/Rock
   iii. ☐ Stucco
   iv. ☐ Mobile Home

4. Which year was your dwelling built? Who built it?
   i. Before 1946 ☐ Authority ☐ Self
   ii. Between 1946 and 1980 ☐ Authority ☐ Self
   iii. Between 1981 and 1994 ☐ Authority ☐ Self
   iv. Between 1994 and 2014 ☐ Authority ☐ Self
   v. After 2014 ☐ Authority ☐ Self

5. Have you ever renovated your building? If yes, please write the year the renovation took place. If you are not sure, please indicate
   i. ☐ Yes _____ ☐ Not sure
   ii. ☐ No

6. If yes, what kind of renovation was made?
   i. ☐ Facade renovation with additional thermal insulation
   ii. ☐ Facade renovation without additional thermal insulation
   iii. ☐ Replacement of the roof
   iv. ☐ Replacement of the windows and doors
   v. ☐ Other, specify ____________________

Let's assess your electricity access

7. Is your building electrified?
   i. ☐ Yes
   ii. ☐ No

8. Do you have electricity meter in your household?
   i. ☐ Yes (Is it a Prepaid Meter? Yes/No)
   ii. ☐ No

9. If yes, how many kilowatt-hours (kWh) of electricity you spend on average per month in summer and winter?

	Summer	winter
i.	☐ < 300kWh	☐ < 300kWh
ii.	☐ 300 kWh – 450kWh	☐ 300 kWh – 450 kWh
iii.	☐ 450 kWh – 600kWh	☐ 450 kWh – 600kWh
iv.	☐ > 600kWh	☐ > 600kWh

10. How many times has supply interruption (incl. load shedding) happened over the past one year? And (vi)What was the typical duration of the interruption?
   i. ☐ 0 times
   ☐ 1 – 2 times

i. ☐ 2 – 4 times
ii. ☐ 4 – 6 times
iii. ☐ More than 6 times
iv. ☐ Less than 2 hours ☐ 2 – 5 hours ☐ More than 5 hours ☐ Whole day

Let's analyze the traditional energy forms you use in your household

Indicate the local energy resources you use in your household. What is the average consumption per month in summer and winter

<u>Summer</u>

i.	☐ Paraffin	☐ < 100 liters	☐ 100 liters – 250 liters	☐ > 250 liters
i.	☐ Gas	☐ < 100 liters	☐ 100 liters – 250 liters	☐ > 250 liters
ii.	☐ Fuelwood	☐ Less than 600kg	☐ 600kg – 800kg	☐ More than 800kg
iii.	☐ Coal	☐ Less than 600kg	☐ 600kg – 800kg	☐ More than 800kg
iv.	☐ Agric. waste	☐ Less than 600kg	☐ 600kg – 800kg	☐ More than 800kg
v.	☐ Solar energy			

<u>Winter</u>

ii.	☐ Paraffin	☐ < 100 liters	☐ 100 liters – 250 liters	☐ > 250 liters
iii.	☐ Gas	☐ < 100 liters	☐ 100 liters – 250 liters	☐ > 250 liters
iv.	☐ Fuelwood	☐ < 600kg	☐ 600kg – 800kg	☐ > 800kg
v.	☐ Coal	☐ < 600kg	☐ 600kg – 800kg	☐ > 800kg
vi.	☐ Animal waste	☐ < 600kg	☐ 600kg – 800kg	☐ > 800kg
vii.	☐ Solar energy			

Why do you choose to use the above selected local energy resource?

i. ☐ It's cheaper
ii. ☐ It's convenient
iii. ☐ It's available and accessible
iv. ☐ It's respect for tradition
v. ☐ Its environmentally friendly

Is the above selected local resource always available in your area? How do you obtain them?

i. Yes, always ☐ Area Vendor ☐ Woodlots ☐ Forest ☐ Others, specify_______________
ii. No, not always ☐ Area Vendor ☐ Woodlots ☐ Forest ☐ Others, specify_______________

What distance do you travel to obtain your local energy type?

i. ☐ Less than 100 meters
ii. ☐ 100 meters to 500 meters
iii. ☐ 500 meters to 1 000 meters
iv. ☐ More than 1 000 meters

Do you know about the impacts of the above selected energy resource?

i. ☐ No ☐ Yes, please specify____

When you use the above selected energy type, does it irritate your eyes, throat and affect your breathing?

i. ☐ Yes, very much
ii. ☐ Yes, not too much
iii. ☐ Not at all

If you ticked the (i) or the (ii) above, how often do such irritation happen and how long does it take to go away?

i. ☐ When using the above selected energy ☐ Few days ☐ Few weeks ☐ Few months
ii. ☐ Immediately after using the above selected energy ☐ Few days ☐ Few weeks ☐ Few months
iii. ☐ A long time after using the above selected energy ☐ Few days ☐ Few weeks ☐ Few months

Let's assess your energy use

What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for each purpose.

i. Lighting ☐ Electricity ☐ Paraffin ☐ Fuelwood ☐ Coal ☐ Gas ☐ Candles ☐ Solar ☐ Others, Specify_________

i. Cooking ☐ Electricity ☐ Paraffin ☐ Fuelwood ☐ Coal ☐ Gas ☐ Agric. residue ☐ Solar ☐ Others, Specify________
ii. Heating ☐ Electricity ☐ Paraffin ☐ Fuelwood ☐ Coal ☐ Gas ☐ Agric. residue ☐ Solar ☐ Others, Specify________

Check the large appliances you have in your home by placing the number you have for each. Please indicate if appliance is electric, gas or paraffin

i. ____ Refrigerator ____ Freezer
ii. ____ Vent Hood
iii. ____ Microwave
iv. ____ Dishwasher
v. ____ Stove ☐ Electric ☐ Gas ☐ Paraffin ____ Cooktop ☐ Electric ☐ Gas
vi. ____ Washing Machine ____ Dryer ☐ Electric ☐ Gas _____ Iron
vii. ____ Water Heaters ☐ Electric ☐ Gas
viii. ____ TV ____ Radio ____ Computer ____Video/ DVD ____ Stereo
ix. ____ Landline Telephone ____ Mobile Telephone
x. ____ Other_____________________ ☐ Electric ☐ Gas

What kind of light bulbs do you have in your household?

i. ☐ "Traditional" incandescent bulbs
ii. ☐ Compact Fluorescent bulbs
iii. ☐ LED light bulbs
iv. ☐ Fluorescent bulbs
v. ☐ Halogen bulbs
vi. ☐ Other, specify _______________________________

i) How many of the above selected do you have in your dwelling? ii) How many of those are turned on for more than an hour per day?

i. ____________________
ii. ____________________

What space heating system/s do you use in your home? If applicable, how many?

i. ☐ _____ Electric portable unit
ii. ☐ _____ Gas portable unit
iii. ☐ _____ Heat pump
iv. ☐_____ Wall furnace
v. ☐ _____ Charcoal heater
vi. ☐_____ Other, specify _________________________________

What type of cooling system do you use in your home? If applicable, how many?

i. ☐ _____Window Units
ii. ☐ _____ Electric fan
iii. ☐ _____ Evaporative Cooler(s)
iv. ☐ _____ Other, specify ____________________

During the winter, at what temperature do you keep your home?

	Daytime	Nighttime
i.	☐ 18 – 22 Celsius	☐ 18 – 22 Celsius
ii.	☐ 23 – 26 Celsius	☐ 23 – 26 Celsius
iii.	☐ 27 – 30 Celsius	☐ 27 – 0 Celsius
iv.	☐ Over 30 Celsius	☐ Over 30 Celsius
v.	☐ Turned Off	☐ Turned Off

During the summer, at what temperature do you keep your home?

	Daytime	Nighttime
i.	☐under 15 Celsius	☐under 15 Celsius
ii.	☐ 15 – 20 Celsius	☐ 15 – 20 Celsius
iii.	☐ 21 – 26 Celsius	☐ 21 – 26 Celsius
iv.	☐ Over 26 Celsius	☐ Over 26 Celsius
v.	☐ Turned Off	☐ Turned Off

Is your home insulated? (iii) What colour is the insulation?

i. ☐ Yes
ii. ☐ No
iii. ________________________

Let's assess your behavior to energy use

How much thought and action do you put in to save energy in your home?

i. ☐ A lot
ii. ☐ A fair amount
iii. ☐ Not very much
iv. ☐ None at all

How frequent do you turn the heating down or off when you go out or when you sleep at night?

i. Almost always
ii. Very often
iii. Not very often
iv. Never

How worried are you about the likely future energy price rises?

i. A lot
ii. A fair amount
iii. Not very much
iv. None at all

How worried are you about climate change?

i. A lot
ii. A fair amount
iii. Not very much
iv. None at all

What improvement would you ideally need to make your home more energy efficient?

i. ☐ External insulation
ii. ☐ Internal insulation
iii. ☐ Solar photovoltaic
iv. ☐ Replacement of the roof
v. ☐ Replacement of the windows and doors
vi. ☐ Other, specify ____________________

Indicate what (i) your household and (ii) the authority need to do more, to increase cleaner energy access in your household?

i. ____
ii. ____

Energy burden on your household income

What is the average monthly cost for the energy form (s) you use in your household on a monthly basis?

i. < R300 ☐ Paraffin ☐ Wood ☐ Coal ☐ Gas ☐ Agric. residue ☐ Candles ☐ Solar ☐ Other, Specify________
ii. R301 – R999 ☐ Paraffin ☐ Wood ☐ Coal ☐ Gas ☐ Agric. residue ☐ Candles ☐ Solar ☐ Other, Specify_______
iii. R1 000 – R1 999 ☐ Paraffin ☐ Wood ☐ Coal ☐ Gas ☐ Agric. residue ☐ Candles ☐ Solar ☐ Other, Specify________
iv. > R1 199 ☐ Paraffin ☐ Wood ☐ Coal ☐ Gas ☐ Agric. residue ☐ Candles ☐ Solar ☐ Other, Specify________

What percentage does the cost of your energy type take away from your household monthly income? Please indicate as many as possible.

Appendix 5 **Short Interview Questions Designed For Area Vendors Selling Energy Products In The Case Study Area**

