Analysing the carbon market and co-benefits of carbon offset projects in South Africa:

Functioning, Implementation, Adoption and Impact

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Abstract

Under the Paris Agreement 2016 most national governments have committed to transition to a low-carbon economy to mitigate climate change. Currently reliant on coal-based energy, South Africa is Africa's major GHG emitter, and in pursuit of its commitments, has been developing policies, including a carbon tax and carbon offset regulation. Carbon offset projects have emerged, although they have been criticised as distracting from fundamental reform.

This study assessed the appropriateness of carbon offsetting as a policy tool to enable a low-carbon transition, in a developing-country context where 'co-benefits' are considered desirable to improve livelihoods of poorer households. The study applied a research approach which integrated the 'Multi-Level Perspective' framework with the 'Sustainable Livelihood Approach', to assess purposefully selected case studies of carbon offset projects. Four projects were studied, across five sites (in Cape Town, Johannesburg, Ermelo, and Tzaneen) during 2017-18. Twenty-seven market actors and 24 project actors were interviewed, and 113 households were surveyed.

Market actors themselves generally regard carbon offsetting as a flawed policy tool, primarily because the incentives to maximise profits are poorly articulated with the incentive to reduce emissions. Further, project actors are non-transparent to local communities; partly obscuring their carbon rights, and the market value of credits, current and potential. All carbon offset projects studied do provide co-benefits to households, including reduced energy use, cost-savings (about 41%), and convenience. But continued technology use is uncertain: they are abandoned as soon as they are no longer useful (82% in one site).

In conclusion, the projects studied represent tokenistic transition gestures, involving high costs, but low emission reductions and temporary co-benefits. Carbon offsetting is demonstrably an inappropriate means to promote a fundamental energy transition. Rather than diverting attention with such token activities, governments must develop more appropriate policies and tools to decarbonise the energy sector.

Declaration

I, Jana Hofmann, declare that this thesis is my own work, undertaken with the guidance of my supervisors.

This work has not been submitted in whole or in part for any other degree at the University of East Anglia or elsewhere.

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LIST OF ABBREVIATIONS, ACRONYMS AND UNITS

AFOLU	Agriculture Forestry and Other Land Use
BLCRP	Buffelsdraai Landfill Community Reforestation Project
BM	Basa Magogo
CCBS	Climate, Community & Biodiversity Standard
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
CFL	Compact Fluorescent Lamps
CIF	Climate Investment Fund
CO2-e	Carbon dioxide equivalent
COP26	Conference of the Parties (COP26)
CSR	Corporate Social Responsibility
DSM	Demand-Side Management
DEA	Department of Environmental Affairs
DME	Department of Minerals and Energy
DMRE	Department of Minerals and Energy
DNA	Designated National Authority
DoE	Department of Energy
DOE	Designated Operational Entity
EU ETS	European Union Emissions Trading Scheme
FBE	Free Basic Electricity
GCF	Green Climate Fund
GEEREF	Global Energy Efficiency and Renewable Energy Fund
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GoSA	The Government of South Africa
GS	Gold Standard
HFC	Hydrofluorocarbon
IETA	International Emissions Trading Association
JI	Joint Implementation
ktCO2e	Kilo tonne of carbon dioxide equivalent
KWh	Kilowatt hour
KZN	Kwazulu-Natal
LPG	Liquified Petroleum Gas
LULUCF	Land Use, Land-Use Change and Forestry
MCA	Multi Criteria Assessment
MLP	Multi-Level Perspective
MtCO2e	Million tonne of carbon dioxide equivalent
NDC	Nationally Determined Contribution
NFSD	National Framework for Sustainable Development

NSSD	National Strategy for Sustainable Development
N2O	Nitrous Oxide
NDF	Nordic Development Fund
NGO	Non-governmental organisations
OTC	Over-the Counter
R&D	Research and Development
PDD	Project Design Document
PoA	Programme of Activity
REIPPP	Renewable Energy Independent Power Producer Procurement programme
SDGs	Sustainable Development Goals
SLA	Sustainable Livelihood Approach
SWH	Solar Water Heater
TB	Tuberculosis
TIS	Technological Innovation Systems
TM	Transition Management
UNFCCC	United Nations Framework Convention on Climate Change
VCM	Voluntary carbon market
VCS	Verified Carbon Standard
VCUs	Verified Carbon Units
VERs	Voluntary Emission Reductions (VERs)
WB	Wonderbag

Chapter 1: Transition to low-carbon economy

South Africa ratified the Paris Agreement in 2016 and committed to reduce its Greenhouse Gas (GHG) emissions. South Africa is one of the major emitters of CO_2 emissions (474MtCO_2-e in 2019; Enerdata, 2020) in the world, due primarily to its coal-based energy production. The electricity sector accounts for half of its emissions as 88% of electricity is generated by coal (Marquard and McCall, 2020). The South African government has been developing several policies, including a carbon tax and carbon offset regulation to fulfil its commitments under the Paris Agreement 2016.

It is argued that carbon offset interventions can help facilitate a low-carbon transition as carbon-intensive technologies are gradually replaced with new low-carbon energy innovations (Andonova et al., 2018; Sato et al., 2019). However, in practice there are numerous problems with this policy. Since carbon offsets, in essence, provide a licence to pollute, the environmental integrity remains questionable (Smith, 2022).

Co-benefits, e.g., poverty alleviation, improved health and others, are promoted rhetorically as justification for offsetting, yet their provision remains limited (Dalsgaard, 2022). As a result, this chapter outlines the research that unveils the key problems around carbon offsetting and highlights the importance of carrying out this research. Drawing insights from the South African case study can help guide and inform other countries as they embark on their net zero transition.

The chapter is organised as follows. It summarises the context in which this research takes place. It states the key problems that require attention, and the relevant questions that will be answered in subsequent chapters. Lastly, it explains the theoretical foundation of the study and outlines the structure of the thesis.

1.1 Research context

1.1.1. Global climate change crisis and mitigation solutions

The effects of global warming are now felt around the world. Human-induced activities have already led to 1.0°C of global warming above pre-industrial levels – a figure which is likely to reach 1.5°C between 2030 and 2052 if greenhouse gas emissions continue to increase at the current rate (IPCC, 2021). It is predicted that increases in global temperature will intensify unprecedented climate events, such as extreme heat waves, heavy rainfalls, intense drought, wildfires, and coastal flooding due to the irreversible loss of ice sheets that will cause sea levels to rise (IPCC, 2021). Growing concerns have triggered international and national climate change policy debates and the search for mitigation and adaptation solutions.

Global warming induced by human activities has already been observed for more than 80 years. Economists classify it as an externality problem caused by market failure (Stern, 2007) or, more bluntly, as 'a measure of our ignorance' (Solow, 1957). Since the costs of GHG emissions and pollution are not priced into the costs of goods and services, companies and consumers have little or no incentive to reduce GHG emissions and protect the public good (Jaffe et al., 2005; Baranzini et al., 2015).

To 'internalise' the costs of a negative externality (GHG emissions), economists agree that carbon pricing is needed to penalise those who pollute (Stiglitz et al., 2017; Stavins, 2011). This involves formalising regulations (Pigou, 1932) or creating market-based solutions (Coase, 1960) to help bring private costs of emitting GHG emissions into line with the social costs of global warming (Ekins and Barker, 2001).

There are several prominent market-based solutions that draw upon the Coase theorem, such as European Union's Emissions Trading Scheme (EU ETS), the Clean Development Mechanism (CDM) and Joint Implementation (JI) (Hepburn, 2007). The general understanding is that companies can either sell their surplus permits (carbon rights) to other firms or offset excess emissions in other parts of their facilities (Stavins, 2003). The focus of this study will be on the CDM. It is designed to allow industrialised (Annex I) countries to reduce their GHG emissions in a cost-effective way by purchasing carbon credits from carbon offset projects that avoid GHG emissions in developing (Non-Annex I) countries (UNFCCC, n.d., b). Carbon offsets are typically quantified in carbon credits. One tonne of carbon credits is equivalent to a reduction of one tonne of carbon dioxide or its equivalent in other greenhouse gases (CO2-e) from the atmosphere.

Carbon offset projects may include, for example, fossil fuel switch, energy efficiency, renewable energy and others that achieve emission reductions. Carbon offsetting is understood to be underpinned by the scientific consensus that GHGs are mixed throughout the global atmosphere and emissions can be reduced anywhere in the world in a cost-effective way (Stern, 2007; Bumpus and Liverman, 2008).

However, CDM project-based offsets have earned a poor reputation for both efficiency and effectiveness, leading many researchers and practitioners to question the legitimacy of the CDM as a mitigation policy tool (Blum and Lövbrand, 2019; Watt, 2021). Furthermore, the collapse in global carbon prices in 2012 created insufficient incentives for firms to invest in these projects (Newell, 2012) and limited the development of new CDM projects (Michaelowa et al., 2019b).

As the Paris Agreement came into force in 2016, the appetite for carbon offsetting has gained momentum. Ambitions to reach net zero carbon emissions opened a new avenue for companies to compensate for their emissions through purchasing carbon credits to reach their emission reduction targets (George, 2020; Naik and Whieldon, 2021; Edwards, 2021). Carbon offsets have become integrated as part of many companies' carbon management strategies, typically used to offset emissions that could not easily or quickly be avoided (Tucker, 2019).

1.1.2. Mitigation process in South Africa

South Africa is the world's 14th largest emitter of green greenhouse gases (World Bank, 2020). Energy intensity of South Africa in 2019 (3,759 kWh/per capita) was above the world's average of 3,316 kWh/capita (Our World in Data, 2019). The country is the largest polluter on the African continent, accounting for 8.7 tCO_2e/person, compared to Africa's average of 1.1 tCO_2e/person (Statista, 2021).

South Africa produces coal-to-liquid fuels and relies mainly on domestic coal deposits to generate electricity (DoE, 2015; Strambo et al., 2019). The state-owned power utility Eskom, together with Sasol, a chemical company, account for more than 50% of the country's GHG emissions (Strambo et al., 2019). South Africa faces both a mitigation challenge as well as numerous development challenges, such as extreme poverty and inequality, low education levels and high unemployment.

The impacts of climate change in the country, such as droughts, ecological destruction, loss of livestock and decreased agricultural output, have rapidly escalated – jeopardising food security, health, life and livelihoods of many South Africans (Masipa, 2017). Furthermore, the effects of accelerating climate change are felt more sharply due to the country's deficits in structural development. Since the South African economy was caught in a period known as 'state-capture'[1] over the past 10 years, policy implementation remained a challenging task due to political uncertainty and turmoil (Averchenkova et al., 2019).