SURVEY (INTERVIEW) QUESTIONS: LOCAL SUPPLIERS

1. Where do you obtain your products?

   ____

2. Are the source of your products always available? Is there any potential threat to your product source?

   ____

3. How much weight of the products do you purchase and sell on a monthly basis?

   ____

4. What is the price structure of your product? Is it affordable by the dwellers?

   ____

5. Do you think you will ever run out of products and why?

   ____

6. What are the barriers you foresee that will make your business not sustainable?

   ____

Appendix 6 Excel sheet data of Responses From Householder Questionnaires

No on the questionnaire	1.i) How many members are living in your home	How many members are above 18 years?	2.How long have you and your household members been living in this dwelling?	2i. Provide the number of years	3.What type of material was used in building your home?	4i.Which year was your dwelling built? Who built it? [i. Before 1946]	4i.Which year was your dwelling built? Who built it? [ii. Between 1946 and 1980]	4i.Which year was your dwelling built? Who built it? [iii. Between 1981 and 1994]	4i.Which year was your dwelling built? Who built it? [iv. Between 1994 and 2014]	4i.Which year was your dwelling built? Who built it? [v. After 2014]	5i.Have you ever renovated your building? If yes, please write the year the renovation took place. If you are not sure, please indicate	5ii. If yes, please write the year the renovation took place. If you are not sure, please indicate
194	1		i. More than a year	3	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
70	5	3	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
188	3	3	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
91	3	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting						No	
187	2	2	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
81	4	2	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting						No	
205	3	2	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
126	2	1	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting				Self		Yes	
125	2	1	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
27	2	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
178	2	1	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting				Self		Yes	
138	2	2	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	2017
127	2	0	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
41	4	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
143	3	2	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
195	3	3	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Self		Yes	
191	3		i. More than a year		i. Wood Frame/Corrugated Metal Sheeting	Self					Yes	2018
193	1	1	i. More than a year	4	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
100	4	2	i. More than a year	3	i. Wood Frame/Corrugated Metal Sheeting					Authority	No	
186	8	5	i. More than a year	4	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
146	4	4	i. More than a year	1	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
189	1	1	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
113	4	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
175	3		i. More than a year	4	i. Wood Frame/Corrugated Metal Sheeting					Self	Not sure	
179	1	1	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
141	4	3	i. More than a year	4	i. Wood Frame/Corrugated Metal Sheeting					Self	Not sure	
64	5	3	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
181	2	2	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
65	3	1	i. More than a year	3	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
66	3	1	i. More than a year	3	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
99	4	2	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
98	4	1	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
46	1	1	i. More than a year	5	i. Wood Frame/Corrugated Metal Sheeting					Authority	No	
73	4	2	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
72	4	2	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
61	4	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
85	8	4	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
69	3	2	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
92	3	2	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
93	1	1	i. More than a year	1	i. Wood Frame/Corrugated Metal Sheeting						Yes	
80	1	1	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
109	7	5	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting				Self		No	
22	3	2	i. More than a year	3	Mobile Home				Authority		Yes	
26	8	3	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
33	2	2	i. More than a year	1	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
154	5	3	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting				Authority		Yes	
164	2	2	i. More than a year	3	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	2017
165	3	3	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
101	1	1	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	2017
121	2	2	i. More than a year	1	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
52	3	3	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	2017
130	4	2	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
38	3	3	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	2018
115	4	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
110	2	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
104	4	2	i. More than a year	1	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
51	4	2	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
3	5	3	i. More than a year	10	i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
42	4	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
43	4	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting			Authority			No	
44	2	2	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
45	3	2	i. More than a year	5	i. Wood Frame/Corrugated Metal Sheeting				Self		No	
171	1		i. More than a year	1	i. Wood Frame/Corrugated Metal Sheeting					Self	No	
150	2	1	i. More than a year	8	i. Wood Frame/Corrugated Metal Sheeting				Authority		Yes	
159	1	1	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
161	2		i. More than a year	9	i. Wood Frame/Corrugated Metal Sheeting				Authority		Yes	
162	2	1	i. More than a year	1	i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
13	8	6	i. More than a year	2	i. Wood Frame/Corrugated Metal Sheeting				Self		No	
129	8	5	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Self		Yes	
184	2	1	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
48	3		i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
40					i. Wood Frame/Corrugated Metal Sheeting					Self	No	
122	1	1	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting	Self					Yes	
182	1	1	ii. Less than a year.		Mobile Home					Self	No	
62	4	2	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
173	2	0			i. Wood Frame/Corrugated Metal Sheeting	Self					No	
900	2		i. More than a year						Authority		No	
103					i. Wood Frame/Corrugated Metal Sheeting				Self		No	
49	5	3	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
169	4	3	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
176	2	1	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	Not sure	
185	2	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
97	1	1	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
114	1		i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Authority	No	
174	4	2	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
142	4	2	i. More than a year	3	i. Wood Frame/Corrugated Metal Sheeting	Self					Not sure	
500	4	4	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting	Authority					Yes	
96	3	1	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
23	3	2	i. More than a year	18	i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
7	9	4	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
67	5	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
8	6	3	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
83	3		ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	Not sure	
68	4	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting						No	
185	3	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
9	5	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
34	4	1	i. More than a year	12	i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
35	4	1	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
56	2	1	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Authority	Yes	
118	2	2	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
111	5	3	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
124	1	1	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
59	2		i. More than a year							Authority	Yes	
119	4		ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
112			i. More than a year								No	
76	1	1	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
32	2	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Self		Not sure	
78	7	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting						No	
4	6	2	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
5	5	3	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Authority	No	
47	3		i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
152	3		i. More than a year		i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
151	6	3	i. More than a year	5	i. Wood Frame/Corrugated Metal Sheeting				Authority		No	
170	1		i. More than a year		i. Wood Frame/Corrugated Metal Sheeting	Self					Not sure	
168	2		ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	
133	5	2	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
132	3	2	ii. Less than a year.		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
136	1		i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	No	
123	1	1	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting	Self					Yes	
116	5	5	i. More than a year		i. Wood Frame/Corrugated Metal Sheeting					Self	Yes	

No on the questionnaire	6.If yes, what kind of renovation was made? [i. Facade renovation with additional thermal insulation]	6.If yes, what kind of renovation was made? [ii. Facade renovation without additional thermal insulation]	6.If yes, what kind of renovation was made? [iii. Replacement of the roof]	6.If yes, what kind of renovation was made? [iv. Replacement of the windows and doors]	6.If yes, what kind of renovation was made? [v. Other]	6i. If other, specify	7.Is your building electrified?	8.Do you have electricity meter in your household?	8i. Is it a Prepaid Meter?	9.If yes, how many kilowatt-hours (kWh) of electricity you spend on average per month in summer and winter? [i. < 300kWh]	9.If yes, how many kilowatt-hours (kWh) of electricity you spend on average per month in summer and winter? [ii. 300 kWh â€“ 450kWh]	9.If yes, how many kilowatt-hours (kWh) of electricity you spend on average per month in summer and winter? [iii. 450 kWh â€“ 600kWh]
194							ii. No	i. Yes	No			
70							ii. No	ii. No				
188							ii. No	ii. No				
91							ii. No	ii. No				
187							ii. No	ii. No				
81							ii. No	ii. No				
205					Indicate		i. Yes	ii. No				
126			Indicate				ii. No	ii. No				
125			Indicate				ii. No	ii. No				
27							ii. No	ii. No				
178			Indicate				ii. No	ii. No				
138			Indicate				ii. No	ii. No				
127			Indicate				ii. No	ii. No				
41							ii. No	ii. No				
143			Indicate				ii. No	ii. No				
195				Indicate			ii. No	ii. No				
191			Indicate				ii. No	ii. No				
193							ii. No	i. Yes	No			
100							ii. No	ii. No				
186							ii. No	ii. No				
146							ii. No	ii. No				
189							ii. No	ii. No				
113							ii. No	ii. No				
175							ii. No	ii. No				
179					Indicate	flooring	ii. No	ii. No				
141							ii. No	ii. No				
64							ii. No	ii. No				
181							ii. No	ii. No				
65							ii. No	ii. No				
66							ii. No	ii. No				
99							ii. No	ii. No				
98							ii. No	ii. No				
46							ii. No	ii. No				
73			Indicate	Indicate			ii. No	ii. No				
72			Indicate				i. Yes	ii. No				
61			Indicate				ii. No	ii. No				
85							ii. No	ii. No				
69							ii. No	ii. No				
92							ii. No	ii. No				
93			Indicate	Indicate			ii. No	ii. No				
80							ii. No	ii. No				
109							ii. No	ii. No				
22			Indicate				ii. No	ii. No				
26							ii. No	ii. No	No			
33			Indicate				ii. No	ii. No				
154			Indicate				ii. No	ii. No				
164			Indicate				ii. No	ii. No				
165	Indicate						ii. No	ii. No				
101	Indicate						ii. No					
121			Indicate				ii. No	ii. No				
52				Indicate			ii. No	ii. No				
130	Indicate						ii. No	ii. No				
38			Indicate				ii. No	ii. No				
115							ii. No	ii. No				
110							ii. No	ii. No				
104							ii. No	ii. No				
51					Indicate	leveling	ii. No	ii. No				
3							ii. No	ii. No				
42							ii. No	ii. No				
43							ii. No	ii. No				
44							ii. No	ii. No				
45							ii. No	ii. No				
171							ii. No	ii. No				
150					Indicate	rebuilt	ii. No	ii. No				
159							ii. No	ii. No				
161	Indicate						ii. No	ii. No				
162			Indicate				ii. No	ii. No				
13				Indicate			ii. No	ii. No				
129			Indicate	Indicate			ii. No					
184							ii. No	ii. No				
48							ii. No	ii. No				
40							ii. No					
122			Indicate				ii. No	ii. No				
182							ii. No	ii. No				
62							ii. No	ii. No				
173							i. Yes	ii. No				
900							ii. No	ii. No				
103							ii. No	ii. No				
49							ii. No	ii. No				
169							ii. No	ii. No				
176							ii. No	ii. No				
185							ii. No	ii. No				
97							ii. No	ii. No				
114							ii. No	ii. No				
174			Indicate				ii. No	ii. No				
142							ii. No	ii. No				
500			Indicate				ii. No	ii. No				
96							ii. No	ii. No				
23							ii. No	ii. No				
7							ii. No	ii. No				
67							ii. No	ii. No				
8							ii. No	ii. No				
83							ii. No	ii. No				
68							ii. No	ii. No				
185			Indicate				ii. No	ii. No				
9							ii. No	ii. No				
34							ii. No	ii. No				
35							ii. No	ii. No				
56			Indicate				ii. No	ii. No				
118							ii. No	ii. No				
111	Indicate						ii. No	ii. No				
124							ii. No	ii. No				
59							ii. No	ii. No				
119							ii. No	ii. No				
112							ii. No	ii. No	No			
76							ii. No	ii. No				
32							ii. No	ii. No				
78							ii. No	ii. No				
4							ii. No	ii. No				
5		Indicate					i. Yes	i. Yes				
47							ii. No	ii. No				
152							ii. No	ii. No				
151							ii. No	ii. No				
170							ii. No	ii. No				
168			Indicate				ii. No	ii. No				
133							ii. No	ii. No				
132							ii. No	ii. No				
136							ii. No	ii. No				
123			Indicate				ii. No	ii. No				
116			Indicate				ii. No	ii. No				

No on the questionnaire	9.If yes, how many kilowatt-hours (kWh) of electricity you spend on average per month in summer and winter? [iv. > 600kWh]	10.How many times has supply interruption (incl. load shedding) happened over the past one year?	10ii. What was the typical duration of the interruption?	11a.Indicate the local energy resources you use in your household. What is the average consumption per month in summer [i. Paraffin]	11a.Indicate the local energy resources you use in your household. What is the average consumption per month in summer [Gas]	11a.Indicate the local energy resources you use in your household. What is the average consumption per month in summer [iii. Fuelwood]	11a.Indicate the local energy resources you use in your household. What is the average consumption per month in summer [iv. Coal]	11a.Indicate the local energy resources you use in your household. What is the average consumption per month in summer [v. Agric. waste]	11a.Indicate the local energy resources you use in your household. What is the average consumption per month in summer [vi. Solar energy]
194		i. 0 times		>250l	100l â€“ 250l				
70				100l â€“ 250l		>800kg			
188				Indicate					
91				>250l					
187				<100l					
81				<100l				<600kg	
205				<100l					
126				Indicate					
125				Indicate					
27				>250l					
178				Indicate					
138				<100l					
127				Indicate					
41					Indicate				
143				Indicate	Indicate				
195				100l â€“ 250l					
191					<100l				
193				>250l	100l â€“ 250l				
100					Indicate				
186				>250l					
146					Indicate				
189				100l â€“ 250l					
113				Indicate					
175				<100l					
179					100l â€“ 250l				
141					<100l				
64					Indicate				
181				Indicate					
65				<100l					
66				<100l					
99				>250l			600kg â€“ 800kg		
98				100l â€“ 250l					
46				>250l					
73				100l â€“ 250l			600kg â€“ 800kg		
72				Indicate					
61				Indicate					
85					100l â€“ 250l				
69				<100l		Indicate		Indicate	
92				Indicate					
93				100l â€“ 250l					
80				<100l	100l â€“ 250l				
109						600kg â€“ 800kg			
22				100l â€“ 250l					
26				Indicate					
33				<100l					
154					100l â€“ 250l				
164				100l â€“ 250l					
165				100l â€“ 250l					
101				<100l					
121				<100l					
52				100l â€“ 250l					
130				>250l					
38				<100l					
115				Indicate					
110				100l â€“ 250l					
104				>250l	>250l		>800kg		
51				<100l					
3				<100l					
42				<100l					
43				<100l					
44				<100l					
45				100l â€“ 250l					
171				<100l					
150				Indicate					
159				<100l					
161				100l â€“ 250l	100l â€“ 250l				
162				100l â€“ 250l					
13						>800kg			
129				Indicate	Indicate		Indicate		
184					Indicate				
48				Indicate					
40				<100l					
122				Indicate					
182					Indicate				
62				100l â€“ 250l					
173				>250l					
900				<100l					
103				<100l					
49				Indicate					
169									
176				Indicate					
185					Indicate				
97				Indicate					
114				Indicate	100l â€“ 250l				
174				100l â€“ 250l					
142				Indicate					
500				>250l					
96				Indicate					
23				Indicate					
7						>800kg			
67				>250l					
8						Indicate			
83				Indicate					
68				Indicate		Indicate			
185				<100l					
9				Indicate					
34				Indicate					
35				Indicate					
56				<100l					
118				<100l					
111				<100l					
124				<100l					
59				100l â€“ 250l					
119				Indicate					
112					Indicate				
76				<100l					
32				Indicate					
78				<100l					
4				Indicate					
5				<100l			Indicate		
47				Indicate					
152				Indicate					
151				Indicate					
170				<100l					
168					Indicate				
133					<100l				
132					<100l				
136				<100l					
123				Indicate					
116				<100l					

No on the questionnaire	11b.Indicate the local energy resources you use in your household. What is the average consumption per month in winter [i. Paraffin]	11b.Indicate the local energy resources you use in your household. What is the average consumption per month in winter [Gas]	11b.Indicate the local energy resources you use in your household. What is the average consumption per month in winter [iii. Fuelwood]	11b.Indicate the local energy resources you use in your household. What is the average consumption per month in winter [iv. Coal]	11b.Indicate the local energy resources you use in your household. What is the average consumption per month in winter [v. Agric. waste]	11b.Indicate the local energy resources you use in your household. What is the average consumption per month in winter [vi. Solar energy]	12.Why do you choose to use the above selected local energy resource?	13i.Is the above selected local resource always available in your area? How do you obtain them? [i. Yes, always]
194	100l â€“ 250l			600kg â€“ 800kg			i. Itâ€™s cheaper	
70	100l â€“ 250l		>800kg				iii. Itâ€™s available and accessible	
188	Indicate						ii. Itâ€™s convenient	
91	>250l						i. Itâ€™s cheaper	
187	<100l						i. Itâ€™s cheaper	Area Vendor
81	100l â€“ 250l				<600kg		iii. Itâ€™s available and accessible	
205	100l â€“ 250l						v. Its environmentally friendly	
126	Indicate						iii. Itâ€™s available and accessible	
125	Indicate						iii. Itâ€™s available and accessible	
27	>250l						i. Itâ€™s cheaper	Area Vendor
178	Indicate						iii. Itâ€™s available and accessible	
138	<100l						i. Itâ€™s cheaper	Area Vendor
127	Indicate						iii. Itâ€™s available and accessible	
41		Indicate					i. Itâ€™s cheaper	Area Vendor
143	Indicate	Indicate					iii. Itâ€™s available and accessible	
195	>250l						i. Itâ€™s cheaper	
191		<100l					v. Its environmentally friendly	
193	100l â€“ 250l			600kg â€“ 800kg			i. Itâ€™s cheaper	
100	Indicate						iii. Itâ€™s available and accessible	
186	>250l						iii. Itâ€™s available and accessible	
146		Indicate					i. Itâ€™s cheaper	Area Vendor
189	100l â€“ 250l						ii. Itâ€™s convenient	
113	Indicate						iii. Itâ€™s available and accessible	Area Vendor
175	<100l						i. Itâ€™s cheaper	Area Vendor
179		>250l					iii. Itâ€™s available and accessible	Area Vendor
141	<100l						i. Itâ€™s cheaper	
64		Indicate					iii. Itâ€™s available and accessible	Area Vendor
181	>250l						ii. Itâ€™s convenient	
65	100l â€“ 250l						iii. Itâ€™s available and accessible	
66	100l â€“ 250l						iii. Itâ€™s available and accessible	
99	>250l		600kg â€“ 800kg	>800kg			i. Itâ€™s cheaper	
98	100l â€“ 250l						v. Its environmentally friendly	
46	>250l						iii. Itâ€™s available and accessible	
73	>250l		>800kg	>800kg			iii. Itâ€™s available and accessible	Area Vendor
72	Indicate						iii. Itâ€™s available and accessible	Area Vendor
61	Indicate						iii. Itâ€™s available and accessible	
85	100l â€“ 250l	100l â€“ 250l					ii. Itâ€™s convenient	Area Vendor
69	<100l		Indicate				i. Itâ€™s cheaper	
92	Indicate						iii. Itâ€™s available and accessible	
93	100l â€“ 250l						ii. Itâ€™s convenient	
80	100l â€“ 250l	100l â€“ 250l					iii. Itâ€™s available and accessible	Area Vendor
109							iii. Itâ€™s available and accessible	Forest
22	>250l						i. Itâ€™s cheaper	
26	Indicate						i. Itâ€™s cheaper	Area Vendor
33	100l â€“ 250l						i. Itâ€™s cheaper	
154		100l â€“ 250l	>800kg				iii. Itâ€™s available and accessible	Area Vendor
164	>250l						i. Itâ€™s cheaper	
165	>250l						ii. Itâ€™s convenient	
101	<100l						iii. Itâ€™s available and accessible	
121	<100l						iii. Itâ€™s available and accessible	
52	>250l						i. Itâ€™s cheaper	
130	>250l						i. Itâ€™s cheaper	
38	<100l						i. Itâ€™s cheaper	Area Vendor
115	Indicate						ii. Itâ€™s convenient	
110	>250l						iii. Itâ€™s available and accessible	
104	>250l	>250l		>800kg			i. Itâ€™s cheaper	Other
51	100l â€“ 250l						i. Itâ€™s cheaper	Area Vendor
3				Indicate			iii. Itâ€™s available and accessible	Area Vendor
42	<100l						i. Itâ€™s cheaper	Area Vendor
43	Indicate						iii. Itâ€™s available and accessible	Area Vendor
44	<100l						i. Itâ€™s cheaper	Area Vendor
45	>250l						iii. Itâ€™s available and accessible	Area Vendor
171	100l â€“ 250l						i. Itâ€™s cheaper	
150	Indicate						iii. Itâ€™s available and accessible	Area Vendor
159	<100l						i. Itâ€™s cheaper	Area Vendor
161	<100l	100l â€“ 250l					iii. Itâ€™s available and accessible	Area Vendor
162	100l â€“ 250l						i. Itâ€™s cheaper	Area Vendor
13			>800kg				iii. Itâ€™s available and accessible	
129	Indicate	Indicate		Indicate			i. Itâ€™s cheaper	
184		Indicate					ii. Itâ€™s convenient	Area Vendor
48	Indicate						i. Itâ€™s cheaper	
40	<100l						i. Itâ€™s cheaper	Area Vendor
122	Indicate						iii. Itâ€™s available and accessible	
182		Indicate					i. Itâ€™s cheaper	
62	>250l						iii. Itâ€™s available and accessible	
173	>250l						i. Itâ€™s cheaper	Area Vendor
900	<100l						i. Itâ€™s cheaper	
103	Indicate						i. Itâ€™s cheaper	
49	Indicate						i. Itâ€™s cheaper	
169								
176	Indicate						i. Itâ€™s cheaper	
185		Indicate					ii. Itâ€™s convenient	Area Vendor
97	Indicate							
114	Indicate						iii. Itâ€™s available and accessible	Area Vendor
174	>250l						i. Itâ€™s cheaper	
142	<100l						i. Itâ€™s cheaper	
500	>250l			>800kg			i. Itâ€™s cheaper	
96	Indicate						i. Itâ€™s cheaper	
23	Indicate						i. Itâ€™s cheaper	
7			>800kg				iii. Itâ€™s available and accessible	
67	>250l						iii. Itâ€™s available and accessible	
8			Indicate				iii. Itâ€™s available and accessible	
83	Indicate						i. Itâ€™s cheaper	
68	Indicate		Indicate					Area Vendor
185	>250l						i. Itâ€™s cheaper	
9	Indicate						i. Itâ€™s cheaper	Area Vendor
34	Indicate						i. Itâ€™s cheaper	
35	Indicate						i. Itâ€™s cheaper	
56	<100l						i. Itâ€™s cheaper	Area Vendor
118	<100l						iii. Itâ€™s available and accessible	
111	100l â€“ 250l						iii. Itâ€™s available and accessible	
124	100l â€“ 250l						i. Itâ€™s cheaper	
59	>250l						iii. Itâ€™s available and accessible	
119	Indicate						iv. Itâ€™s respect for tradition	
112		Indicate					i. Itâ€™s cheaper	
76	<100l						i. Itâ€™s cheaper	
32	Indicate						i. Itâ€™s cheaper	
78	<100l						i. Itâ€™s cheaper	Area Vendor
4	Indicate						i. Itâ€™s cheaper	
5	100l â€“ 250l						i. Itâ€™s cheaper	Area Vendor
47	Indicate						i. Itâ€™s cheaper	
152	Indicate						i. Itâ€™s cheaper	
151	Indicate						i. Itâ€™s cheaper	
170	100l â€“ 250l						i. Itâ€™s cheaper	
168		Indicate					i. Itâ€™s cheaper	
133		100l â€“ 250l					i. Itâ€™s cheaper	
132			<600kg				i. Itâ€™s cheaper	
136	<100l						iii. Itâ€™s available and accessible	
123	Indicate						iii. Itâ€™s available and accessible	
116	<100l						iii. Itâ€™s available and accessible	

No on the questionnaire	13i.Is the above selected local resource always available in your area? How do you obtain them? [ii. No, not always]	13ii. If other, Please specify	14.What distance do you travel to obtain your local energy type?	15.Do you know about the impacts of the above selected energy resource?	15ii. If yes, please specify	16.When you use the above selected energy type, does it irritate your eyes, throat and affect your breathing?	17.If you ticked the (i) or the (ii) above, how often do such irritation happen.	17i. How long does it take to go away?	18i.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Lighting. [Electricity]
194	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	iii. A long time after using the above selected energy	Few months	Lighting
70	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few days	
188	Area Vendor		ii. 100 meters to 500 meters	i. No		ii. Yes, not too much	i. When using the above selected energy	Few months	Lighting
91	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much			
187			i. Less than 100 meters	ii. Yes	it can burn the house	i. Yes, very much	iii. A long time after using the above selected energy		
81	Area Vendor		i. Less than 100 meters	ii. Yes	dangerous to health	i. Yes, very much	ii. Immediately after using the above selected energy	Few days	
205	Other		i. Less than 100 meters	i. No		ii. Yes, not too much	ii. Immediately after using the above selected energy	Few days	
126	Area Vendor		iv. More than 1 000 meters	ii. Yes	it can cause fire	i. Yes, very much	iii. A long time after using the above selected energy	Few months	
125	Area Vendor		iv. More than 1 000 meters	ii. Yes	fire	i. Yes, very much	iii. A long time after using the above selected energy	Few months	
27			i. Less than 100 meters			i. Yes, very much			
178	Area Vendor		iv. More than 1 000 meters	ii. Yes	fire	i. Yes, very much	iii. A long time after using the above selected energy	Few months	
138			i. Less than 100 meters	ii. Yes	fire	i. Yes, very much	ii. Immediately after using the above selected energy		
127	Area Vendor		iv. More than 1 000 meters	ii. Yes	fire	i. Yes, very much	iii. A long time after using the above selected energy	Few months	
41			i. Less than 100 meters	i. No		iii. Not at all			
143	Area Vendor		iv. More than 1 000 meters	ii. Yes	fire	i. Yes, very much	iii. A long time after using the above selected energy	Few months	
195	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few weeks	
191	Area Vendor		i. Less than 100 meters	i. No		iii. Not at all			Lighting
193	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	iii. A long time after using the above selected energy		Lighting
100	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	i. When using the above selected energy		Lighting
186	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few days	Lighting
146			i. Less than 100 meters	i. No		iii. Not at all			
189	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few days	
113			i. Less than 100 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy		
175			ii. 100 meters to 500 meters	i. No		i. Yes, very much	i. When using the above selected energy		
179			i. Less than 100 meters	i. No		ii. Yes, not too much	ii. Immediately after using the above selected energy	Few days	
141	Woodlots		iv. More than 1 000 meters	i. No		i. Yes, very much	iii. A long time after using the above selected energy	Few days	
64				ii. Yes	fire	iii. Not at all			
181	Area Vendor		i. Less than 100 meters	i. No		ii. Yes, not too much	ii. Immediately after using the above selected energy		
65			i. Less than 100 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few weeks	
66			i. Less than 100 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few weeks	
99	Area Vendor		iii. 500 meters to 1 000 meters	ii. Yes	asthma	i. Yes, very much	i. When using the above selected energy	Few months	
98	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	iii. A long time after using the above selected energy		
46	Area Vendor		iii. 500 meters to 1 000 meters	ii. Yes	fire	i. Yes, very much	i. When using the above selected energy	Few months	Lighting
73			i. Less than 100 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few months	Lighting
72			i. Less than 100 meters	ii. Yes		i. Yes, very much	i. When using the above selected energy	Few weeks	Lighting
61	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few months	
85			i. Less than 100 meters	i. No		iii. Not at all			
69	Other		iv. More than 1 000 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few days	
92	Area Vendor		i. Less than 100 meters	ii. Yes	sickness	i. Yes, very much	i. When using the above selected energy	Few days	
93				ii. Yes		i. Yes, very much	i. When using the above selected energy	Few weeks	
80			i. Less than 100 meters	i. No		ii. Yes, not too much	i. When using the above selected energy		
109			ii. 100 meters to 500 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few weeks	
22	Area Vendor		iii. 500 meters to 1 000 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few days	
26			ii. 100 meters to 500 meters	ii. Yes		i. Yes, very much	ii. Immediately after using the above selected energy		
33	Area Vendor		iii. 500 meters to 1 000 meters	i. No		i. Yes, very much	i. When using the above selected energy		
154			i. Less than 100 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy		
164	Area Vendor		iii. 500 meters to 1 000 meters	i. No		i. Yes, very much	i. When using the above selected energy		
165	Area Vendor		iii. 500 meters to 1 000 meters	ii. Yes	fire	i. Yes, very much	i. When using the above selected energy	Few weeks	
101	Area Vendor		iv. More than 1 000 meters	i. No		i. Yes, very much			
121	Woodlots		ii. 100 meters to 500 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy		
52	Area Vendor		iii. 500 meters to 1 000 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few days	
130	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few months	
38			i. Less than 100 meters	ii. Yes	fire	i. Yes, very much	ii. Immediately after using the above selected energy		
115	Area Vendor		i. Less than 100 meters	i. No		ii. Yes, not too much	iii. A long time after using the above selected energy		
110	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy		
104			i. Less than 100 meters	ii. Yes	illness	i. Yes, very much	i. When using the above selected energy	Few days	
51			i. Less than 100 meters	ii. Yes	asthma	i. Yes, very much	i. When using the above selected energy	Few months	
3			i. Less than 100 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy		
42			i. Less than 100 meters	ii. Yes	dangerous to children	i. Yes, very much	ii. Immediately after using the above selected energy		
43			i. Less than 100 meters	ii. Yes	fire	iii. Not at all			
44			i. Less than 100 meters	ii. Yes	dangerous to children	i. Yes, very much	ii. Immediately after using the above selected energy		
45			ii. 100 meters to 500 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few days	
171	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few days	
150			i. Less than 100 meters	i. No		ii. Yes, not too much	i. When using the above selected energy		Lighting
159			i. Less than 100 meters	ii. Yes	fire	i. Yes, very much	iii. A long time after using the above selected energy	Few months	
161			i. Less than 100 meters	i. No		i. Yes, very much	iii. A long time after using the above selected energy		
162			ii. 100 meters to 500 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy		
13	Woodlots		ii. 100 meters to 500 meters	i. No		ii. Yes, not too much	i. When using the above selected energy	Few weeks	
129	Area Vendor		ii. 100 meters to 500 meters			i. Yes, very much	i. When using the above selected energy		
184			i. Less than 100 meters	ii. Yes		i. Yes, very much	i. When using the above selected energy		
48			ii. 100 meters to 500 meters						
40			i. Less than 100 meters	i. No		iii. Not at all			
122	Area Vendor		ii. 100 meters to 500 meters			i. Yes, very much	ii. Immediately after using the above selected energy		
182	Area Vendor		iv. More than 1 000 meters	i. No		iii. Not at all	iii. A long time after using the above selected energy		
62	Area Vendor		i. Less than 100 meters	i. No		ii. Yes, not too much	i. When using the above selected energy		
173			i. Less than 100 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few days	Lighting
900			i. Less than 100 meters	i. No		iii. Not at all	i. When using the above selected energy	Few weeks	
103	Area Vendor		ii. 100 meters to 500 meters	ii. Yes	health issues	i. Yes, very much	ii. Immediately after using the above selected energy	Few weeks	
49			ii. 100 meters to 500 meters						
169									
176			i. Less than 100 meters	i. No		i. Yes, very much			
185			i. Less than 100 meters	i. No		i. Yes, very much	i. When using the above selected energy		
97	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	i. When using the above selected energy		
114				i. No			iii. A long time after using the above selected energy		
174	Area Vendor		iv. More than 1 000 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few days	
142	Area Vendor		iii. 500 meters to 1 000 meters	i. No		i. Yes, very much	i. When using the above selected energy		
500			iv. More than 1 000 meters			i. Yes, very much	iii. A long time after using the above selected energy		
96	Area Vendor		i. Less than 100 meters	i. No		ii. Yes, not too much	ii. Immediately after using the above selected energy		
23	Area Vendor		i. Less than 100 meters	i. No		ii. Yes, not too much	ii. Immediately after using the above selected energy	Few weeks	
7			ii. 100 meters to 500 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few months	
67	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	iii. A long time after using the above selected energy		
8	Woodlots		i. Less than 100 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few weeks	
83	Area Vendor		ii. 100 meters to 500 meters	i. No		ii. Yes, not too much	i. When using the above selected energy	Few days	
68			i. Less than 100 meters	i. No					
185	Area Vendor		iv. More than 1 000 meters	ii. Yes		i. Yes, very much	ii. Immediately after using the above selected energy	Few months	
9			ii. 100 meters to 500 meters	ii. Yes		i. Yes, very much	ii. Immediately after using the above selected energy		
34	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few days	
35			ii. 100 meters to 500 meters						
56			i. Less than 100 meters	i. No		iii. Not at all	iii. A long time after using the above selected energy	Few days	
118	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy		
111	Area Vendor		iv. More than 1 000 meters	i. No		i. Yes, very much	iii. A long time after using the above selected energy		
124	Area Vendor		i. Less than 100 meters	i. No		ii. Yes, not too much	i. When using the above selected energy	Few days	
59	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few days	
119	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	i. When using the above selected energy		
112			i. Less than 100 meters			iii. Not at all			
76	Area Vendor		i. Less than 100 meters	i. No		iii. Not at all			
32	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	iii. A long time after using the above selected energy	Few months	
78			i. Less than 100 meters	i. No		iii. Not at all			
4			ii. 100 meters to 500 meters						
5				ii. Yes		iii. Not at all			
47			ii. 100 meters to 500 meters						
152	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	i. When using the above selected energy		
151	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few days	
170	Area Vendor		i. Less than 100 meters	i. No		i. Yes, very much	i. When using the above selected energy	Few days	
168	Area Vendor		i. Less than 100 meters	i. No		iii. Not at all			
133	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few days	
132	Woodlots		ii. 100 meters to 500 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few days	
136	Area Vendor		ii. 100 meters to 500 meters	ii. Yes	burnt	i. Yes, very much	iii. A long time after using the above selected energy	Few days	
123	Area Vendor		ii. 100 meters to 500 meters			i. Yes, very much	ii. Immediately after using the above selected energy		
116	Area Vendor		ii. 100 meters to 500 meters	i. No		i. Yes, very much	ii. Immediately after using the above selected energy	Few days	