The South African government has been actively participating in addressing climate change internationally. Under the Paris Agreement, the government pledged to reduce its emissions in the range between 398 to 510 $MtCO_2$-e over the period between 2021 and 2025, with an aspiration to become a net zero economy by 2050 (Republic of South Africa, 2021). Since more than 80% of South Africa's energy is generated from coal, the government committed to reduce it to 45% by 2030 and diversify the energy-mix with zero emission energy sources, such as wind, solar, hydro and nuclear (DMRE, 2019). To balance the phasing out of coal with the socioeconomic development in the country, the government has emphasised the need for an inclusive and 'just transition' to support all workers and communities that depend on coal (DFFE, 2021; Burton et

[1] According to Transparency International (2014), state capture is defined as "a situation where powerful individuals, institutions, companies or groups within or outside a country use corruption to shape a nation's policies, legal environment and economy to benefit their own private interests".

al., 2018). Despite these grand ambitions, in reality the country's transition to a low-carbon economy has been very slow. The government still does not have a plan nor a policy in place to phase out coal power plants (Marquard and McCall, 2020). On the contrary, it continues commissioning new coal power plants for construction (DMRE, 2019).

Furthermore, energy supplies even under the current high emission system are intermittent. Residents and businesses still suffer from 'load shedding' – described as the rotational national power shutdowns scheduled in two-to-four hour slots, potentially up to multiple times a day (Rakotonirainy et al., 2019). The cause of these rolling blackouts stems from insufficient generation capacity as a result of technical failure of old, inefficient generators, inadequate maintenance of the coal-fired capacity and poor forward planning (Winkler, 2021; Gorjão and Maritz, 2023). The accelerated rollout of renewable energy to the national grid has been limited and riddled with delays. This appears partly motivated as a political-economic measure to protect the incumbent coal and nuclear sectors, including Eskom's monopoly in the electricity sector (Winkler, 2021).

To reduce GHG emissions and fulfil its commitments under the Paris Agreement, the South African government introduced a carbon tax together with carbon offset regulation in 2019 (National Treasury, 2018a). The carbon tax is set at a rate of R120/tonCO_2-e (€6) and perceived by the South African government to be an important step towards a transition to a low-carbon economy (National Treasury, 2013).

However, some scholars argue that the carbon tax rate is simply too low to transform the economy (Winkler and Marquard, 2019; Baker, 2022) According to Alton et al., (2014), a carbon tax of at least US$30 or €25 per ton of CO_2e would be needed to meet South Africa's emissions target. Some local environmental groups in South Africa consider a carbon tax as a money-spinning initiative to generate income that will simply fill up government coffers (Isa, 2019).

Among many other policies, carbon offset regulation is believed to facilitate investments into rural development, create employment and unlock mitigation potential in various sectors, such as the agriculture, forestry and other land use (AFOLU) sector (National Treasury, 2014). Despite the fact that international and national experiences with carbon offset projects are disputed (Bond et al., 2012; Wang and Corson, 2015), the government still considers carbon offsetting as a suitable solution to help mitigate GHG emissions (National Treasury, 2014).

1.2 Rationale for research

Carbon offsets have been extensively criticised by several scholars for being a 'false solution' that provides an avenue for polluters to buy their way out of their obligations to reduce GHG emissions at source (Gilbertson, 2017; Bäckstrand and Lövbrand, 2019). Scaling up of carbon offset projects is contested by civil society and academia, due to fraud, corruption and over-estimation of emission reductions (Lohmann, 2009; Newell and Paterson, 2010, p. 134; Dobson, 2015). However, carbon still remains an international fungible commodity. Offsetting is believed by others to facilitate the development of clean technologies and innovative ideas (Lovell and Liverman, 2010; Blum, 2020) to foster pro-poor growth and environmental conservation (Benessaiah, 2012; Loh, 2018).

Although local actors' perspectives on the CDM market in South Africa are known, scientific studies are out of date. Scholars argue that further research is needed to deepen the knowledge and understanding of local markets, including the behaviours of local actors, their discourses and any imbalances they create in the carbon market[2] (Bumpus, 2011; Ullström, 2017). This gap is addressed in Chapter 8.

Research reveals that project developers in South Africa experienced various challenges in project implementation of carbon offset projects, such as high upfront costs, no governmental support, insufficient funding etc. (Koster, 2018; Schomer and van Asselt, 2012). Studies mainly focused on one best practice case, the Kuyasa CDM project. As a result, more research is needed into other projects (specifically SWH projects) to learn more from the experiences of others (Schomer and van Asselt, 2012; Koster, 2018).

Several studies showed that carbon finance can help with the uptake of low-carbon technologies, such as improved cook stoves, in countries like Uganda and Kenya. However, these projects also remained vulnerable to subsidy withdrawals, insufficient governmental support and fluctuations in the global carbon price (Lambe et al., 2015; Lietaer et al., 2019; Berrueta et al., 2017). Scholars admit that further research is needed to learn from other African countries on how nascent technologies can be implemented using carbon finance. Future research could focus on project developers' intentions, their business models and use of carbon revenue (Lambe et al., 2015). To close this knowledge gap, these topics are explored in the empirical Chapter 9.

Empirical research revealed that technology adoption is complex and may be inconsistent among users. Current research focuses on various factors, such as seasonality, household and demographic characteristics, location, technology design and project implementation approaches, that influence users' ability to adopt low-carbon technologies (Wlokas, 2011; Mukwada et al., 2014; Kapfudzaruwa et al., 2017; Pailman et al., 2018). However, studies paid less attention to

[2] Carbon market and carbon offset market are used interchangeably in this thesis.

social practices, such as daily routines, habits and culture that are essential to consider when studying this topic (Stove, 2004).

Scholars agree that evidence from field studies cannot be easily transferred or used in other contexts. As a result, further case studies are needed to provide a deeper understanding of technology adoption (Debbi et al., 2014). Current studies do not explore users' consistent technology use, which is essential for this study. It determines the amount of GHG emissions reduced by carbon offset projects and impacts the transition to a low-carbon economy. Taking these comments into account, Chapter 10 will address these gaps.

The research literature reports mixed experiences of local communities with carbon offset projects in South Africa. The provision of co-benefits by carbon offset projects is context-specific and remains an unresolved issue. Scholars claim that there are not enough field studies available that capture experiences of local communities with carbon offset projects, hence a wider assessment of multiple case studies is needed to compare carbon offset projects in relation to livelihood outcomes (Diga et al., 2016; Johnson, 2018). My research will therefore fill this gap in the empirical Chapter 11.

1.3 Research Questions

The overarching research question of this study is as follows:

Do carbon offset projects contribute to livelihoods within communities in South Africa, and if so, how?

To help answer this, the following sub-questions have been developed:

1. How does the carbon offset market function in South Africa?
2. How are carbon offset projects implemented in South Africa?
3. How are low-carbon technologies adopted within households in South Africa?
4. How do livelihoods of households change as a result of carbon offset project interventions in South Africa?

Carbon offsetting has become one of the important policy tools to facilitate a transition to a low-carbon economy in South Africa. As a result, this research seeks to understand how the carbon market functions in South Africa. It aims to analyse actors' perceptions and apparent discourse networks in the market, including actors' perceptions on co-benefits provided by carbon offset projects in the country.

To analyse how carbon offset projects are implemented, the study aims to capture the realities of project implementation and any issues project actors experienced during this process. To find out how technologies are adopted within households, this research examines project developers' and users' perceptions on technology adoption. It aims to investigate consistent technology use and how low-carbon technologies are integrated within households, including various barriers that may limit the adoption in the long-term.

To understand how livelihoods of households change as a result of carbon offset project intervention, the study analyses households' daily lives (demographics and socio-economic characteristics, and energy use). The study aims to explore users' experiences with technologies in urban and rural areas across four carbon offset projects.

1.4 Conceptual foundation for the study

This thesis frames carbon offsetting as an approach to achieve an intervention which replaces carbon intensive technology with low-carbon energy innovations in order to reduce the negative externality (of GHG emissions) and facilitate an incremental socio-technical transition. A socio-technical transition is characterised as a dynamic interplay between three different levels: 'niche' (micro), 'regime' (meso), and 'landscape' (macro) (Geels, 2002).

Based on the Multi-Level Perspective (MLP), the study conceptualises the carbon offset market as a 'niche' element of a bigger energy system. The ostensible function of the carbon offset market is to introduce low-carbon technologies that facilitate sustainable pathways of energy consumption (Hyams and Fawcett, 2013; Kollmuss et al., 2010) and help decarbonise the fossil fuel energy regime. However, the carbon market is also characterised as complex 'sub-regime', which includes several rules and structures to channel investments into nascent technologies at a lower cost (Fearnehough et al., 2020).

Carbon offset projects are understood as 'technological niches' that collectively create change within the residential sector to facilitate an incremental socio-technical transition. They include innovative low-carbon technologies that are designed, tested and rolled out to individuals or a group of people in project areas. Actors within technological niches are responsible for monitoring technology use, estimating and verifying GHG emissions that are then issued as carbon offset credits and traded in the carbon offset market.

To examine the effects of low-carbon technologies at the household level, I combine the Multi-Level Perspective with the Sustainable Livelihood Approach (SLA). The integrated MLP-SLA framework is central to this study. It provides a comprehensive understanding of the socio-technical transition by considering: (a) market actors' perspectives of the carbon market 'sub-regime', (b) project implementation processes within 'technological niches', (c) technology use and integration of low-carbon technologies within households and (d) the impact these technologies have on households' daily lives. In my model, I argue that as soon as low-carbon technologies are successfully adopted, they reduce energy demand and GHG emissions within the residential sector. This puts less pressure on the energy regime and an incremental socio-technical transition is facilitated. A detailed explanation of the integrated MLP-SLA model is provided in Chapter 4.

1.5 Structure of the thesis

This thesis consists of thirteen chapters. Chapters are summarised as follows:

Chapter 2 reviews economic theories and concepts that underpin this research. The chapter briefly explains GHG emissions as an externality problem and possible solutions to resolve it. I then provide an understanding of carbon offsetting, technological innovations and technology adoption. I examine factors that may influence and/or obstruct users to adopt technologies in the long run. To understand technological change, I introduce the concept of technological innovation systems and socio-technical transitions. Lastly, I examine three approaches of socio-technical transitions and critically discuss them.

Chapter 3 reviews actors' experiences in the South African carbon market. I use case studies to examine the uptake of carbon offset projects in South Africa and beyond (Kenya, Uganda and Mexico). I examine current knowledge on technology adoption and impacts carbon offset projects created on households' livelihoods in South Africa. The chapter identifies the gaps and provides guidance for the study.

Chapter 4 presents and critically discusses the theoretical framework of this study. The framework deployed is the integrated Multi-Level Perspective–Sustainable Livelihood Approach. The framework presents a nested sub-regime that helps analyse a socio-technical transition from 'multi-actor', 'multi-factor' and 'multi-level' perspectives. It provides a dynamic approach to answer the research question.