No on the questionnaire	18i.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Lighting. [Paraffin]	do you use for these purposes? Please indicate if you use more than one of these for Lighting. [Fuelwood]	18i.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Lighting. [Coal]	18i.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Lighting. [Gas]	18i.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Lighting. [Candles]	18i.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Lighting. [Agric. residue]	18i.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Lighting. [Solar]	18ii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Cooking. [Electricity]	18ii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Cooking. [Paraffin]
194					Lighting				Cooking
70					Lighting				Cooking
188	Lighting								Cooking
91	Lighting								Cooking
187	Lighting				Lighting				Cooking
81	Lighting				Lighting				Cooking
205	Lighting								Cooking
126	Lighting								Cooking
125	Lighting								Cooking
27	Lighting				Lighting				Cooking
178	Lighting								Cooking
138	Lighting								Cooking
127	Lighting								Cooking
41					Lighting				
143	Lighting								Cooking
195					Lighting				Cooking
191									
193					Lighting				Cooking
100	Lighting							Cooking	
186	Lighting				Lighting				Cooking
146					Lighting				
189					Lighting				Cooking
113					Lighting				Cooking
175	Lighting								Cooking
179				Lighting	Lighting		Lighting		
141					Lighting				Cooking
64					Lighting				
181	Lighting				Lighting				Cooking
65	Lighting								Cooking
66	Lighting				Lighting				Cooking
99	Lighting				Lighting				Cooking
98	Lighting								Cooking
46	Lighting				Lighting				Cooking
73	Lighting				Lighting				Cooking
72	Lighting	Lighting			Lighting			Cooking	Cooking
61	Lighting								Cooking
85	Lighting				Lighting				Cooking
69	Lighting				Lighting				Cooking
92					Lighting				Cooking
93	Lighting				Lighting				Cooking
80	Lighting				Lighting				
109			Lighting						
22	Lighting				Lighting				Cooking
26	Lighting								Cooking
33	Lighting				Lighting				Cooking
154	Lighting				Lighting				
164	Lighting				Lighting				Cooking
165	Lighting								Cooking
101	Lighting		Lighting		Lighting				Cooking
121	Lighting				Lighting				Cooking
52	Lighting				Lighting				Cooking
130	Lighting								Cooking
38	Lighting				Lighting				Cooking
115					Lighting				Cooking
110	Lighting				Lighting				Cooking
104	Lighting		Lighting	Lighting	Lighting				
51	Lighting								Cooking
3	Lighting				Lighting				Cooking
42					Lighting				Cooking
43	Lighting				Lighting				Cooking
44	Lighting				Lighting				Cooking
45	Lighting								Cooking
171					Lighting				Cooking
150	Lighting								Cooking
159	Lighting				Lighting				Cooking
161					Lighting				
162					Lighting				Cooking
13					Lighting				
129	Lighting				Lighting				Cooking
184					Lighting				
48	Lighting								Cooking
40					Lighting				Cooking
122	Lighting								Cooking
182									
62	Lighting								Cooking
173	Lighting				Lighting				Cooking
900	Lighting								
103					Lighting				Cooking
49	Lighting								Cooking
169	Lighting								
176	Lighting								Cooking
185					Lighting				
97					Lighting				Cooking
114									
174	Lighting				Lighting				Cooking
142	Lighting				Lighting				Cooking
500	Lighting				Lighting				
96	Lighting				Lighting				Cooking
23	Lighting				Lighting				
7		Lighting			Lighting				
67	Lighting				Lighting				Cooking
8		Lighting			Lighting				
83					Lighting				
68				Lighting	Lighting				Cooking
185	Lighting			Lighting					Cooking
9	Lighting								Cooking
34	Lighting								Cooking
35	Lighting								Cooking
56	Lighting				Lighting				Cooking
118	Lighting				Lighting				Cooking
111	Lighting	Lighting			Lighting				Cooking
124	Lighting								Cooking
59	Lighting		Lighting				Lighting		Cooking
119	Lighting				Lighting				Cooking
112				Lighting					
76	Lighting								Cooking
32	Lighting								
78	Lighting								Cooking
4	Lighting								Cooking
5	Lighting							Cooking	Cooking
47	Lighting								Cooking
152	Lighting	Lighting			Lighting				Cooking
151	Lighting	Lighting			Lighting				Cooking
170	Lighting				Lighting				Cooking
168	Lighting				Lighting				
133	Lighting				Lighting				
132					Lighting				
136	Lighting								Cooking
123	Lighting								Cooking
116					Lighting				Cooking

No on the questionnaire	18ii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Cooking. [Fuelwood]	18ii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Cooking. [Coal]	18ii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Cooking. [Gas]	18ii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Cooking. [Agric. residue]	18ii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for Cooking. [Solar]	18iii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for heating. [Electricity]	18iii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for heating. [Paraffin]	18iii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for heating. [Fuelwood]	18iii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for heating. [Coal]
194			Cooking				heating	heating	heating
70	Cooking						heating	heating	
188							heating		
91								heating	
187	Cooking						heating		
81				Cooking			heating		
205							heating		
126							heating		
125							heating		
27	Cooking						heating		
178							heating		
138							heating		
127							heating		
41			Cooking				heating		
143			Cooking				heating		
195							heating		
191			Cooking						
193			Cooking				heating	heating	heating
100									heating
186									heating
146			Cooking						
189									heating
113							heating		
175									
179			Cooking	Cooking					
141								heating	
64			Cooking						
181									heating
65							heating		
66							heating		
99	Cooking	Cooking						heating	heating
98							heating		
46	Cooking							heating	heating
73	Cooking	Cooking					heating	heating	heating
72	Cooking						heating		heating
61							heating		
85			Cooking				heating		
69	Cooking						heating	heating	
92							heating		
93	Cooking						heating		
80			Cooking	Cooking			heating		
109	Cooking							heating	
22							heating		
26							heating		
33							heating	heating	
154			Cooking					heating	
164								heating	
165							heating		
101			Cooking						heating
121							heating		
52							heating		
130									
38							heating		
115							heating		
110							heating		
104			Cooking						heating
51							heating		
3									heating
42									
43									
44							heating		
45							heating		
171							heating		
150							heating		
159							heating		
161			Cooking				heating		
162							heating		
13	Cooking							heating	
129							heating		
184			Cooking					heating	
48							heating		
40							heating		
122							heating		
182									
62									
173								heating	
900									
103							heating		
49							heating		
169									
176							heating		
185			Cooking					heating	
97									
114				Cooking			heating		
174							heating		
142							heating		
500									
96							heating		
23									
7	Cooking							heating	
67							heating		
8	Cooking							heating	
83	Cooking							heating	
68	Cooking						heating	heating	
185									heating
9							heating		
34							heating		
35							heating		
56									
118							heating		
111							heating		
124							heating		
59							heating		heating
119									heating
112		Cooking							
76							heating		
32									
78									
4							heating		
5			Cooking			heating	heating		
47							heating		
152							heating		heating
151							heating		heating
170							heating		
168			Cooking						
133	Cooking		Cooking				heating	heating	
132	Cooking		Cooking					heating	
136							heating		
123							heating		
116							heating		

No on the questionnaire	18iii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for heating. [Gas]	18iii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for heating. [Candles]	18iii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for heating. [Agric. residue]	18iii.What energy form(s) do you use for these purposes? Please indicate if you use more than one of these for heating. [Solar]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Refrigerator]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Freezer]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Vent Hood]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Microwave]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Dishwasher]
194						Indicate			
70									
188									
91									
187									
81			heating		Indicate				
205									
126									
125									
27									
178									
138									
127									
41									
143									
195									
191	heating				Indicate				
193						Indicate			
100									
186									
146	heating								
189									
113									
175									
179			heating						
141									Indicate
64	heating								
181									
65									
66									
99									
98								Indicate	
46									
73					Indicate				
72					Indicate				
61					Indicate				
85					Indicate				
69									
92									
93					Indicate	Indicate		Indicate	
80									
109					Indicate				
22									
26									
33									
154					Indicate				
164									
165					Indicate				
101									
121									
52	heating								
130	heating								
38									
115									
110									
104					Indicate				
51									
3	heating				Indicate				
42									
43									
44									
45	heating				Indicate	Indicate			
171									
150					Indicate			Indicate	
159									
161					Indicate			Indicate	
162					Indicate				
13					Indicate				
129									
184									
48									
40									
122									
182									
62									
173					Indicate			Indicate	Indicate
900									
103									
49									
169									
176									
185									
97									
114									
174									
142									
500									
96									
23									
7					Indicate				
67					Indicate	Indicate			
8									
83									
68									
185							Indicate		
9									
34									
35									
56									
118									
111									
124									
59									
119									
112									
76									
32									
78					Indicate				
4									
5									
47									
152									
151									
170									
168	heating								
133								Indicate	
132								Indicate	
136									
123									
116									

No on the questionnaire	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Stove]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Cooktop]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Washing Machine]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Dryer]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Iron]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Water Heaters]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [TV]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Radio]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Computer]
194	Indicate	Indicate					Indicate	Indicate	Indicate
70	Indicate								
188	Indicate	Indicate							
91	Indicate								
187	Indicate								
81	Indicate						Indicate	Indicate	
205	Indicate		Indicate	Indicate			Indicate		
126	Indicate								
125	Indicate								
27	Indicate								
178	Indicate								
138	Indicate								
127	Indicate								
41									
143	Indicate								
195	Indicate								
191	Indicate				Indicate		Indicate	Indicate	
193							Indicate	Indicate	Indicate
100	Indicate								
186	Indicate								
146									
189									
113									
175	Indicate								
179	Indicate								
141	Indicate								
64									
181	Indicate								
65	Indicate								
66	Indicate								
99	Indicate							Indicate	
98							Indicate	Indicate	
46	Indicate								
73	Indicate				Indicate		Indicate	Indicate	
72	Indicate						Indicate	Indicate	
61	Indicate				Indicate		Indicate	Indicate	
85	Indicate		Indicate	Indicate	Indicate		Indicate	Indicate	
69									
92	Indicate								
93	Indicate						Indicate	Indicate	
80	Indicate					Indicate			
109	Indicate						Indicate		
22	Indicate								
26									
33									
154	Indicate						Indicate		
164									
165	Indicate								
101	Indicate		Indicate		Indicate		Indicate		
121	Indicate						Indicate		
52	Indicate								
130	Indicate	Indicate							
38									
115	Indicate								
110	Indicate								
104	Indicate		Indicate		Indicate		Indicate		
51	Indicate								
3	Indicate						Indicate		
42	Indicate								
43	Indicate								
44	Indicate								
45	Indicate								
171	Indicate								
150	Indicate						Indicate		
159	Indicate								
161	Indicate						Indicate	Indicate	
162							Indicate		
13							Indicate		
129									
184	Indicate								
48									
40									
122	Indicate								
182									
62									
173	Indicate						Indicate	Indicate	
900	Indicate						Indicate	Indicate	
103									
49									
169	Indicate								
176									
185									
97	Indicate								
114									
174									
142	Indicate					Indicate		Indicate	
500	Indicate								
96									
23	Indicate								
7							Indicate		
67							Indicate		
8								Indicate	
83	Indicate								
68	Indicate								
185	Indicate								
9									
34	Indicate								
35									
56							Indicate		
118	Indicate								
111	Indicate								
124	Indicate								
59	Indicate								
119									
112	Indicate								
76	Indicate								
32									
78									
4									
5						Indicate			
47									
152	Indicate								
151	Indicate								
170	Indicate								
168									
133	Indicate			Indicate	Indicate		Indicate		
132	Indicate						Indicate	Indicate	
136									
123	Indicate								
116	Indicate								

No on the questionnaire	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Video/ DVD]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Stereo]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Landline Telephone]	appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [Mobile Telephone]	19.Check the large appliances you have in your home. Please indicate if appliance is electric, gas or paraffin [None]	19i. Write the number you have for each	20.What kind of light bulbs do you have in your household? [i. â€œTraditionalâ€ incandescent bulbs]	20.What kind of light bulbs do you have in your household? [ii. Compact Fluorescent bulbs]	20.What kind of light bulbs do you have in your household? [iii. LED light bulbs]	20.What kind of light bulbs do you have in your household? [iv. Fluorescent bulbs]
194									Indicate	
70										
188							Indicate			
91										
187										
81										
205							Indicate			
126										
125										
27										
178										
138										
127										
41										
143										
195										
191	Indicate			Indicate			Indicate			
193									Indicate	
100							Indicate			
186							Indicate			
146										
189										
113										
175							Indicate			
179										
141										
64										
181				Indicate			Indicate			
65										
66										
99				Indicate			Indicate			
98	Indicate						Indicate			
46							Indicate			
73	Indicate						Indicate			
72	Indicate			Indicate			Indicate			
61				Indicate						
85	Indicate			Indicate					Indicate	
69										
92							Indicate			
93	Indicate			Indicate					Indicate	
80							Indicate			
109										
22		Indicate	Indicate	Indicate						
26										
33										
154										
164										
165				Indicate						
101	Indicate			Indicate						
121										
52										
130									Indicate	
38										
115				Indicate						
110				Indicate			Indicate			
104				Indicate						
51							Indicate			
3										
42										
43										
44										
45									Indicate	
171										
150									Indicate	
159										
161	Indicate									
162										
13				Indicate						
129										
184										
48										
40										
122										
182										
62										
173				Indicate						
900	Indicate			Indicate						
103										
49										
169										
176							Indicate			
185										
97										
114										
174										
142				Indicate			Indicate			
500									Indicate	
96							Indicate			
23							Indicate			
7										
67	Indicate						Indicate			
8				Indicate						
83							Indicate			
68										
185							Indicate			
9										
34										
35										
56							Indicate			
118										
111										
124										
59										
119							Indicate			
112				Indicate						
76										
32										
78										
4										
5	Indicate			Indicate					Indicate	
47										
152							Indicate			
151							Indicate			
170										
168							Indicate			
133									Indicate	
132	Indicate								Indicate	
136										
123										
116										

No on the questionnaire	20.What kind of light bulbs do you have in your household? [v. Halogen bulbs]	20.What kind of light bulbs do you have in your household? [Other]	21i. How many of the above selected do you have in your dwelling?	21ii. How many of those are turned on for more than an hour per day?	22.What space heating system/s do you use in your home? If applicable, how many?	22ii. If other, Please specify	22iii. If applicable, how many of the above do you have?	23.What type of cooling system do you use in your home	23i. If other, specify	23ii. If applicable, how many?	24.During winter, at what temperature do you keep your home? [Daytime]	24.During winter, at what temperature do you keep your home? [Nighttime]	25.During summer, at what temperature do you keep your home? [Daytime]	25.During summer, at what temperature do you keep your home? [Nighttime]	26.Is your home insulated?
194			2		v. Charcoal heater		1	i. Window Unit	1		Over 30 Celsius	Over 30 Celsius	under 15 Celsius	15 â€“ 20 Celsius	Yes
70								i. Window Units							No
188			1	1	v. Charcoal heater			i. Window Units			18 â€“ 22 Celsius	18 â€“ 22 Celsius	under 15 Celsius	under 15 Celsius	No
91		Indicate	camping bulb	two	vi. Other			iv. Other			18 â€“ 22 Celsius	Turned Off	Turned Off	Turned Off	Yes
187								i. Window Unit	2						No
81								i. Window Unit	2						No
205					vi. Other			i. Window Unit	4		ii.23 â€“ 26 Celsius	18 â€“ 22 Celsius	Over 26 Celsius	Over 26 Celsius	Yes
126					vi. Other			iv. Other			Turned Off	Turned Off	Turned Off	Turned Off	No
125											Turned Off	Turned Off	Turned Off	Turned Off	No
27															No
178											Turned Off	Turned Off	Turned Off	Turned Off	No
138								i. Window Unit	4						No
127											Turned Off	Turned Off	Turned Off	Turned Off	No
41					ii. Gas portable unit										No
143											Turned Off	Turned Off	Turned Off	Turned Off	No
195															No
191					ii. Gas portable unit			i. Window Units			27 â€“ 30 Celsius	18 â€“ 22 Celsius	Over 26 Celsius	15 â€“ 20 Celsius	No
193			2		v. Charcoal heater			i. Window Units			Over 30 Celsius	Over 30 Celsius	under 15 Celsius	15 â€“ 20 Celsius	Yes
100					v. Charcoal heater						18 â€“ 22 Celsius	18 â€“ 22 Celsius	under 15 Celsius	Turned Off	No
186					v. Charcoal heater						18 â€“ 22 Celsius	18 â€“ 22 Celsius	under 15 Celsius	Turned Off	No
146															
189					v. Charcoal heater			i. Window Units							
113															
175								i. Window Units							
179					ii. Gas portable unit						Turned Off	Turned Off	Turned Off	Turned Off	No
141					v. Charcoal heater			i. Window Units			Turned Off	Turned Off	Turned Off	Turned Off	No
64					ii. Gas portable unit			i. Window Units							No
181					v. Charcoal heater						Turned Off	Turned Off	Turned Off	Turned Off	No
65															No
66															No
99			2		v. Charcoal heater			i. Window Units			Over 30 Celsius	27 â€“ 30 Celsius	15 â€“ 20 Celsius	15 â€“ 20 Celsius	Yes
98					vi. Other			i. Window Units			18 â€“ 22 Celsius	18 â€“ 22 Celsius	Turned Off	Turned Off	No
46			2	4	v. Charcoal heater			iii. Evaporative Cooler(s)			27 â€“ 30 Celsius	Over 30 Celsius	21 â€“ 26 Celsius	15 â€“ 20 Celsius	No
73			7	5	iii. Heat pump			i. Window Units			ii.23 â€“ 26 Celsius	18 â€“ 22 Celsius	Over 26 Celsius	21 â€“ 26 Celsius	Yes
72			6	5	i. Electric portable unit		6	ii. Electric fan	1		18 â€“ 22 Celsius	ii.23 â€“ 26 Celsius	15 â€“ 20 Celsius	under 15 Celsius	Yes
61								i. Window Units							Yes
85			2	2	v. Charcoal heater			i. Window Units			ii.23 â€“ 26 Celsius	ii.23 â€“ 26 Celsius			
69								i. Window Units							
92								i. Window Units			18 â€“ 22 Celsius	27 â€“ 30 Celsius	Over 26 Celsius	21 â€“ 26 Celsius	Yes
93					iii. Heat pump										No
80				3	v. Charcoal heater			i. Window Units			27 â€“ 30 Celsius	18 â€“ 22 Celsius	under 15 Celsius	15 â€“ 20 Celsius	No
109											27 â€“ 30 Celsius	27 â€“ 30 Celsius	21 â€“ 26 Celsius	21 â€“ 26 Celsius	Yes
22					v. Charcoal heater						18 â€“ 22 Celsius	ii.23 â€“ 26 Celsius	under 15 Celsius	15 â€“ 20 Celsius	No
26					vi. Other	paraffin heater		i. Window Units							No
33					vi. Other	paraffin heater		i. Window Units							Yes
154								i. Window Units			18 â€“ 22 Celsius	ii.23 â€“ 26 Celsius	15 â€“ 20 Celsius	21 â€“ 26 Celsius	No
164															No
165															
101											Turned Off	Turned Off	Turned Off	Turned Off	
121															Yes
52					ii. Gas portable unit		8				Turned Off	Turned Off	Turned Off	Turned Off	No
130			3		ii. Gas portable unit			i. Window Units			Turned Off	Turned Off	Turned Off	Turned Off	No
38								i. Window Units							No
115					vi. Other	paraffin heater		i. Window Units			ii.23 â€“ 26 Celsius	18 â€“ 22 Celsius	15 â€“ 20 Celsius	15 â€“ 20 Celsius	No
110					vi. Other	paraffin heater									No
104											Turned Off	Turned Off	Turned Off	Turned Off	
51					v. Charcoal heater			i. Window Units			27 â€“ 30 Celsius	Over 30 Celsius	under 15 Celsius	15 â€“ 20 Celsius	No
3					v. Charcoal heater			i. Window Units							No
42								i. Window Units							No
43					i. Electric portable unit										No
44								i. Window Units							No
45					ii. Gas portable unit			i. Window Units			Turned Off	Turned Off	under 15 Celsius	Turned Off	No
171					vi. Other	paraffin heater					ii.23 â€“ 26 Celsius		15 â€“ 20 Celsius		
150			5	4	vi. Other	paraffin heater		i. Window Units			18 â€“ 22 Celsius	ii.23 â€“ 26 Celsius	15 â€“ 20 Celsius	under 15 Celsius	No
159								i. Window Units							No
161			5	7	vi. Other	paraffin heater		i. Window Units			18 â€“ 22 Celsius	18 â€“ 22 Celsius	15 â€“ 20 Celsius	15 â€“ 20 Celsius	No
162					vi. Other	paraffin heater		i. Window Units			18 â€“ 22 Celsius	ii.23 â€“ 26 Celsius	15 â€“ 20 Celsius	15 â€“ 20 Celsius	No
13								i. Window Units			18 â€“ 22 Celsius	ii.23 â€“ 26 Celsius	15 â€“ 20 Celsius	21 â€“ 26 Celsius	No
129															
184															
48					vi. Other	paraffin heater		i. Window Units							No
40															No
122					vi. Other	paraffin heater		i. Window Units			Turned Off	Turned Off	Turned Off	Turned Off	Yes
182					vi. Other	none		i. Window Units			18 â€“ 22 Celsius	18 â€“ 22 Celsius	under 15 Celsius	under 15 Celsius	No
62								i. Window Units							
173								i. Window Units			18 â€“ 22 Celsius	ii.23 â€“ 26 Celsius	under 15 Celsius	21 â€“ 26 Celsius	No
900								i. Window Units			18 â€“ 22 Celsius	18 â€“ 22 Celsius	under 15 Celsius	under 15 Celsius	No
103					vi. Other	paraffin heater					ii.23 â€“ 26 Celsius	18 â€“ 22 Celsius	15 â€“ 20 Celsius	15 â€“ 20 Celsius	
49					vi. Other	paraffin		i. Window Units							No
169															
176					v. Charcoal heater										No
185															
97								i. Window Units			Turned Off	Turned Off	Turned Off	Turned Off	No
114					v. Charcoal heater			i. Window Units			Over 30 Celsius	ii.23 â€“ 26 Celsius	under 15 Celsius	under 15 Celsius	No
174								i. Window Units							Yes
142													15 â€“ 20 Celsius	15 â€“ 20 Celsius	No
500													under 15 Celsius	under 15 Celsius	No
96					v. Charcoal heater			i. Window Units					21 â€“ 26 Celsius	15 â€“ 20 Celsius	No
23					v. Charcoal heater			i. Window Units			27 â€“ 30 Celsius	27 â€“ 30 Celsius	21 â€“ 26 Celsius	15 â€“ 20 Celsius	No
7								i. Window Units			18 â€“ 22 Celsius	Over 30 Celsius	15 â€“ 20 Celsius	Over 26 Celsius	Yes
67								i. Window Units			18 â€“ 22 Celsius	ii.23 â€“ 26 Celsius	15 â€“ 20 Celsius	21 â€“ 26 Celsius	No
8								i. Window Units							Yes
83															No
68															
185					v. Charcoal heater						ii.23 â€“ 26 Celsius	18 â€“ 22 Celsius	Over 26 Celsius	15 â€“ 20 Celsius	Yes
9					vi. Other	paraffin		i. Window Units							No
34					vi. Other	paraffin		i. Window Units			18 â€“ 22 Celsius	18 â€“ 22 Celsius	under 15 Celsius	under 15 Celsius	No
35					vi. Other	paraffin		i. Window Units							No
56					i. Electric portable unit										
118					vi. Other	paraffin									Yes
111								i. Window Units							No
124					vi. Other	paraffin		i. Window Units							
59					v. Charcoal heater			i. Window Units			ii.23 â€“ 26 Celsius	Over 30 Celsius			No
119					v. Charcoal heater			i. Window Units			Turned Off	Turned Off	Turned Off	Turned Off	No
112															
76					vi. Other	paraffin									No
32															
78					iii. Heat pump						18 â€“ 22 Celsius	18 â€“ 22 Celsius	Over 26 Celsius	Over 26 Celsius	No
4					vi. Other	paraffin									No
5					iii. Heat pump	paraffin		i. Window Unit	electric fan		Turned Off	18 â€“ 22 Celsius	under 15 Celsius	under 15 Celsius	No
47					vi. Other	paraffin		i. Window Units							No
152					v. Charcoal heater			i. Window Units			18 â€“ 22 Celsius	Turned Off	21 â€“ 26 Celsius	Turned Off	
151					v. Charcoal heater			i. Window Units			18 â€“ 22 Celsius	Turned Off	15 â€“ 20 Celsius	Turned Off	
170					vi. Other	paraffin									No
168								i. Window Units			Turned Off	Turned Off	Turned Off	Turned Off	No
133					v. Charcoal heater			i. Window Units			ii.23 â€“ 26 Celsius	27 â€“ 30 Celsius	15 â€“ 20 Celsius	21 â€“ 26 Celsius	No
132					v. Charcoal heater			i. Window Units			27 â€“ 30 Celsius	Over 30 Celsius	15 â€“ 20 Celsius	21 â€“ 26 Celsius	No
136															
123					vi. Other	paraffin		i. Window Units			Turned Off	Turned Off	Turned Off	Turned Off	Yes
116															No