Chapter 5 describes the methodological approach used to conduct the study. It justifies the qualitative nature of this study and the multiple case study approach used to answer the research question. It outlines the research design, including the methods used to collect and analyse the data.

Chapter 6 presents the methodology of four case studies selected for this research. The chapter introduces each project, provides geographical context and describes living conditions of households in the project areas.

Chapter 7 provides background in relation to South Africa's energy regime. I examine the vulnerability of South African citizens to climate change and review the South African government's international and national policies in response to climate change impacts. The chapter then explains how the CDM is governed and compares different carbon standards. I then provide analytical insight into the historical development of carbon offset projects in South Africa, considering their geographical location, project types and emission reductions.

Chapter 8 is the first of four empirical chapters, which focuses on market actors' perceptions using discourse network analysis. I analyse actors' storylines in relation to the functioning of the carbon offset market and the provision of co-benefits of carbon offset projects in South Africa.

Chapter 9 is the second of four empirical chapters. It provides findings on project implementation processes of four carbon offset projects. I analyse factors that influence the project implementation processes in South Africa and present barriers that threatened the existence of some carbon offset projects or even led, in some cases, to their collapse.

Chapter 10 is the third of four empirical chapters. I analyse the adoption of low-carbon technologies among users in urban and rural areas of South Africa. I identify and present several issues, such as seasonal changes, maintenance requirements, technical issues and habits that influenced the integration of low-carbon technologies within low-income households.

Chapter 11 is the fourth empirical chapter. Here, I examine changes created by low-carbon technologies on livelihoods within households in urban and rural areas of South Africa. I introduce the demographic and socio-economic characteristics of households that participated in the study and analyse users' experiences with low-carbon technologies.

Chapter 12 discusses the findings of this research obtained from the empirical chapters (Chapter 8-11). I make a theoretical contribution around innovation theory. I reflect on lessons learned related to the functioning of the carbon market, project implementation processes, adoption and changes in livelihoods. I conclude that low-carbon technologies studied in this research are not suitable to decarbonise the residential sector and facilitate an incremental socio-technical transition in South Africa.

Chapter 13 concludes the study by presenting the key findings and contributions of this study. It reviews research questions, highlights limitations and provides recommendations for further research.

Chapter 2: Innovation theory and carbon offsetting

This chapter elaborates on concepts that will be used in this research. Firstly, it examines the theoretical basis and explain the logic behind carbon pricing. The chapter briefly explains the concept of carbon offsetting. It then presents the conceptual understanding of technological innovations. It reviews the literature on technology adoption to analyse how low-carbon technologies can be adopted by end-users. Lastly, the chapter reviews the literature on innovation systems and introduces the concept of socio-technical transitions. The chapter reviews the main characteristics of socio-technical transitions and critically discusses their limitations.

2.1 GHG emissions as an externality

Human-induced climate change resulting from Greenhouse Gas (GHG) emissions related to economic activities from energy, industry, transport and land use is considered by economists as a negative externality problem (Bowen, 2011; Stern et al., 2022). Since companies and consumers do not have to pay for the environmental damage they cause, they have little or no incentive to reduce emissions (Jaffe et al., 2000; Baranzini et al., 2015). As a result, neither the social costs of pollution, nor the cost of abatement, are priced into the costs of goods and services – leading to 'market failure' (Hepburn, 2010; Stern, 2022).

To correct the market failure, economists agree that emission externalities need to be internalised either through regulations (Pigou, 1932) or market mechanisms (Coase, 1960). While Pigou (1932) proposes a tax on polluters (the emitters of GHGs emissions), the Coase theorem states that government intervention is not necessary and the externality can be reduced using market forces (Coase, 1960). In this theorem, legal 'property' rights[3] are assigned to parties that pollute and/or victims that suffer from pollution. The creation of these rights enables the market to endogenously develop a price (Fang, 2018). Parties then negotiate incentives (e.g., compensation) and/or exchange these rights in order to mitigate the negative effects of pollution (Tacconi, 2012).

There are several prominent policy instruments based on Coase's solution in relation to climate change mitigation. These include three carbon trading mechanisms established under the Kyoto Protocol: the European Union's Emissions Trading Scheme (EU ETS), the Clean Development

[3] Property rights are defined as 'the ability to exclude others from one's asset property and to use benefit from and dispose of assets in cooperation with others' (Forsyth, 2005, p.567). They can be tangible assets (e.g. real estate) or intangible (e.g. ideas).

Mechanism (CDM), and Joint Implementation (JI) (Hepburn, 2010). This thesis focuses on the CDM and a detailed description of this mechanism is provided in Chapter 7.

These carbon trading mechanisms create a market environment, in which the price per ton on carbon emissions (or carbon equivalents for methane and other GHGs) is determined. They allocate allowances for emissions under legally binding agreements. To meet the allowable emission target, polluters can either reduce emissions at source or buy 'emission rights' from someone else (Bebbington and Larrinaga-González, 2008). The rationale behind using a market mechanism, is to achieve emission reduction at lower cost and seek a gradual shift towards lower-carbon emitting technologies (Bebbington and Larrinaga-González, 2008; Stiglitz and Stern, 2017). Scholars believe that this abatement option can equalise marginal abatement costs[4] across the sources and sectors to which the carbon price applies (Stiglitz and Stern, 2017).

2.2 Understanding carbon offsetting

Within carbon pricing, carbon offsetting is a policy instrument that is used as a low-cost abatement option in the short and medium term to reduce GHG emissions (Chomitz, 2000). It is oriented towards green technologies and technological innovations that are understood to enable gradual change (altering the pattern of consumption and industrial production) and deal with environmental issues (Gillenwater et al., 2007; Harris, 2007; Bowen, 2011; Sato et al., 2019).

The emitters can either reduce their emissions within their own facilities at source or fund emission reductions elsewhere within their own country or abroad to compensate for their own excess emissions. The term 'offsetting' is used to balance out some or all of an emitter's emissions so as not to exceed certain voluntary or legally imposed emission limits (Hyams and Fawcett, 2013).

Carbon offsetting is based on the principle that greenhouse gasses are mixed throughout the global atmosphere and hence emissions can be reduced anywhere in the world in a cost-effective way (Stern, 2007; Bumpus & Liverman, 2008). Carbon offsets are typically quantified in carbon credits. One tonne of carbon credits is equivalent to a reduction of one tonne of carbon dioxide or its equivalent in other greenhouse gases (CO2-e) from the atmosphere. Carbon offset activities are facilitated under both mandatory (compliance) schemes and voluntary programs that are elaborated further in Chapter 7.

[4] The marginal abatement cost is defined as the cost of one additional unit or ton of pollution that is abated, or not emitted (Stiglitz and Stern, 2017).

2.3 Understanding technological innovations

A technology is defined in this study as either a physical artifact, e.g., product or equipment, or non-physical component, e.g., knowledge or a method ('know-how') (Kumar et al., 1999). Innovation is viewed by many authors as a path dependent process which is influenced by interacting actors, technologies and systems (Foxton and Pearson, 2008; Grubb et al., 2021; Hekkert et al., 2007; Gallagher et al., 2012), where old structures and technologies are destroyed and replaced in favour of new ones (termed 'creative destruction' – Schumpeter, 1942).

Schumpeter (1942) observes that innovation can follow either a radical or a gradual incremental process. Radical innovation is seen as key to economic development, where disruptive fundamental changes in technologies, structures and practices occur regularly (Dewar and Dutton, 1986). Examples of radical innovations within the environmental space include renewable electricity derived from wind, solar, hydro and biomass, smart meters, heat pumps and biomass stoves (Geels, 2019).

In contrast, incremental innovations create minor improvements and make simple adjustments to existing technologies (Dewar and Dutton, 1986). Examples include 'clean coal' power plants, car-sharing, urban congestion charges (Geels, 2019) or loft insulation (Sovacool et al., 2019). However, incremental innovations like car-sharing may also support the development of radical innovations e.g., digital app-based technologies (Uber, Zipcar) within the broader socio-technical system (Sarasini et al., 2017).

Going beyond Schumpeter's dichotomy, scholars also argue that innovative activities are spurred by 'technology-push' and 'demand-pull' forces (Constantini et al., 2015; Grubb et al., 2021) that determine the rate and direction of innovation (Nemet, 2009). The 'technology-push' factors are supply-side driven and are mostly a linear, iterative process of innovation derived from Research and Development (R&D)[5] activities (Constantini et al., 2015).

In contrast, 'demand-pull' factors are determined by market conditions, users and their expectations. These factors create opportunities for firms to invest in innovations and incentivise research in new directions to satisfy unmet needs (Nemet, 2009; Constantini et al., 2015; Grubb et al., 2021). In the context of energy efficiency technological innovations, it is observed that they are not only influenced by 'technology-push' and 'demand-pull' factors, but are also vulnerable to

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[5]Research and Development (R&D) is defined as 'a systematic investigation or experimentation involving innovation or technical risk, the outcome of which is new knowledge, with or without a specific practical application of new or improved products, processes, materials, devices or services (Rogers, 1998, p.3)

energy prices, policies and carbon prices. They often have to compete with fossil fuel technologies on the basis of energy costs rather than on the basis of offering new or better functionality (Grubb et al., 2021).

'Energy efficiency' technology is defined as technology, which reduces the quantity of the primary or conventional energy sources required to achieve the maximum output of energy services possible, such as heating, lighting, cooling or mobility (Lopes et al., 2012). Such technologies are understood as incremental innovations that require changes in user practices (Sovacool et al., 2019). The authors point out that these technologies have immense opportunity, especially for lower income households, to deliver positive co-benefits, e.g., reduce household energy bills and improve air pollution.

However, Jeffe et al., (2022) highlight that these innovations still suffer from high R&D investments which impacts competitiveness and overall project viability. They are perceived to be highly uncertain and have limited knowledge spill-over. Specific regulatory support and policies (subsidies) are required to create favourable conditions for such innovations to increase their market competitiveness (Kemp, 1997; Constantini et al., 2015).

2.4 Understanding technology adoption

Shove and Walker (2010) note that technological innovations do not proliferate unless they are adopted. However, technology adoption is a complex process and influenced by several factors. Rogers' innovation diffusion theory understands technology adoption as a five-stage decision-making process involving (1) users' knowledge about the innovation (2) persuasion, e.g., users' attitudes towards an innovation, (3) decision to accept or reject the innovation, (4) implementation, e.g., putting the innovation into use and (5) confirmation if the innovation is fully adopted (Rogers, 2003). Rogers believes that it takes time for individuals to move through the adoption process stated above.