No on the questionnaire	26i. What colour is the insulation?	27.How much thought and action do you put in to save energy in your home?	28.How frequent do you turn the heating down or off when you go out or when you sleep at night?	29.How worried are you about the likely future energy price rises?	30.How worried are you about climate change?	31.What improvement would you ideally need to make your home more energy efficient? [i. External insulation]	31.What improvement would you ideally need to make your home more energy efficient? [ii. Internal insulation]	31.What improvement would you ideally need to make your home more energy efficient? [iii. Solar photovoltaic]	31.What improvement would you ideally need to make your home more energy efficient? [iv. Replacement of the roof]	31.What improvement would you ideally need to make your home more energy efficient? [v. Replacement of the windows and doors]	31.What improvement would you ideally need to make your home more energy efficient? [vi. other]
194	white	i. A lot	i. Almost always	i. A lot	i. A lot					Indicate	
70		i. A lot	i. Almost always	i. A lot	i. A lot						Indicate
188		i. A lot	iv. Never	i. A lot	i. A lot		Indicate				
91		i. A lot	i. Almost always	i. A lot	i. A lot						Indicate
187		i. A lot	i. Almost always	i. A lot	i. A lot				Indicate		
81		i. A lot	i. Almost always	i. A lot	i. A lot	Indicate	Indicate				
205	white	iii. Not very much	i. Almost always	i. A lot	i. A lot	Indicate					
126		i. A lot	i. Almost always	i. A lot	i. A lot						Indicate
125		i. A lot	i. Almost always	i. A lot	i. A lot						Indicate
27		iv. None at all	i. Almost always	iv. None at all	i. A lot						Indicate
178		i. A lot	i. Almost always	i. A lot	i. A lot						Indicate
138		i. A lot	i. Almost always	i. A lot	i. A lot				Indicate		
127		i. A lot	i. Almost always	i. A lot	i. A lot						Indicate
41		i. A lot	ii. Very often	i. A lot	i. A lot		Indicate				
143		i. A lot	i. Almost always	i. A lot	i. A lot						Indicate
195		iv. None at all	i. Almost always	i. A lot	i. A lot	Indicate					
191		i. A lot	i. Almost always	i. A lot	i. A lot				Indicate		
193	white	i. A lot	i. Almost always	i. A lot	i. A lot					Indicate	
100		i. A lot	i. Almost always	i. A lot	i. A lot						
186		i. A lot	iv. Never	i. A lot	i. A lot						
146		i. A lot		i. A lot	i. A lot						
189		iv. None at all	iii. Not very often	i. A lot	i. A lot				Indicate		
113		i. A lot		i. A lot	i. A lot						
175		i. A lot	i. Almost always	i. A lot	i. A lot						
179		ii. A fair amount	i. Almost always	i. A lot	i. A lot	Indicate					
141		iv. None at all	i. Almost always	iv. None at all						Indicate	
64		ii. A fair amount	iv. Never	i. A lot	ii. A fair amount				Indicate	Indicate	
181		ii. A fair amount	i. Almost always	i. A lot	i. A lot	Indicate					
65		iv. None at all	iv. Never	i. A lot	i. A lot						Indicate
66		iv. None at all	iv. Never	i. A lot	i. A lot						Indicate
99	green	i. A lot	i. Almost always	i. A lot	i. A lot			Indicate			
98		i. A lot	i. Almost always	i. A lot	i. A lot	Indicate	Indicate	Indicate	Indicate	Indicate	Indicate
46		i. A lot	i. Almost always	i. A lot	i. A lot			Indicate			
73	black	i. A lot	i. Almost always	i. A lot	i. A lot		Indicate		Indicate	Indicate	
72	black	i. A lot	i. Almost always	i. A lot	i. A lot				Indicate		
61	red	iv. None at all	iv. Never	iv. None at all	iv. None at all						
85		iii. Not very much	i. Almost always	i. A lot	i. A lot				Indicate		Indicate
69		iv. None at all	i. Almost always	i. A lot	i. A lot	Indicate					
92	green	i. A lot	i. Almost always	i. A lot	i. A lot						Indicate
93		i. A lot	i. Almost always	i. A lot	i. A lot				Indicate		
80		i. A lot	i. Almost always	i. A lot	ii. A fair amount		Indicate				
109	green	iv. None at all	ii. Very often	i. A lot	i. A lot					Indicate	
22		iv. None at all	i. Almost always	iv. None at all	i. A lot		Indicate				
26		i. A lot	iv. Never	iv. None at all	i. A lot						Indicate
33	white	i. A lot	i. Almost always	i. A lot	i. A lot				Indicate		
154		i. A lot	ii. Very often	i. A lot	i. A lot						Indicate
164		i. A lot	i. Almost always	i. A lot	i. A lot						
165		i. A lot	i. Almost always	i. A lot	i. A lot	Indicate					
101		i. A lot	ii. Very often	i. A lot	i. A lot						
121		i. A lot	iii. Not very often	i. A lot	i. A lot						
52		i. A lot	i. Almost always	i. A lot	i. A lot						Indicate
130		i. A lot	i. Almost always	i. A lot	i. A lot				Indicate		
38		i. A lot		i. A lot	i. A lot				Indicate		
115		iv. None at all	ii. Very often	i. A lot	i. A lot						Indicate
110			i. Almost always	i. A lot	i. A lot	Indicate	Indicate			Indicate	
104		i. A lot	ii. Very often	i. A lot	i. A lot						
51		i. A lot	i. Almost always	ii. A fair amount	i. A lot	Indicate					
3		i. A lot	i. Almost always	iii. Not very much	i. A lot	Indicate					
42		iv. None at all	i. Almost always	i. A lot	i. A lot	Indicate					
43		i. A lot	i. Almost always	i. A lot	i. A lot				Indicate		
44		i. A lot	i. Almost always	i. A lot	i. A lot	Indicate					
45		iv. None at all	iv. Never	i. A lot	i. A lot	Indicate					
171		iii. Not very much	i. Almost always	ii. A fair amount	iii. Not very much						
150		ii. A fair amount	iii. Not very often	i. A lot	i. A lot			Indicate			
159		i. A lot	iv. Never	i. A lot	i. A lot				Indicate		
161		i. A lot	i. Almost always	i. A lot	i. A lot						Indicate
162		i. A lot	i. Almost always	i. A lot	i. A lot				Indicate		
13		i. A lot	iii. Not very often	i. A lot	i. A lot					Indicate	
129											
184		i. A lot		i. A lot	i. A lot						
48		i. A lot	iv. Never		i. A lot						Indicate
40		i. A lot	ii. Very often	i. A lot	i. A lot		Indicate				
122	green	iv. None at all	i. Almost always	i. A lot	i. A lot	Indicate					
182		i. A lot	iv. Never	i. A lot	i. A lot		Indicate				
62				i. A lot	i. A lot						
173		i. A lot	ii. Very often	i. A lot	i. A lot				Indicate		
900		iv. None at all	ii. Very often	i. A lot	ii. A fair amount						
103		i. A lot	i. Almost always	i. A lot	i. A lot	Indicate	Indicate				
49		i. A lot	iv. Never		i. A lot						Indicate
169											
176		iv. None at all		i. A lot	i. A lot						
185		i. A lot		i. A lot	i. A lot						
97		iv. None at all	iv. Never		i. A lot						
114		iv. None at all	i. Almost always	i. A lot	i. A lot					Indicate	
174	red			i. A lot	i. A lot				Indicate	Indicate	
142		iv. None at all	iv. Never	iv. None at all	iv. None at all				Indicate		
500		iv. None at all		ii. A fair amount	i. A lot						
96		ii. A fair amount	iii. Not very often	i. A lot	i. A lot						
23		ii. A fair amount	iii. Not very often	i. A lot	i. A lot		Indicate				
7	BROWN	i. A lot	i. Almost always	i. A lot	i. A lot					Indicate	
67		i. A lot									
8		i. A lot	i. Almost always	i. A lot	i. A lot						
83		iv. None at all									
68				i. A lot	i. A lot						
185	WHITE	i. A lot	i. Almost always	iv. None at all	i. A lot					Indicate	
9		i. A lot	iv. Never		i. A lot						Indicate
34		iv. None at all	iv. Never	iv. None at all	iv. None at all					Indicate	
35		i. A lot	iv. Never		i. A lot						Indicate
56											
118		i. A lot	iii. Not very often	i. A lot							
111											
124											
59											
119		i. A lot	iv. Never	iv. None at all	i. A lot						
112											
76		i. A lot	i. Almost always	i. A lot	i. A lot				Indicate		
32											
78		iv. None at all		iv. None at all	iv. None at all						
4		i. A lot	iv. Never		i. A lot						Indicate
5		iii. Not very much	iv. Never	iv. None at all	i. A lot			Indicate			
47		i. A lot	iv. Never		i. A lot						Indicate
152			ii. Very often	i. A lot	iii. Not very much		Indicate	Indicate	Indicate	Indicate	
151		iii. Not very much	ii. Very often	i. A lot	iii. Not very much		Indicate	Indicate	Indicate	Indicate	
170		i. A lot	i. Almost always	i. A lot					Indicate		
168		i. A lot		i. A lot	i. A lot				Indicate		
133		ii. A fair amount	ii. Very often	ii. A fair amount	i. A lot					Indicate	
132		ii. A fair amount	ii. Very often	iii. Not very much	i. A lot					Indicate	
136											
123		iv. None at all	i. Almost always	i. A lot	i. A lot	Indicate					
116		i. A lot	iii. Not very often	i. A lot	i. A lot						