Depending on the amount of time it takes for an individual to adopt a technology, Rogers (2003) categorises individuals into different groups, e.g., innovators, early adopters, early majority and late majority (also called mainstream adopters) and laggards (late adopters). The scholar believes that the adoption process follows an S-shape or a normal bell-shaped curve, which includes a slow take-off, followed by a strong increase (a so-called 'tipping point') and then a slow down once a certain level of market saturation has been reached.

However, Lopes et al., (2012) argue that Rogers' innovation diffusion theory remains limited in its assumptions and does not consider 'domestication' of innovations. It assumes that technologies are simply adopted through awareness and perceptions. Ruiz-Mercado et al., (2011), who analysed the adoption of improved cook stoves, add that adoption is not a static nor linear process which ends upon the initial acceptance of the technology or its mere first use. It involves consistent long-term use which ultimately leads to the users' decision to adopt.

This research makes a conceptual distinction between 'acceptance' and 'adoption' of an innovation. 'Acceptance' of technology is defined as users' interest or willingness to use a technology (Reneau et al., 2013). It deals with users' attitudes and perceptions before use and does not consider the process towards full adoption. Acceptance is understood as a more of a passive action, in which individuals and communities receive technologies without contestation. They may tolerate, but not actually support or use them (Batel et al., 2013).

In contrast, 'adoption' of a technology is understood as a multi-phase process (selecting, obtaining and committing to a technology which achieves continuous use and involves domestication and integration of a technology into household daily practice (Reneau et al., 2013). In other words, technology adoption involves the 'conversion' of users in which a technology becomes part of their identity. In this way, users signal to the outside world their participation in innovation and adopt the technology in the long run (Silverstone and Haddon, 1998; Ling, 2001).

Furthermore, Tidd (2010) argues that adoption of an innovation depends on the interaction of supply-, and demand-side factors. The supply-side factors include five attributes of the technology itself (relative advantage, compatibility, complexity, trialability and observability), market conditions (costs, energy prices), policy interventions and feedback between developers and users (Rogers, 2003; Tidd, 2010; Tidd and Bessant, 2020). In contrast, demand-side factors deal with users' characteristics (age, education, income), values, perceptions of benefits and risks, and interactions among potential adopters (Tidd, 2010; Southerton, 2006). The empirical evidence of this in the South African context is presented in Chapter 3.

For users to adopt a new technology, it must offer a relative advantage (economic or social) and be better than the one it is replacing (Rogers, 2003). The easier and simpler an innovation is for potential users to understand or use, the faster the adoption will be (Rogers, 2003). Users who need to learn a new skill or knowledge, will typically slow down the adoption process (Tidd, 2010; Driessen and Hillebrand, 2002). It is understood that the more compatible an innovation is with existing values, past experience, and needs of potential adopters, the higher the adoption rate will be. If new technologies can be tried by users before buying, it is believed that they will generally be adopted more quickly in comparison to innovations that cannot offer such an option. Lastly, the scholar argues that the easier it is for potential users to see the benefits of a technology, the more likely they will adopt it (Rogers, 2003). Bandura (1986) adds that visibility of technology benefits can be stimulated by social interactions and networks, e.g., peer discussions with friends and neighbours. In contrast, Banerjee (1992) notes that herd behaviour, which is understood as ‘everyone is doing what everyone else is doing’ will either accelerate the rate of adoption of innovations or resist change due to peer pressure even if it runs counter to economic rationality (Reddy and Painuly, 2004).

In relation to this thesis, Nkosi and Daniels (2007) argue that social capital (social relations and support) is of high priority within South African urban and rural communities mainly due to unstable economic conditions faced by community members (poverty, unemployment, lack of income). As a result, social interactions are important to consider in this study as they may influence technology adoption.

Furthermore, it is believed that technology adoption is influenced by choices people make (Shove, 2010). These choices may be influenced by common motivators, such as ‘a feel-good factor’, social norms, individual benefits (e.g., health, financial outlay), ease or the feeling of ‘being part of something’. However, technology adoption may also be constrained by peoples’ domestic practices that are invisible and tied up to routines and habits, appliance specific requirements and household infrastructure (Shove, 2003). Changing behaviour often requires breaking old habits and creating new ones (Stern, 2000). However, this may not be possible due to the issue of so-called ‘inertia’ (Marechal and Lazaric, 2010; Thollander et al., 2010; Andrews and Johnson, 2016).

It is observed that people have their own habits and routines and do not tend to welcome changes in their environment (Andrews and Johnson, 2016). Individuals may therefore passively or actively resist change (Ram and Sheth, 1989). Individuals may also be disinclined to adopt an innovation for cultural reasons. General risk-aversion may play a factor and prompt overly-cautious/irrational concerns that an innovation is too risky and thus postpone the decision on adoption. Consumers that are convinced that the innovation is not suitable, may actively resist it through protests or voicing their opinions (Ram and Sheth, 1989).

Since people’s habits are deeply ingrained, scholars argue that people may be ‘locked-in’ into their daily unsustainable energy consumption behaviour patterns which may be difficult to shift (Marechal and Lazaric, 2010; Shove, 2010). Another interesting perspective is provided by Shove and Southerton (2000), who studied the adoption of freezers in the UK. The scholars observe that new innovations may ‘lock-in’ users into certain practices and make them dependent on supporting infrastructures required to operate the technology. The scholars conclude that this situation may subsequently lead to potential tensions and persistent unsustainable consumption.

It is apparent that adoption of technologies is inherently unpredictable. The conceptual understanding helps assess how technological innovations are integrated within South African households that use multiple energy sources. However, Geels and Johnson (2018) argue that the concept of technology adoption cannot be seen as a stand-alone issue and one that is reduced to simply a technology and its users. The concept needs to be integrated and rather studied as a wider process, which includes actors, policy makers, project implementation and the wider public. This research therefore analyses the technology adoption as part of a socio-technical transition system.

2.5 Technological innovation systems

The concept of innovation systems provides the first step towards understanding of the nature and rate of technological change. Scholars argue that innovations are rarely developed in isolation, but involve actors, networks and institutions within a broader innovation system to develop new technologies or create structural change (Jacobsson and Bergek, 2004; Bergek, 2002).

Innovations are classified into national[6] (Lundvall, 1992; Nelson, 1993), regional[7] (Cooke et al., 1997), sectoral[8] (Malerba 2002), and technological[9] (Bergek et al., 2008) innovation systems. While these approaches have their own boundaries and deal with different actors, the core idea of all systems is to develop, diffuse and utilise innovations (Johnson, 2001). In order to understand the change facilitated by these systems, they are assessed and compared with regards to the 'functions' they fulfil (Negro et al., 2007; Hekkert et al., 2007; Bergek et al., 2006). For example, Jacobsson and Bergek (2004) propose a set of five 'functions' that are used to analyse innovation systems: (1) 'new knowledge', (2) 'guidance of the search' (legitimacy, expectations), (3) 'the supply of resources' (competency and capital), (4) 'market formation' and (5) 'creation of positive externalities.

These functions are not independent from each other and changes in one component may create a set of actions and reactions in the whole system (Bergek and Jacobsson, 2003; Carlsson et al., 2002). Negro et al., (2007), who analysed the innovation system for biomass digestion in the Netherlands, state that as soon as these functions are fulfilled, a positive performance of the

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[6] National innovation system focuses on socio-technical structural changes of national systems and non-firm organisations, e.g., quality of educational system, health system (Negro and Hekkert, 2008).

[7] Regional innovation system applies the same logic as the national innovation system, but focuses on a specific region (Lundvall, 2008).

[8] Sectoral innovation system takes into account market actors (firms) and creates change in certain sectors of the economy, e.g. chemical engineering, manufacturing (Malerba, 2002)

[9] Technological innovation system deals with a network of agents interacting in a specific economic/industrial generating, diffusing and utilising a particular technology or a set of technologies (Bergek et al., 2008)

innovation system is achieved, e.g., innovations are effectively developed, diffused and utilised. However, the reverse outcome may also be true when functions are not accomplished, which can lead to negative performance and failure of the system.

Several scholars have criticised the innovation system concept for its static nature, its primary focus on the functioning of the system and its neglect of multi-dimensional aspects that go beyond the bounds of the technology, such as societal needs (culture, behaviour), political context, institutions and policies (Hekkert et al., 2007; van den Bergh et al., 2011; Geels, 2006; 2011; Lachman, 2013). To address these weaknesses, scholars combine the concepts of innovation systems with sociology (Rip and Kemp, 1998; Hughes, 1987) and political science (Meadowcroft, 2009). Innovations are viewed as the seed for a transition (Geels et al., 2018) that incorporate the factors mentioned above.

2.6 Socio-technical transitions

A 'transition' is understood by Geels (2008) as a process in which one socio-technical system shifts to another. It is commonly applied to changes in particular sub-systems or regimes (energy, mobility, cities) focusing on social, technological and institutional interactions (Hölscher et al., 2018). Furthermore, several well documented case studies are available that use a socio-transition concept to analyse sustainable pathways of renewable technologies. These include wind turbines in the Netherlands and Denmark (Kamp et al., 2004), biogas technology in Denmark (Geels and Raven, 2007), biofuel in Sweden (Hillman et al., 2008) and biomass gasification technology in India (Verbong et al., 2010). In relation to this research, the socio-technical transition concept is used to analyse how carbon offset activities could help reduce the negative externality caused by GHG emissions and facilitate a socio-technical transition in South Africa.

The most relevant approaches for the theoretical framing of a socio-technical transition are: Strategic Niche Management (SNM) (Kemp et al., 1998), the Multi-Level Perspective (MLP) (Rip and Kemp, 1998) and Transition Management I (Rotmans and Kemp, 2001). While these frameworks have different characteristics, they share a number of basic commonalities. They all focus on radical socio-technical innovations. Their application is mainly within a European context, where technologies are not diffused rapidly through firms but are embedded within social and economic networks (Rip and Kemp, 1998). All systems exhibit non-linear behaviour which allow them to adapt to the external environment to accelerate the transition process (Loorbach, 2007).

To provide brief context to the Strategic Niche Management, this approach deals with unproven technologies in the early development phase (infant stage) (see Table 1). New technologies are treated as protected spaces (incubators) and trigger ongoing learning with the strategic aim to experiment and develop a technology and to prepare it for further diffusion (Rip and Kemp, 1998; Truffer et al., 2002; Geels and Raven, 2006). Actors in technological niches create networks and appropriate infrastructures with an expectation that infant technologies will progress into the next stage of maturity (Kemp et al., 1998; Caniëls and Romijn, 2008).