No on the questionnaire	31ii. If other, specify	household and (ii) the authority need to do more, to increase cleaner energy access in your household?	33.What is the average monthly cost for the energy form (s) you use in your household on a monthly basis? [Paraffin]	33.What is the average monthly cost for the energy form (s) you use in your household on a monthly basis? [Coal]	33.What is the average monthly cost for the energy form (s) you use in your household on a monthly basis? [Gas]	33.What is the average monthly cost for the energy form (s) you use in your household on a monthly basis? [Agric. residue]	33.What is the average monthly cost for the energy form (s) you use in your household on a monthly basis? [Candles]	33.What is the average monthly cost for the energy form (s) you use in your household on a monthly basis? [Solar]	33.What is the average monthly cost for the energy form (s) you use in your household on a monthly basis? [Other]	33i. If other, specify
194		Renovation								
70	all of the above									
188										
91	electricity									
187										
81										
205			< R300							
126	electricity	electricity								
125	electricity									
27	electricity	electricity								
178	electricity	electricity								
138										
127	electricity									
41		electric meters								
143	electricity	electricity								
195										
191										
193		renovation								
100										
186										
146		electric meters								
189			< R300							
113			< R300							
175										
179										
141										
64										
181										
65	rdp									
66	rdp									
99		electricity								
98	electricity									
46		electricity								
73										
72										
61										
85	electricity	renovation								
69										
92	electricity									
93										
80										
109	electricity									
22			< R300							
26	electricity									
33										
154	electricity, water									
164										
165		electricity								
101										
121										
52	paraffin									
130		electricity, external insulation								
38										
115	electricity									
110										
104										
51										
3										
42										
43										
44		clean emvironment								
45		electricity								
171										
150										
159										
161	electricity									
162										
13		Electricity								
129										
184										
48	electricity									
40		electricity								
122										
182										
62										
173										
900										
103										
49	electricity									
169										
176										
185										
97										
114										
174										
142										
500										
96										
23										
7										
67										
8										
83										
68										
185										
9	electricity									
34										
35	electricity									
56										
118										
111										
124										
59										
119										
112										
76										
32										
78										
4	electricity									
5										
47	electricity									
152										
151										
170										
168										
133										
132										
136										
123										
116										

No on the questionnaire	33ii.What is the average monthly cost for the energy form (s) you use in your household on a monthly basis? [ii. R301 â€“ R999]	33ii.What is the average monthly cost for the energy form (s) you use in your household on a monthly basis? [iii. R1 000 â€“ R1 999]	monthly cost for the energy form (s) you use in your household on a monthly basis? [iv. > R1 199]	34.What percentage does the cost of your energy type take away from your household monthly income? Please indicate as many as possible. [Electricity]	34.What percentage does the cost of your energy type take away from your household monthly income? Please indicate as many as possible. [Paraffin]	34.What percentage does the cost of your energy type take away from your household monthly income? Please indicate as many as possible. [Wood]	34.What percentage does the cost of your energy type take away from your household monthly income? Please indicate as many as possible. [Coal]	34.What percentage does the cost of your energy type take away from your household monthly income? Please indicate as many as possible. [Gas]
194			Indicate					
70	Indicate							
188	Indicate							
91	Indicate							
187								
81	Indicate							
205								
126	Indicate							
125	Indicate							
27	Indicate							
178	Indicate							
138								
127	Indicate							
41	Indicate							
143	Indicate							
195								
191								
193			Indicate					
100								
186	Indicate							
146	Indicate							
189								
113								
175								
179	Indicate							
141				<5%				
64	Indicate							
181								
65	Indicate							
66	Indicate							
99			Indicate					
98								
46			Indicate					
73		Indicate						
72	Indicate							
61	Indicate							
85								
69	Indicate							
92								
93	Indicate							
80								
109	Indicate							
22								
26								
33								
154								
164		Indicate						
165	Indicate							
101								
121	Indicate							
52								
130								
38								
115	Indicate							
110	Indicate							
104								
51								
3								
42								
43								
44								
45								
171	Indicate							
150								
159								
161								
162		Indicate						
13								
129	Indicate							
184								
48								
40	Indicate							
122	Indicate							
182								
62	Indicate							
173	Indicate							
900	Indicate							
103	Indicate							
49								
169								
176								
185								
97								
114								
174								
142								
500		Indicate						
96								
23								
7								
67								
8								
83								
68								
185								
9								
34								
35								
56								
118	Indicate							
111	Indicate							
124								
59	Indicate							
119								
112								
76								
32								
78								
4								
5								
47								
152	Indicate							
151	Indicate							
170								
168								
133								
132	Indicate							
136								
123								
116	Indicate							

No on the questionnaire	34.What percentage does the cost of your energy type take away from your household monthly income? Please indicate as many as possible. [Agric. residue]	34.What percentage does the cost of your energy type take away from your household monthly income? Please indicate as many as possible. [Candles]	34.What percentage does the cost of your energy type take away from your household monthly income? Please indicate as many as possible. [Solar]	34.What percentage does the cost of your energy type take away from your household monthly income? Please indicate as many as possible. [Other]	34.What percentage does the cost of all energy type take away from your household monthly income? Please indicate as many as possible. [<5%]	34.What percentage does the cost of all energy type take away from your household monthly income? Please indicate as many as possible. [10%]	34.What percentage does the cost of all energy type take away from your household monthly income? Please indicate as many as possible. [20%]	34.What percentage does the cost of all energy type take away from your household monthly income? Please indicate as many as possible. [30%]
194					Indicate			
70						Indicate		
188							Indicate	
91								
187								
81							Indicate	
205					Indicate			
126								
125								
27								
178								
138					Indicate			
127								
41								
143								
195								
191						Indicate		
193					Indicate			
100						Indicate		
186						Indicate		
146								
189						Indicate		
113					Indicate			
175					Indicate			
179								
141					Indicate			
64								
181								
65								
66								
99								
98								
46								
73								
72								Indicate
61							Indicate	
85						Indicate		
69								Indicate
92					Indicate			
93					Indicate			
80					Indicate			
109								
22					Indicate			
26					Indicate			
33								
154								
164								
165								
101								
121								
52								
130						Indicate		
38								
115								
110						Indicate		
104								
51						Indicate		
3						Indicate		
42								Indicate
43					Indicate			
44								Indicate
45								
171								Indicate
150								Indicate
159								
161						Indicate		
162								
13								
129								
184								
48								
40								
122					Indicate			
182								
62								
173								
900					Indicate			
103								
49								
169								
176								
185								
97								
114					Indicate			
174								
142								
500								
96								
23								
7								
67								
8								
83								
68								
185								
9								
34								
35								
56					Indicate			
118								
111								
124								
59								
119								
112								
76								
32								
78								
4								
5								
47								
152								
151								
170								
168								
133								
132								
136						Indicate		
123					Indicate			
116								

No on the questionnaire	34.What percentage does the cost of all energy type take away from your household monthly income? Please indicate as many as possible. [40%]	34.What percentage does the cost of all energy type take away from your household monthly income? Please indicate as many as possible. [50%]	34i. If other, specify	35.What is the average monthly cost for electricity in your household?	36.What is the average number of study hours in your household daily? What energy is used? [Electricity]	36.What is the average number of study hours in your household daily? What energy is used? [Paraffin]	36.What is the average number of study hours in your household daily? What energy is used? [Candle]	37.How many members of the household gained education?	37ii. What level of education gained or to be gained?	38.Does your household run a family business from home?	38i. If yes, please specify the type of business
194				none			6 hours to 10 hours		iv. No education at all	No	
70							2 hours to 6 hours	2	i. High school	No	
188						< 2 hours	< 2 hours	1	ii. Degree/Diploma	No	
91	Indicate					2 hours to 6 hours		1	iii. Higher degrees	No	
187	Indicate									No	
81				R900		< 2 hours	< 2 hours		i. High school	No	
205						< 2 hours		1	i. High school	No	
126		Indicate		R1000		2 hours to 6 hours			i. High school	No	
125		Indicate				2 hours to 6 hours			i. High school	No	
27		Indicate				2 hours to 6 hours	2 hours to 6 hours		i. High school	No	
178		Indicate		-950		2 hours to 6 hours			i. High school	No	
138				-210						No	
127		Indicate		-1000		2 hours to 6 hours			i. High school	No	
41		Indicate					2 hours to 6 hours		i. High school	No	
143		Indicate	-1000						i. High school	No	
195		Indicate					< 2 hours		iv. No education at all	No	
191							< 2 hours		iv. No education at all	No	
193										No	
100						2 hours to 6 hours			i. High school	No	
186					< 2 hours		< 2 hours		i. High school	No	
146		Indicate					2 hours to 6 hours				
189							< 2 hours	2	i. High school	No	
113										No	
175						2 hours to 6 hours			i. High school	No	
179		Indicate				< 2 hours		1	i. High school	No	
141							< 2 hours		i. High school	No	
64							2 hours to 6 hours	1	i. High school	No	
181	Indicate						< 2 hours		i. High school		
65	Indicate					2 hours to 6 hours	2 hours to 6 hours	3	i. High school	No	
66	Indicate					2 hours to 6 hours	2 hours to 6 hours	3	i. High school	No	
99		Indicate				< 2 hours	< 2 hours	2	i. High school	No	
98		Indicate				> 10 hours			iv. No education at all	No	
46		Indicate				> 10 hours	> 10 hours		ii. Degree/Diploma	No	
73	Indicate					6 hours to 10 hours	6 hours to 10 hours	2	i. High school	No	
72					6 hours to 10 hours	6 hours to 10 hours	6 hours to 10 hours		iv. No education at all	Yes	food sale
61						< 2 hours		1	i. High school	No	
85							< 2 hours	5	ii. Degree/Diploma	No	
69						2 hours to 6 hours	2 hours to 6 hours	2	i. High school	No	
92							< 2 hours	2	i. High school		
93						2 hours to 6 hours	2 hours to 6 hours		i. High school	No	
80							< 2 hours		i. High school	Yes	
109		Indicate					< 2 hours		i. High school	No	
22						2 hours to 6 hours	2 hours to 6 hours		i. High school	No	
26						2 hours to 6 hours			i. High school	No	
33	Indicate								i. High school	Yes	fashion
154		Indicate					2 hours to 6 hours		i. High school	No	
164	Indicate					6 hours to 10 hours	6 hours to 10 hours		iv. No education at all	No	
165		Indicate				2 hours to 6 hours	2 hours to 6 hours	3	ii. Degree/Diploma	No	
101		Indicate				< 2 hours	< 2 hours	2	i. High school	No	
121		Indicate				2 hours to 6 hours	2 hours to 6 hours	2	i. High school	No	
52	Indicate			-350		2 hours to 6 hours		3	iii. Higher degrees		
130						< 2 hours			iv. No education at all		2
38	Indicate					2 hours to 6 hours	2 hours to 6 hours	1	ii. Degree/Diploma	No	
115	Indicate					2 hours to 6 hours			i. High school	No	
110											
104		Indicate				< 2 hours	< 2 hours	2	i. High school	No	
51						< 2 hours			iv. No education at all	Yes	
3										No	
42				-220					iv. No education at all	No	
43				-230						No	
44				-220						No	
45		Indicate				< 2 hours			iv. No education at all	No	
171						2 hours to 6 hours	2 hours to 6 hours		i. High school	No	
150										No	
159	Indicate						2 hours to 6 hours		iv. No education at all	No	
161						< 2 hours			iv. No education at all	No	
162	Indicate						< 2 hours			Yes	hair salon
13							< 2 hours		iii. Higher degrees	No	
129		Indicate							i. High school	No	
184		Indicate					2 hours to 6 hours		i. High school	No	
48						6 hours to 10 hours			i. High school	No	
40		Indicate					2 hours to 6 hours			No	
122						> 10 hours	> 10 hours		i. High school	No	
182							< 2 hours		ii. Degree/Diploma	No	
62									i. High school		
173		Indicate									
900										No	
103							2 hours to 6 hours		i. High school		
49						6 hours to 10 hours			i. High school	No	
169						< 2 hours			i. High school		
176							< 2 hours		i. High school		
185		Indicate					2 hours to 6 hours		i. High school	No	
97							2 hours to 6 hours				
114									i. High school	No	
174											
142						< 2 hours	< 2 hours		i. High school	No	
500							< 2 hours		i. High school		
96						< 2 hours	< 2 hours		i. High school	No	
23							< 2 hours		i. High school	No	
7											
67											
8									iv. No education at all	No	
83									iv. No education at all		
68						< 2 hours	< 2 hours			No	
185							2 hours to 6 hours		i. High school	No	
9						2 hours to 6 hours			i. High school	No	
34							< 2 hours		iv. No education at all	No	
35						2 hours to 6 hours			i. High school	No	
56						< 2 hours	< 2 hours		i. High school	No	
118		Indicate				2 hours to 6 hours	2 hours to 6 hours		iv. No education at all	No	
111									i. High school	No	
124						2 hours to 6 hours			i. High school	No	
59									i. High school	No	
119									iv. No education at all	No	
112										No	
76											
32											
78									i. High school	No	
4						2 hours to 6 hours			i. High school	No	
5									iv. No education at all	No	
47						2 hours to 6 hours			i. High school	No	
152						2 hours to 6 hours	2 hours to 6 hours		iv. No education at all	No	
151						2 hours to 6 hours	2 hours to 6 hours		iv. No education at all	No	
170						< 2 hours	< 2 hours		iv. No education at all	No	
168									i. High school	No	
133						< 2 hours	< 2 hours		i. High school	No	
132									i. High school	No	
136						2 hours to 6 hours			iv. No education at all	No	
123						> 10 hours	> 10 hours		i. High school	No	
116						2 hours to 6 hours	2 hours to 6 hours		i. High school		