Table 1: Summary of socio-technical transitions

Socio-technical systems	Characteristics	Authors	Limitations	Authors
Strategic Niche Management	• Deals with unproven technologies in the early development phase; provides a 'protective space' or 'incubator' for these technologies. • Triggers ongoing learning and maintains an expectation that infant technologies will mature	Rip and Kemp, 1998; Geels (2002); Hoogma et al., (2002);	• A bottom-up stand-alone model; • Insufficient to guarantee a successful technological transition • Too much emphasis on the niche • Does not take into account network dynamics	Kemp et al., (1998); Raven et al., (2010); Caniëls and Romijn, 2008
Multi-Level Perspective	• Socio-technical transition occurs through an interaction of three different levels: 'landscape', 'regimes' and 'niches'.	Rip and Kemp (1998); Geels et al., (2002)	• Over-functional, neglects social dynamics and power struggles among actors; • Too much emphasis on 'technological niches'; pays less attention to the landscape and regime actors	Geels 2010; Genus and Coles, 2008 Berkhout et al., 2004; Power et al., 2016 Kern and Smith (2008)
Transition Management	• Multi-level governance model • Builds on the concept of the MLP • Focuses on the improvement of existing systems that offer collective benefits instead of changing the incumbent regime.	Rotmans and Kemp, 2001; Kemp et al., 2007; Van der Brugge, 2005	• Unrealistic and highly uncertain. • Does not pay sufficient attention to actors' economic interests, who may disagree and hinder socio-technical transition	Meadowcroft (2005); Loorbach (2007); Kemp et al., (2007)

Source: Author's compilation

However, this model is understood to be an overoptimistic tool for a transition (Hoogma et al., 2002). Technology niches are far weaker than expected by their stakeholders and experiments remain isolated events. In practice, only occasionally do experiments evolve into actual niches and can influence strategic decisions and shift the regime towards a more sustainable path. The power of experiments may be limited, and these niches may not change the world in a direct and visible way (Hoogma et al., 2002).

Furthermore, the Strategic Niche Management is a stand-alone model and consists of 'inter-stakeholders' that are directly involved in the R&D activities of a technology (Caniëls and Romijn, 2008). The model does not take into account 'inter-actor' network dynamics, such as customers, suppliers, partners, consultants, civil society organisations and even governmental bodies. As a result, there is a lack of understanding about the processes as to how experiments can become viable market niches that successfully contribute to a regime shift (Caniëls and Romijn, 2008).

To address the limitation of the Strategic Niche Management, scholars introduce the Multi-Level Perspective (MLP) model and argue that a socio-technical transition is a dynamic interplay between three different levels: 'niche', 'regime', and 'landscape' (Rip and Kemp, 1998; Geels, 2002) (see Table 1). The Multi-Level Perspective goes beyond single niche innovations and takes a wider/more interconnected view. A socio-technical transition occurs when all three levels are aligned allowing for a shift from one regime to another to take place (Geels, 2010; 2011). The Multi-Level Perspective includes networks of actors, social groups, institutions and rules (regulative, normative and cognitive)[10].

While rules provide stability to the regime, the Multi-Level Perspective is criticised on several grounds for being over functional, based on rational choice and neglecting social dynamics and power struggles between different actors (Genus and Coles, 2008; Geels, 2010) (see Table 1). Furthermore, it places too much emphasis on 'technological niches' as the main contributor to regime change and pays less attention to the powerful landscape and regime actors (Berkhout et al., 2004; Power et al., 2016) (see Table 1). Since transitions occur in different contexts, scholars highlight the need to apply political economic analysis to develop a better understanding of actors' discourses, institutions and interests for a transition (Power et al., 2016). Further discussion on the MLP and its limitations are provided in Chapter 4.

The Transition ManagemI(TM) model was developed with less emphasis on transitions and more on existing system improvement. The model does not enforce any changes but engages with ongoing dynamics of the system (see Table 1) (Rotmans and Kemp, 2001). It is understood as a multi-level governance model (Kemp et al., 2007; Van der Brugge, 2005). It includes a set of socially formulated goals and explores the possibilities of system improvement (Meadowcroft, 2009) through addressing state and non-state actors at the regime and niche levels, who co-

[10] Normative rules are role relationships, values, behavioural norms. Regulative rules include regulations, standards, laws and cognitive rules are belief systems, innovation agendas, guiding principles (Scott, 1995).

produce and coordinate policies to create societal change (Kemp et al., 2007; Van der Brugge, 2005). The Transition Management has been extensively studied and applied in the Netherlands to manage improvements in the transportation sector (Kemp et al., 2011), water management (van der Brugge et al., 2005; van der Brugge and Rotmans, 2007), waste management (Kemp et al., 2007; Parto et al., 2007), and in energy supply systems (Loorbach et al., 2008).

While the model builds on the concept of the Multi-Level Perspective, it has been criticised for its limitations. Similar to the Multi-Level Perspective, scholars observe that the Transition Management is overly optimistic and neglects power and political actors' dynamics in a transition (Kern and Smith, 2008). It is also characterised as unrealistic because actors have divergent economic interests and may not agree on or support policies towards a socio-technical transition (Meadowcroft, 2005) (see Table 1). Meadowcroft emphasises that it cannot be expected that the political system provides a sufficiently stable context towards transitions that can last for decades. Since the Transition Management mainly focuses on governance, it is understood to be highly uncertain providing limited control over policy implementation (Loorbach, 2007; Kemp et al., 2007). This phenomenon can create an 'escape for straightforward action' (Loorbach, 2007) or divert actors' attention from concrete problems (Meadowcroft, 2009).

2.7 Chapter Summary

GHG emissions are known as a negative externality caused by market failure. It is a form of pollution which occurs because there is no effective regulation to protect the common interest or the public good. This lack of regulation allows private agents to emit freely without restriction. Carbon pricing has become a prevalent policy response to correct the market failure and internalise the cost of the externality (Stiglitz et al, 2017). Within the carbon pricing, carbon offsetting has been recognised as a policy instrument that helps mitigate GHG emissions by making it more expensive for polluters to emit and incentive the development of low-carbon technologies that facilitate a gradual socio-technical transition.

The chapter showed that an innovation is a dynamic and path dependent process, which is facilitated by various actors. However, the adoption process of innovations takes time and depends on the technology itself, market conditions, policy interventions and end-users' domestic practices (habits, daily routines, social relations etc.). These factors may also serve as barriers to technology adoption when users resist, and innovations fail to integrate within households.

Innovations are understood to be part of innovation systems and facilitated through functions until they are developed, diffused and utilised. Furthermore, three socio-technical approaches were reviewed: the Strategic Niche Management, Multi-Level Perspective and Transition Management. While each of these models fulfil a unique function within the socio-technical transition concept, they all share some basic commonalities. The models target radical innovations, have only been used in the European context and slowly diffuse innovative technologies through social and economic networks. This knowledge helps to select the most suitable framework for this research and is examined in Chapter 4. The next chapter (Chapter 3) critically discusses the empirical evidence of the carbon offset market[11], carbon offset project implementation, adoption of low-carbon technologies and their impacts on local communities in South Africa.

[11] Carbon offset market and carbon market are used interchangeably

Chapter 3: Carbon offset market in South Africa

In this chapter, we examine actors' experiences in the South African carbon offset market. We then investigate how carbon offset projects are implemented and low-carbon technologies adopted within South African households. We explain how co-benefits are empirically studied and why field studies are necessary to examine the real impacts of carbon offset projects. The chapter identifies the gaps and determines the empirical direction of this study.

3.1 Actors' experiences in the South African carbon offset market

The South African business environment was widely considered to be conservative and risk-averse (Ntuli, 2012; Little et al., 2007; Thurner and Varughese, 2013). Actors[12] perceived carbon offsetting as a new and unproven concept, hence were reluctant to engage in the CDM (Du Toit, 2006; Little et al., 2007; Thurner and Varughese, 2013). It seems that there was a lack of expertise in the country and not enough awareness and understanding around carbon offsetting in the business and public sectors (Du Toit, 2006; Wilson, 2007; Ntuli, 2012).

Based on key informant interviews, scholars identify three main limiting factors of CDM projects: (1) regulatory, (2) technical and (3) financial that created challenges for actors in the market. The carbon market was perceived to be overly complex and involved bureaucratic procedures (Little et al., 2007; Wilson, 2007; Nkusi et al., 2014; Steenkamp, 2018). There seemed to be insufficient governmental capacity which slowed down project approvals at the national level (Wilson, 2007; Thurner and Varughese, 2013; Steenkamp, 2018).

Scholars report that there was a lack of technical expertise within the country and strict foreign investment rules hindered the development of CDM projects (Kim, 2003; Du Toit, 2006; Steenkamp, 2018). High transaction costs, volatile carbon prices and a lack of funding were frequently cited challenges by actors in the market (Little et al., 2007; Wilson, 2007; Nkusi et al., 2014; Du Toit, 2006; Steenkamp, 2018). It seems that South African actors did not feel the need to engage in carbon offset projects, as they did not take the CDM seriously (Du Toit, 2006) and were sceptical about its effects in the long term (Watt, 2016).

Wilson (2007) and Ntuli (2012) analyse the barriers and drivers of CDM project implementation at the municipal level and find that municipalities' stringent procurement procedures and rules

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[12] Actors are defined as individuals, who were involved and had experience in carbon offset project implementation. They include representatives from the industry, national government, policy makers, project developers, consultants, financial institutions, NGOs, civil society and academics (Du Toit, 2006; Little et al., 2007; Kim, 2003)

inhibited or delayed the implementation of CDM projects. Municipalities often lacked the capacity and technical expertise to register such types of projects (Ntuli, 2012). Since they have several other responsibilities to fulfil - such as delivery of essential services, housing, education and social upliftment - CDM projects were not amongst their top priorities (Wilson, 2007).

However, it seems that government officials were still enthusiastic towards such projects. Government officials believed that engagement in carbon offset projects could lead to the transfer of skills and better access to advanced technology at low or no cost (Ntuli, 2012). However, Wilson (2007) contradicts this perspective and notes that some government officials were hesitant to adopt untested technologies and had a mindset that technology transfer facilitated through carbon offset projects could create a 'dumping ground for failed technology' in the country.

Nkusi et al., (2014) analyse the entrepreneurship culture in South Africa and identify the issue of unequal access to the local carbon offset market. The authors reveal that the market was skewed towards certain ethnic groups. Although black South Africans could engage in carbon trading through partnerships, the market was largely occupied by white and Indian counterparts. Whites, who controlled the major share of the financial markets, had an incentive to enter the carbon offset market as service providers, brokers or evaluators.

Scholars argue that the legacy of apartheid still influenced the networks and the economic capability of different ethnic groups. Since the majority of black South Africans dominate the informal economic sector in the country, their integration into the formal sector remains limited. As a result, carbon trading and the implementation of carbon offset projects remains inaccessible for this group (Nkusi et al., 2014).