No on the questionnaire	39.Which of these do your household have?	39i How many of the above do you have?	40.What form/s of transport do you use to get to school and work each day and why? [School]	40.What form/s of transport do you use to get to school and work each day and why? [Work]	40i. Why do you use the above?	41.How many hospital/clinic visits does your household make on a monthly basis?	42.Does the energy forms you use in your homes save you time, increase your productivity and reduce irritations (eyes, nose and throat) in your home?	All relevant questions completed?
194				By foot		i. Zero visits	i. A lot	
70			Bus/Taxi	Bus/Taxi		iii. Three to four visits	iv. None at all	
188			Train	Train		ii. One to two visits	iii. Not very much	
91	iii. Bicycle(s)	1	Bus/Taxi	Train		ii. One to two visits	iv. None at all	
187				Train	its cheap	ii. One to two visits	i. A lot	
81			Train	Train	its cheap	i. Zero visits	iv. None at all	
205			Car	Train		i. Zero visits	iii. Not very much	
126			Train	Train		i. Zero visits	i. A lot	
125			Bus/Taxi	Train		i. Zero visits	i. A lot	
27						iv. More than four visits	iv. None at all	
178			Train	Train		i. Zero visits	i. A lot	
138						iii. Three to four visits	i. A lot	
127			Train	Train		i. Zero visits	i. A lot	
41						ii. One to two visits	iv. None at all	
143				Train		i. Zero visits	i. A lot	
195			Train	Train		i. Zero visits	iv. None at all	
191	i. Car(s)		Car	Car		i. Zero visits	iii. Not very much	
193				By foot		i. Zero visits	i. A lot	
100	i. Car(s)		Car	Bus/Taxi		i. Zero visits	i. A lot	
186	iii. Bicycle(s)		Bus/Taxi	By foot		i. Zero visits	i. A lot	
146						ii. One to two visits	iv. None at all	
189						i. Zero visits	iv. None at all	
113			Train	Train		ii. One to two visits	i. A lot	
175	iii. Bicycle(s)		By foot	By foot		i. Zero visits	iv. None at all	
179			Train	Train		i. Zero visits	ii. A fair amount	
141	iii. Bicycle(s)	2	By foot	By foot		i. Zero visits	iv. None at all	
64	i. Car(s)	1	Train	Train		iii. Three to four visits	ii. A fair amount	
181			Train	Train		ii. One to two visits	iii. Not very much	
65			Train	Train	its cheap	i. Zero visits	iv. None at all	
66			Train	Train	cheap	i. Zero visits	iv. None at all	
99			By foot	Train	accessible an	iv. More than four visits	iv. None at all	
98	iii. Bicycle(s)		Cycle	By foot		i. Zero visits	iv. None at all	
46			By foot	By foot		ii. One to two visits	iv. None at all	
73			By foot	Train		ii. One to two visits	i. A lot	
72			Bus/Taxi	Train		i. Zero visits	i. A lot	
61			Bus/Taxi	Train		ii. One to two visits	i. A lot	
85	i. Car(s)	2	Car	Car		i. Zero visits	iii. Not very much	
69			Bus/Taxi	Bus/Taxi		ii. One to two visits	i. A lot	
92	iii. Bicycle(s)			Train	affordable	i. Zero visits	iii. Not very much	
93			Bus/Taxi	Bus/Taxi		i. Zero visits	i. A lot	
80				Bus/Taxi		ii. One to two visits	ii. A fair amount	
109			Bus/Taxi	Bus/Taxi		iv. More than four visits	iv. None at all	
22			By foot	Train	affordable	ii. One to two visits	iv. None at all	
26			By foot			i. Zero visits	ii. A fair amount	
33			Car	Bus/Taxi	available	i. Zero visits	i. A lot	
154			Bus/Taxi	Train		i. Zero visits	i. A lot	
164				Bus/Taxi	affordable	i. Zero visits	i. A lot	
165			Train			ii. One to two visits	iii. Not very much	
101	i. Car(s)	1	Bus/Taxi			i. Zero visits	iv. None at all	
121	iii. Bicycle(s)					ii. One to two visits	iii. Not very much	
52	iii. Bicycle(s)	1	By foot	By foot		i. Zero visits	i. A lot	
130	i. Car(s)			Train		i. Zero visits	ii. A fair amount	
38			Train		affordable	ii. One to two visits	i. A lot	
115			Train	Train		iii. Three to four visits	iv. None at all	
110			Bus/Taxi	Bus/Taxi		ii. One to two visits	i. A lot	
104	i. Car(s)		Bus/Taxi			iii. Three to four visits	iv. None at all	
51						ii. One to two visits	iii. Not very much	
3			By foot	Train		ii. One to two visits	iii. Not very much	
42	iii. Bicycle(s)					ii. One to two visits	i. A lot	
43						ii. One to two visits	i. A lot	
44						ii. One to two visits	i. A lot	
45	iii. Bicycle(s)	1		Train		ii. One to two visits	i. A lot	
171			Bus/Taxi	Bus/Taxi		i. Zero visits	iii. Not very much	
150						iii. Three to four visits	i. A lot	
159			Train	Train	cheaper	ii. One to two visits	i. A lot	
161			Train	Train		i. Zero visits	iii. Not very much	
162			Car			i. Zero visits	i. A lot	
13			Bus/Taxi	Bus/Taxi		iv. More than four visits	iv. None at all	
129			Train			iii. Three to four visits	i. A lot	
184			Bus/Taxi			iii. Three to four visits	i. A lot	
48			By foot			i. Zero visits	ii. A fair amount	
40				Bus/Taxi		ii. One to two visits	iv. None at all	
122				Bus/Taxi		iii. Three to four visits		
182	i. Car(s)	1	Car	Car		i. Zero visits	iii. Not very much	
62			Bus/Taxi	Train		i. Zero visits	iii. Not very much	
173			By foot	By foot		ii. One to two visits	i. A lot	
900				Bus/Taxi		i. Zero visits		
103				Train	cheaper	ii. One to two visits	iii. Not very much	
49			By foot			i. Zero visits	ii. A fair amount	
169	i. Car(s)		Bus/Taxi	Bus/Taxi		ii. One to two visits		
176			By foot			ii. One to two visits		
185			Bus/Taxi			iii. Three to four visits	i. A lot	
97							i. A lot	
114			Train	Train		iv. More than four visits	iii. Not very much	
174								
142	ii. Motor bike(s)		Bus/Taxi	Train		ii. One to two visits	iv. None at all	
500			By foot			ii. One to two visits	iii. Not very much	
96			By foot			iii. Three to four visits	iii. Not very much	
23			By foot			iii. Three to four visits	iii. Not very much	
7								
67								
8	iii. Bicycle(s)			Cycle		i. Zero visits	i. A lot	
83	iii. Bicycle(s)							
68				By foot		i. Zero visits	i. A lot	
185	iii. Bicycle(s)			Train	Affordable	ii. One to two visits	iv. None at all	
9			By foot			i. Zero visits	ii. A fair amount	
34			Bus/Taxi	By foot		i. Zero visits	i. A lot	
35			By foot			i. Zero visits	ii. A fair amount	
56			Train	By foot		i. Zero visits		
118						ii. One to two visits	iii. Not very much	
111				Train		ii. One to two visits	iv. None at all	
124				By foot			iii. Not very much	
59	i. Car(s)		By foot	By foot		ii. One to two visits	iv. None at all	
119						i. Zero visits	i. A lot	
112				By foot		i. Zero visits	iv. None at all	
76								
32								
78			Train		cheaper	ii. One to two visits	i. A lot	
4			By foot			i. Zero visits	ii. A fair amount	
5	iii. Bicycle(s)			By foot		i. Zero visits	i. A lot	
47			By foot			i. Zero visits	ii. A fair amount	
152								
151								
170			Bus/Taxi			i. Zero visits		
168						ii. One to two visits		
133			By foot	Train		ii. One to two visits	ii. A fair amount	
132				By foot		i. Zero visits	iii. Not very much	
136				Car		iv. More than four visits	iv. None at all	
123			Bus/Taxi	Bus/Taxi		iv. More than four visits		
116	i. Car(s)					ii. One to two visits	iii. Not very much	

Appendix 7 Ethical Letter Approval

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology
Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Reference number: EBIT/113/2017 28 March 2018

Ms PI Okoye
GSTM
University of Pretoria
Pretoria
0028

Dear Ms Okoye

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Research Ethics Committee refers.

Approval is granted for the application with reference number that appears above.

1. This means that the research project entitled "A novel systems approach to energy poverty in Sub-Saharan Africa: A South African informal settlement as case study" has been approved as submitted. It is important to note what approval implies. This is expanded on in the points that follow.
2. This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Code of Ethics for Scholarly Activities of the University of Pretoria, or the Policy and Procedures for Responsible Research of the University of Pretoria. These documents are available on the website of the EBIT Research Ethics Committee.
3. If action is taken beyond the approved application, approval is withdrawn automatically.
4. According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of the EBIT Research Ethics Office.
5. The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof JJ Hanekom
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

Appendix 8 Ethical Letter Approval – The City of Cape Town Municipality

CITY OF CAPE TOWN
ISIXEKO SASEKAPA
STAD KAAPSTAD

Date: 27 JUNE 2018
TO: EXECUTIVE DIRECTOR: ORGANISATIONAL POLICY & PLANNING
REF: OPP-RR 0009

Research Approval Request

In terms of the City of Cape Town System of Delegations (May 2018) - Part 29, No 2 Subsection 4, 5 and 6 "Research:

(4) *To consider any request for the commissioning of an organisational wide research report in the City and approve or refuse such a request*

(5) *To grant authority to external parties that wish to conduct research within the City of Cape Town and/or publish the results thereof*

(6) *To after consultation with the relevant Executive Director grant permission to employees of the City of Cape Town to conduct research, surveys etc. related to their studies, within the relevant directorate.*

The Director: Organisational Policy & Planning is hereby requested, in terms of subsection 5, to consider the request received from

Name: Perpetua Okoye
Designation: PhD student
Affiliation: Department of Engineering and Technology Management, School of Engineering, University of Pretoria
Short Title: *A Novel Systems Approach to Energy Poverty in Sub-Saharan Africa: A South African Informal Settlement as Case Study*

Taking into account the recommendations below (see Annexure for detailed review):

Recommendations

That the CCT via the Director: Organisational Policy & Planning grants permission to Perpetua Okoye in her capacity as Ph.D. student in the Department of Engineering and Technology Management, School of Engineering at the University of Pretoria (UP), to access City data subject to the following conditions:

- The Director: Energy is contacted and informed of formal research approval and to advise on data availability and access;
- Access to CCT staff for the purposes of conducting interviews is not included in this research permission;
- The researcher undertakes to abide by all ethical guidelines and conditions in the use and management of the data;
- Submission of the completed research report to the Office of the Executive Director: Corporate Services and the Research Branch: Department of Organisational Policy and Planning and the Director of Energy within 3 months of completion of the PhD; and
- Permission is sought from the ED: Corporate services to publish the study.

Approved ☑ Comment: ______

Not Approved ☐ Comment: ______

Hugh Cole – Director: Organisational Policy and Planning [signature]

Date 29/6/18

27/06/2018

29/6/18

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