3.1.1 Summary

The literature reviewed focuses on several barriers experienced by actors in the South African carbon offset market. However, it pays insufficient attention to actors' behaviour, networks and discourses. Bumpus (2011) and Ullström (2017) highlight that further research is needed to deepen the knowledge of local effects and imbalances created by the behaviour of actors in the local carbon offset markets. In light of this and acknowledging that existing studies are outdated, this research will address these gaps in the empirical chapter (Chapter 8).

3.2 Implementation of carbon offset projects in South Africa

The best researched empirical example in South Africa is the Kuyasa[13] CDM project, analysed by Manning (2008), Koster (2018) and Erion (2007). This project was implemented using a community-based participatory approach. It received a relatively large amount of attention at the local and international level for being the first 'ground breaking' CDM project in Africa.

It seems that this approach allowed the project developer to create open and transparent lines of communication, awareness of the project and improve education in energy access and use (Koster, 2018). Collaboration with various partners, e.g., government departments and NGOs, helped raise the funds required for different stages of the project. However, Erion (2007) highlights that this project turned out to be expensive, costing more than $1 million with a long payback horizon (14 years) (Manning, 2008) (see Table 2).

[13] Kuyasa project involved the installation of SWHs, insulation of the roof with ceiling board and exchanging conventional light bulbs for the more energy efficient compact fluorescent light bulbs (CFL´s) in 2,309 houses in Cape Town (Wlokas, 2011).

Table 2: Overview of case studies and actors' experiences in South Africa and internationally

Case studies	Country	Barriers	Authors
Kuyasa CDM project	South Africa	• High upfront costs (>$1million) and 14 years payback period • Project upscale is challenging – no clarity of national standards and regulations and the deficit of local skills and institutional capacity	Manning (2008) Koster (2018) Erion (2007) Schomer and van Asselt (2012)
Improved cookstoves projects	Kenya	• Carbon finance creates an overall positive impact on the Kenyan cookstove sector • Projects highly vulnerable to subsidies • Projects create asymmetric information	Lambe et al., (2015) Wang and Corson (2015) Stevens et al., (2020)
	Uganda	• Carbon offset projects are funded through subsidies • Subsidies create 'entitlement effect' • Insufficient funding and government support • Lack of appropriate standards	Stevens et al., (2020) Lietaer et al., (2019) Simon et al., (2014)
	Mexico	• High costs • Technical and implementation issues (lack of standards, knowledge) • Cookstove intervention using carbon offsetting is not a legitimate option	Berrueta et al., (2017)

Source: Author's compilation

Koster (2018) and Haque et al., (2021) compare the Kuyasa CDM project with a Solar Water Heater (SWH) project implemented by the government in Joe Slovo, Cape Town. In comparison to Kuyasa, the Joe Slovo project was implemented using a 'top-down' approach without community involvement in the decision-making process. The project appeared less transparent and subsequently received no support from the local community. It suffered from long delays and was not able to install the originally-planned number of SWHs (target 2,886 units versus 1,572 installed) (Koster, 2018).

The rollout of the SWHs in Joe Slovo seemed to have exacerbated the inequality gap between affluent and low-income households (Haque et al., 2021). Due to technical issues, SWHs were perceived by low-income households as 'welfare technology reserved for the poor'. In receiving poor quality SWH technology, residents in Joe Slovo were reminded of the legacy of apartheid and their dire living conditions (Haque et al., 2021). While these residents lived in cramped informal houses with poor access to basic services, scholars argue that wealthy households in surrounding suburbs were fully equipped and enjoyed the conveniences of modern high-quality appliances. This ultimately led to resentment within communities and the subsequent rejection of the technology due to the technical failures and the corrupt local leadership in the project area (Haque et al., 2021).

To obtain deeper insights into the project implementation process, case studies in other countries are examined. Lambe et al., (2015) analyse the role of carbon finance in cookstove projects in Kenya and conclude that it had an overall positive impact (see Table 3). It allowed several large international players to enter the market and introduce high-quality stoves, while creating opportunities for small actors to engage in carbon finance. Carbon finance was perceived by Kenyan project developers as an essential funding source to help launch their business and build partnerships (Lambe et al., 2015).

However, Lambe et al., (2015) highlight that implementing cookstove projects was complex and costly. It involved consistent monitoring of technology use, including unforeseeable behaviour patterns of end-users. These factors may influence project implementers' decision to either discontinue projects or minimise their scope. Since carbon offset prices are inherently volatile, scholars agree that carbon credit revenue as the only source of funding makes project developers highly vulnerable (Lambe et al., 2015; Stevens et al., 2020) (see Table 3). It is an inappropriate funding source for those who do not have a "safety net" to cater for external shocks, such as a sudden drop in the carbon price (Lambe et al., 2015).

Lietaer et al., (2019), who analysed actors' experiences in cookstove carbon offset projects in Uganda, indicate that these projects have been mainly funded through subsidies. Although subsidies allowed companies to maintain commercial relationships with their users, who would otherwise need to buy the stove, scholars consider them as an unsustainable finance source in the long run. They disrupt commercial success of carbon offset projects, especially in situations when they run out or are unexpectedly withdrawn (Lietaer et al., 2019).

Furthermore, subsidies may create an 'entitlement effect' where the users feel entitled to have the new technology for free or at a reduced price (Simon et al., 2014). Moreover, users may refuse to pay more or at all for the technology once the subsidy is reduced or removed (see Table 3). Although carbon finance is widely used to finance carbon offset projects in Uganda, it seemed that enterprises still found it difficult to access finance to grow their business due to insufficient resources (funding) and government support (Lietaer et al., 2019; Stevens et al., 2020). There were weak regulations and a lack of appropriate standards that resulted in poor quality stoves and distortions in the local market (Table 2).

Schomer and van Asselt (2012) examine opportunities for scaling up the Kuyasa CDM project using carbon finance in South Africa. It seems that it was challenging to scale up this project due to institutional constraints, such as a lack of clarity on national standards and regulations, and a deficit of local skills and institutional capacity. Furthermore, there was a mismatch of expectations between project developers and government officials. While project developers seemed to think that government would subsidise carbon offset projects on a perpetual basis, government officials refused to get involved and provide further funding (Schomer and van Asselt, 2012). The authors explain that the South African government was aware of the importance of such interventions. However, it was difficult to gain support for energy-upgrade projects as municipalities depend on selling energy (e.g., electricity) to subsidise their budgets. As a result, they may potentially lose out on income, if energy-upgrade interventions are mandated (Schomer and van Asselt, 2012).

A similar phenomenon is observed in Mexico. Berrueta et al., (2017) examine the intervention of 'Patsari' wood burning cookstoves in rural areas of Mexico and find that cookstove programmes demonstrate a viable economic option for improving the quality of life in rural Mexican communities. However, the uptake of these projects remained limited due to high implementation costs, a volatile carbon price and uncertainties in the carbon market, including technical issues (lack of standards, knowledge) experienced during project implementation. The Mexican government and funding agencies did not consider carbon offset interventions as a legitimate option for local social and economic improvement, hence provided no or very limited support for such projects (Berrueta et al., 2017).

Wang and Corson (2015) analyse a cookstove project registered with the Gold Standard in Kenya (project name unknown) and find an issue of asymmetric information**.** Carbon development consultants and project developers seemed to take advantage of information asymmetry to bolster their share of the carbon revenue generated by the project. The asymmetry involved Kenyan women, who use the stoves on a daily basis, ceding their property rights to emissions reductions without being properly consulted or fully understanding the implications. Scholars call this behaviour a form 'green grabbing', in which project developers purposefully appropriate users' future rights to carbon credits.

3.2.1 Summary

It is believed that the pathway to a successful project implementation is complex and includes innumerable challenges and pitfalls that project developers must navigate. Lambe et al., (2015) emphasise that more case studies on clean cooking technologies are needed from other countries aside from just Kenya to investigate how carbon finance can help with the uptake of such projects. Scholars indicate that the analysis could include motivations and intentions of project actors, their business models, the national policy environment and the use of carbon revenue.

Since the literature reviewed focuses only on one best practice case (the Kuyasa CDM project), scholars emphasise that further research is needed into other carbon offset projects, specifically SWH projects, to provide more insight into project implementation processes and to learn from the experiences of others (Schomer and van Asselt, 2012; Koster, 2018). This study will address these gaps in Chapter 9.

3.3 Adoption of low-carbon technologies within households in South Africa

In this section we review studies related to the Solar Water Heaters (SWHs) and cooking technologies relevant for this research. Scholars believe that the specific approach of project implementation can have significant influence on overall household technology adoption. (Wlokas, 2011; Mukwada et al., 2014). For example, Wlokas (2011) compared two projects, the Kuyasa CDM project and Zanemvula SWH project. The aim of the Zanemvula SWH project was to partially or wholly substitute the use of electricity, Liquified Petroleum Gas (LPG) and oil for water heating in areas with sufficient solar radiation.

Each of these projects generated different outcomes. The Kuyasa CDM project, using a community-based participatory approach, achieved relatively better technology adoption within households than the Zanemvula SWH project that was implemented by the government without any community consultation ('top-down' approach). Wlokas (2011) notes that the government in the Zanemvula SWH project failed to transfer technical skills and educate households on the correct use of the technology, which resulted in limited technology adoption.

A similar finding is provided by Mukwada et al., (2014), who analysed the SWH installation in the rural areas of South Africa. The scholar adds that community members perceived projects implemented using a top-down approach as not socially responsive. The top-down approach often leaves users ill-equipped and with insufficient technical skills needed to maintain the geysers. This has a direct impact on the long-term technology adoption. Scholars also report that these projects suffered from technical issues (poor quality installations, leaks, permanent damage to roofs), creating dissatisfaction and major barriers to users' technology adoption (loss of water and soaring water bills) (Wlokas 2011; Mukwada et al., 2014). Ongoing maintenance of SWH technologies and their associated costs created another challenge for users to fully integrate the technology in the long run (Mukwada et al., 2014). However, despite these issues, households seemed to still accept and continue using the SWHs on a daily basis Wlokas (2011).

Seasonality was another factor that was observed to have affected the adoption of the SWH technology. Mukwada et al., (2014) note that seasonal variations caused unreliable hot water supply for users during the winter period. For example, on cloudy days, the performance of the SWHs was suboptimal, whereas when temperatures fell, SWHs were rendered ineffective. A similar situation was confirmed by Pailman et al., (2018), who analyse Improved Cookstoves (ICSs) in Southern Africa (South Africa, Zambia, Malawi and Mozambique). Improved cookstoves were typically used more in rainy seasons for cooking and heating purposes as cooking indoors in summer was too hot.

It seems that cooking technologies also do not fully meet users' requirements. Pailman et al., (2018) reported that users often experience stove ignition problems, durability concerns (short life, lack of strength, wear and tear) and inherent stove design issues (slow heating). Due to time constraints, the requirement to regularly maintain the stoves was often viewed by users as too onerous. The consensus is that technology adoption is notoriously difficult and deeply rooted within the prevailing societal and cultural context (e.g., spiritual and healing practices, social gatherings), and not necessarily influenced by technology efficiency (Lambe et al., 2015).

Kapfudzaruwa et al., (2017) analyse the uptake of 18 ICSs in 14 African countries and observe a higher rate of adoption of ICSs in South Africa than in any other Western and Southern African country. This was due to higher awareness of the technology and the health issues associated with traditional cooking methods (open fire). However, it seemed that urban consumers with higher income and literacy levels in South Africa had a better adoption rate than the rural households. In rural areas, households tend to have limited knowledge and appreciation of the long-term health and socio-economic benefits of clean cooking. They were risk averse to new technologies and usually preferred to use traditional stoves (Kapfudzaruwa et al., 2017). Overall, rural households may attach themselves to traditional stoves and the particular taste they impart on food and resist change or the use of ICSs (Makonese et al., 2016).

It is believed that a large family size may act as a barrier for ICS adoption (Kapfudzaruwa et al., 2017). For example, large households often share firewood collection and cooking among members. They tend to manage their time and efforts in different ways, and thus pay less attention to the use of ICSs. As a result, the adoption of ICSs within larger South African families remains limited due to an inability of ICSs to cook traditional meals with traditional tastes for family members or social gatherings (Kimemia and Van Niekerk, 2017).

At the same time, the adoption of cookstoves seems to be inconsistent among South African households as they practice so-called energy or stove 'stacking' to meet their basic energy needs – a situation whereby households tend to use ICSs alongside their traditional stoves rather than entirely replacing them (Pailman et al., 2018; Kasangana and Masekamenie, 2019; Kapfudzaruwa et al., 2017). Due to limited income and energy security concerns, fuel stacking involves the use of unsustainable cheap fuel sources, such as coal or wood, to reduce their vulnerability to the unaffordability and lack of availability of cooking stoves and fuels (Johnson and Takama, 2012).

3.3.1 Summary

We have learned that there are many barriers and enablers of technology adoption. Debbi et al., (2014) argue that they are unique in relation to culture, setting, approach, and cannot be easily transferred or used in other contexts. As a result, further research is needed into different types of cooking technologies, their contexts and settings to enrich the current debate.

We note that scholars mainly focus on factors, such as seasonality, durability, household and demographic characteristics, location, technology design, etc. However, to understand how low-carbon technologies are effectively adopted, Shove (2004) argues that social practices, e.g., users' daily routines and habits, are essential to consider. Furthermore, we find that current literature does not explicitly discuss consistent technology use. This is important for this study as the reductions of GHG emissions of carbon offset projects depend on regular long term technology use. Considering these comments, this research addresses the gaps in Chapter 10.

3.4 Empirical understanding of co-benefits in carbon offset projects

Co-benefits are understood in this study as 'the additional and locally-desirable developmental benefits of climate actions' (Zusman, 2008, p.88). They can be monetary and non-monetary incentives ranging from improved human health, food security, biodiversity, air quality, energy access and other changes in livelihoods (IPCC, 2014, p.5). A large body of empirical research literature examines the provision of co-benefits using desk-based reviews of Project Design Documents (PDDs).

Overall, the provision of co-benefits seems to be not at the heart of carbon offset projects (Sirohi, 2007; Sutter and Parreño, 2007; Subbarao and Lloyd, 2011; Olsen and Fenhann, 2008; Crowe, 2013). There is often a trade-off between two CDM objectives[14] - favouring the cost-efficient

[14] CDM objectives are discussed in Chapter 7.

emission reduction objective and neglecting, or at the expense of, sustainable development (Sutter and Parreño, 2007). The provision of co-benefits is understood to be project-specific and depends on the size and technology type of a project (Sihori, 2007).

For example, large-scale industrial gas projects, such as hydrofluorocarbons (HFCs), nitrous oxide (N_2O), and perfluorocarbons (PFCs), claim to reduce emissions, but offer almost no co-benefits (Watts et al., 2015; Olsen and Fenhann, 2008; Sutter and Parreño, 2007), nor do they contribute to any improvement of local air quality (Garg et al., 2006; Lou, 2020). In contrast, scholars claim that renewable energy projects, such as solar, wind and household energy efficiency projects (cookstoves and biomass projects) have created a wide range of co-benefits for communities. Such benefits include employment, income, improved local air quality, welfare and access to alternative energy (Olsen and Fenhann, 2008; Wood, 2011; Mori-Clement, 2019).

However, He et al., (2014) highlight that the desk-based studies mainly rely on information provided in the Project Design Documents, hence can be deceptive and unreliable. Their findings may be inconclusive and provide a certain degree of uncertainty due to self-reported and undefined claims (Mori-Clement, 2019). Furthermore, the project documents may offer lip service (Sirohi, 2007) and are not able to examine the real impacts experienced by users (Lou, 2020). As a result, case studies are important to consider and are presented in the next section.

3.5 Co-benefits provision of carbon offset projects in South Africa

There are few field studies available that analyse experiences of communities of carbon offset projects in South Africa. However, the ones that are reviewed for the purpose of this thesis provide mixed experiences. For example, Erion (2007) and Wlokas (2011), who conducted interviews with households regarding co-benefits received from the Kuyasa project, find that the use of SWHs had a positive effect on households' electricity costs, improved health and wellbeing (respiratory, orthopaedic and rheumatic conditions) and provided a more comfortable life for residents in 2,309 homes.

Field studies in large-scale reforestation carbon offset projects conducted by Diga et al., (2016) in Durban, and Polak and Snowball (2019) in the Eastern Cape, also show positive results and find that these projects created education, training and employment opportunities for communities in project areas. However, Polak and Snowball (2019) argue that the employment of these projects was typically short-lived, and income received from planting trees was unlikely to allow households to live above the national poverty line (Diga et al., 2016), which is approximately R1,268 (£67) per month (Stats SA, 2020). Furthermore, the operation of these projects was highly uncertain as they heavily relied on government funding, which was unsustainable in the long run (Polak and Snowball, 2019; Diga et al., 2016).

In contrast, studies led by Bond et al., (2012) and Bond (2007) examine the large-scale CDM landfill-gas Bisasar Road project and provide the opposite results. Community members, who lived in close proximity to the landfill gas project, confirmed that this project caused unnecessary health hazards to local communities. Bond and colleagues state that residents suffered from asthma, sinusitis, pneumonia and even tuberculosis as a result of being continuously exposed to airborne pollutants dispersed from the project activity. The project caused intra-community conflicts and socio-racial divisions (Bond et al., 2012; Bond, 2007).

3.5.1 Summary

It appears that the literature on field studies analysing co-benefits of carbon offset projects in South Africa is limited. Diga et al., (2016) and Johnson (2018) highlight that a wider assessment of multiple case studies is needed to gain a better understanding of impacts generated by carbon offset projects. This is necessary to bridge the gap between desk-based reviews and the field studies (Karhunmaa et al., 2015). Taking these comments into account, this thesis will address the gap in Chapter 11.

3.6 Chapter Summary

The chapter examined actors' experiences in the South African carbon offset market and project implementation. It revealed that actors encountered several issues and barriers (e.g., high costs, lack of institutional support, lack of expertise) that restricted their involvement in the market and hindered the development of carbon offset projects in the country. Although carbon finance created positive impacts on the cookstove sector in countries like Kenya and helped create partnerships, it was still difficult for project actors to scale up these projects due to insufficient resources (funding) and government support. The studies confirmed that national governments in South Africa, Uganda and Mexico did not consider carbon offsetting as a priority nor a legitimate option for social and economic improvement.

The chapter reviewed the literature on factors that influence technology adoption both in South Africa and internationally. It seems that factors - such as technical issues, insufficient technical skills and education, poor quality of the technology - limit users' technology adoption. Studies concluded that adoption of technologies is complex and deeply rooted within the social and cultural context and goes beyond technology efficiency or the economics thereof. However, we acknowledged that the literature on this subject in relation to South African carbon offset projects is scarce and requires further attention.

Furthermore, we reviewed studies on the provision of co-benefits of carbon offset projects using the desk-based approach. This approach provided limited scope of assessment as they mainly relied on information provided by the Project Design Documents that have self-reported and undefined claims. As a result, field studies were needed to examine the real impacts of carbon offset projects.

Lastly, we examined field studies in South Africa that provided mixed results on the provision of co-benefits of carbon offset projects. It was concluded that the provision of co-benefits is context-specific and a wider assessment of multiple case studies is needed to gain a better understanding of the outcomes generated by these projects. We have provided an empirical guidance as to how this research will develop. The next chapter (Chapter 4) will present and critically discuss the theoretical framework selected for this study.

Chapter 4: Theorising the carbon offset market from a multi-level and sustainable livelihood perspective

This chapter presents the theoretical framework that structures and guides this study. It introduces the Multi-Level Perspective (Rip and Kemp, 1998) and justifies its adoption as a framework to analyse the socio-technical transition. Whilst the Multi-Level Perspective is a strong framework, we examine the model's shortcomings.

The chapter introduces the Sustainable Livelihood Approach to help understand households' vulnerability, technology adoption and the impacts low-carbon technologies have on end-users. To deepen the knowledge of a socio-technical transition, I integrate the Multi-Level Perspective and the Sustainable Livelihood Approach. I explain the linkages between these two models and argue that the MLP-SLA model provides a suitable approach to answer the research question.

4.1 The Multi-Level Perspective

The MLP framework was developed by Rip and Kemp (1998) and further refined by Geels (2002). Scholars theorise a transition as a process facilitated through dynamic non-linear interactions between three different levels that are called: '*niches*' (micro), '*regimes*' (meso), and '*landscapes*' (macro) (Schot and Geels, 2008; Verbong and Geels, 2007). These levels are based on economic theories, both micro and macro and sociology of technology. They help understand the relationships and interplay between different actors, networks, policy makers and social groups that contribute to a socio-technical transition (Jørgensen, 2012; Geels and Schot, 2007; Geels 2012).

Whilst the MLP is used to understand transitions across a variety of different contexts, it has been commonly applied within the field of sustainability to analyse large-scale societal transitions. This would include transitions within the domains of transportation and mobility systems (Nykvist and Whitmarsh, 2008; Moradi and Vagnoni, 2018), agriculture and food systems (El Bilali, 2018, 2019; Kaweesa, 2020), low-carbon electricity pathways (Barton et al., 2018; Verbong and Geels, 2007) and domestic energy policies (Lee et al., 2020). The model focuses on 'deep structural changes' in these systems (Geels, 2011) and enables to understand shifts of 'radical' innovations over longer periods (between 40 and 90 years) (Genus and Coles 2008; Schot and Kanger, 2018).

The relationship between the three levels (niche, regime and landscape) is understood as a 'nested' hierarchy, meaning that regimes are integrated within the landscape and niches within regimes (Geels, 2005) (see Figure 1). In Figure 1, '*niche*' innovations are treated as a 'protected space' (incubators) where experimental 'radical' technologies are tested and developed (Geels, 2011; Raven et al., 2010). A 'radical' innovation is defined as a unique and original product, system or business model that replaces an already existing one. There is a high degree of uncertainty of success due to the level of newness, the potential radical nature of the innovation and its design, including the lack of certainty around the expected market reaction to it (Groenewegen and de Langen, 2012).

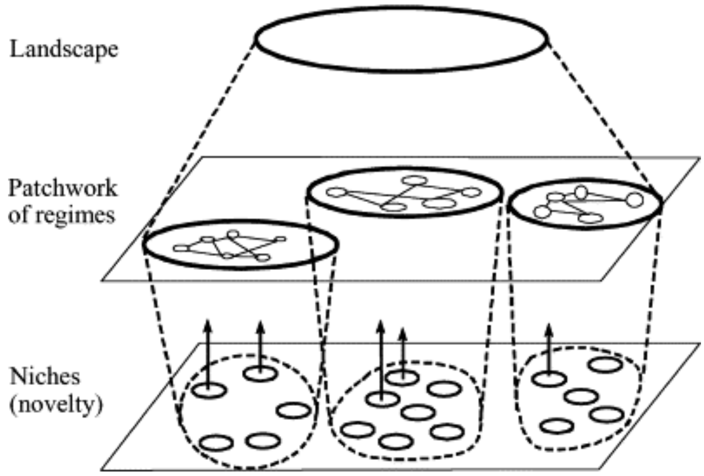

Figure 1: The Multi-Level Perspective as a nested hierarchy. Source: Geels, 2002

'*Niche*' innovations often include a series of experimental and pilot projects (Raven et al., 2010). They have relatively low technical performance; are cumbersome and expensive (Geels, 2002). However, they are geared to addressing the problems of the existing incumbent regimes (hence, the arrows in the Figure 1) (Geels, 2005) and can act as the seed for change (Geels, 2002). It is understood that niche actors create small networks that help them innovate and promote their social, environmental and business interests (see Figure 2), hoping to overthrow the incumbent regimes and have their novelties breakthrough into the mainstream market (Geels, 2005).

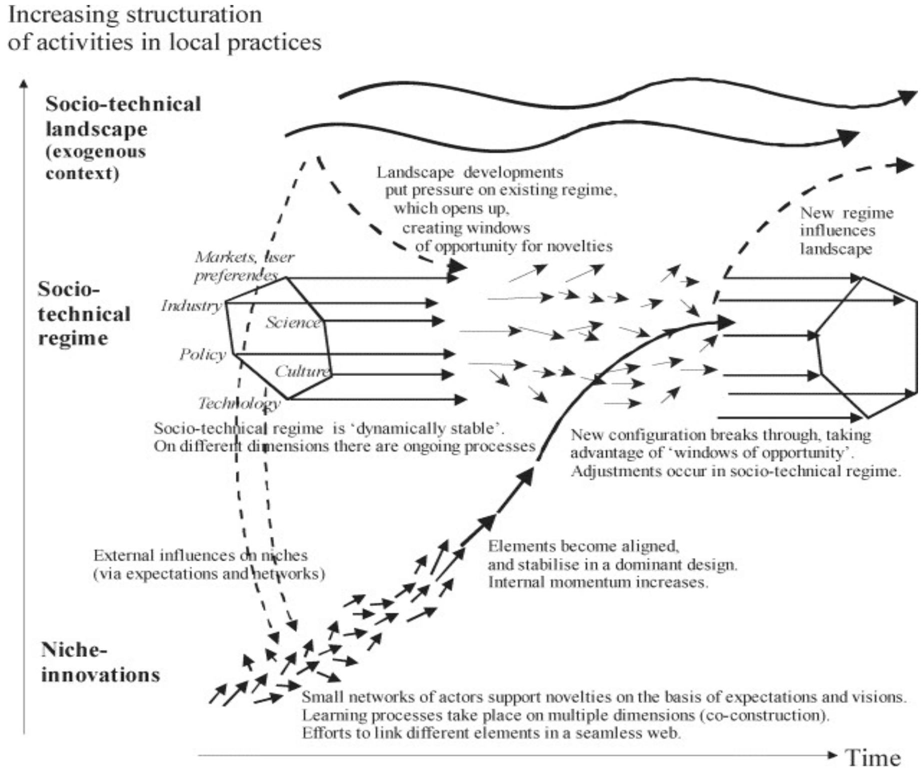

Figure 2: The Multi-Level Perspective on low-carbon transitions. Source: Geels and Schot, 2007

However, while the niches may create transformative ideas and capabilities, scholars argue that they are not 'blueprints' (Smith et al., 2010). They can fail to reach the economies of scale or become competitive, especially if no support is provided by the regime and the landscape (Power et al., 2016). Since the existing regime is entrenched in many ways (e.g., institutionally, organisationally, economically, culturally), it may be difficult for disruptive niches to break through and replace the regime (Geels, 2005).

As a result, it is believed that niches may align their actors' expectations with existing expectations in the regime, termed a *'fit-and-conform'* strategy (Raven et al., 2016). However, a different pathway to a transition may occur, in which expectations of niche actors may not align with expectations in a regime (known as a *'stretch-and-transform'* strategy) (Raven et al., 2016). In this instance, actors may articulate how to solve regime challenges and imposes rules on a regime to change in order to suit the niche innovations (Smith and Raven, 2012; Raven et al., 2016)

The '*stretch-and-transform'* strategy typically attracts early adopters of niche innovations, such as civil society, environmental activists, political parties, trade unions, opinion formers in media and education, and institutional investors (Smith and Raven, 2012). They often create discourse coalitions and express their practical (niche) opinions and visions to either mobilise or counter-mobilise societal changes due to their powerful vested interests (Geels et al., 2016a; Smith and Raven, 2012).

A socio-technical '*regime*' is understood as a pattern of technologically determined behaviour that is shaped by a semi-coherent set of rules, structure and practices and shared by a specific group of actors (Geels, 2004; Geels and Schot, 2007- see Figure 2). The regime is highly interrelated and consists of stable but always evolving configurations of technologies and complex networks that include firms, policy actors, scientists and users (Geels, 2011; Scrase and Smith, 2009). It is fairly predictable, homogenous and monolithic (Geels, 2022).

According to Geels and Schot (2007), the stability of the regime is understood to be guided by cognitive, normative, regulative or formal rules. While the regime is based on tangible and measurable elements (such as standards, protocols, regulations and laws), it also includes the interpretive analytical capacity of intangible elements, such as actors' beliefs, values, social expectations and behavioural norms, rules of thumb and shared visions (Geels, 2011).

The '*landscape*' is characterised as the external environment that influences both the regime and niche (Markard and Truffer, 2008). The landscape includes slow-changing environments, e.g., macro-economic trends, societal concerns, geo-politics, policies and external shocks that are out of the actors' control (Geels, 2002; 2019). Changes in landscape are deemed to be divergent, large and sudden. They can either reinforce regime trajectories or put pressure and destabilise the regime to prompt consideration of niche alternatives and re-create a new regime around them (Lachman, 2013; Smith et al., 2010; Sovacool 2016 – see Figure 2). The scholars conclude that the landscape creates opportunities for new innovative technologies and can either de-align or re-align the existing regime (Geels and Schot, 2007; Sovacool, 2016).

Drawing on insights from the conceptual literature, Geels (2002) concludes that structural changes in socio-technical systems occur when there is an alignment[15] across the three levels. This alignment is understood to be a necessary pre-condition for a successful transition to occur (Geels 2002; Power et al., 2016).

4.2 Limitations of the MLP framework and its adaptation to the South African context

The MLP helps analyse historical transition pathways and understand the overall transition process (Jørgensen, 2012). It mainly focuses on long-term 'radical' innovations that overthrow, substitute and discontinue the incumbent regime in favour of new innovations (Geels et al., 2017;

[15] The alignment is understood as a successful process within which the niche reinforces changes in the regime, which is influenced by the socio-technical landscape, that puts pressure on the regime for the change to occur (Kemp et al., 2001, p. 276-277).

Roberts and Geels, 2018). However, McMeekin et al., (2019) observe that it is not the only pathway to achieve a socio-technical transition. A socio-technical transition does not need to focus on single innovations to radically shift the entire system as envisaged by the MLP.

There are many nested and overlapping 'societal sub-systems' that are considered to create gradual change within a system or incumbent regime (McMeekin et al., 2019). A similar understanding is provided by Sovacool (2016) that socio-technical transitions cannot focus on complex long-term transitions only, but can be accelerated by an incremental technological substitution that is less complex and easier to implement. The scholar argues that transitions are path dependent and may not fully revolutionise or substitute the incumbent regime. New solutions do not evolve in isolation, but interact with existing practices and technologies (Grübler, 1996).

An 'incremental' transition is defined by McMeekin et al., (2019) as a small improvement of a technology that creates minimal changes to the dominant regime. Here, a gradual reconfiguration of the incumbent regime occurs through network expansion to accommodate new low-carbon innovations and technology adoption at the consumer level. In the context of energy transition[16], end-user devices – such as smart meters, energy efficient lighting, cook stoves and flex-fuel vehicles – are good examples for such transitions (Sovacool 2016; McMeekin et al., 2019). Such technologies typically reduce pressure on fossil fuel energy resources and regime infrastructure whilst also creating immediate co-benefits to the end-users associated with less pollution, improved public health and cost savings (Sovacool, 2016).

Furthermore, scholars argue that the MLP focuses on supply driven large-scale socio-technical transitions, like energy supply (Geels and Raven, 2006), transportation (Elzen and Wieczorek, 2005) and water infrastructure (van der Brugge et al., 2005), and neglects demand oriented small-scale innovations. As a result, more attention needs to be paid to community energy niches that can contribute to decentralised sustainable energy systems (van der Schoor and Scholtens, 2015; Pilloni et al., 2020).

Power et al., (2016) suggest that access to energy is far from universal. In the South African context, energy use in the residential sector ranges from grid-connected electricity to burning coal, paraffin, kerosine, firewood and Liquified Petroleum Gas (LPG) (Mbonane, 2018). Power et al., (2016) state that the MLP model overlooks the development of various informal networks of

[16] Energy transition involves a change in energy system, typically to a particular fuel source, technology or a prime mover (device that converts energy into useful services, e.g. an automobile - Sovacool, 2016).

innovation and diffusion that contribute to the increasing uptake of technologies in Southern African countries, such as cook stoves or solar PVs (Power et al., 2016).

Berkhout et al., (2004) and Power et al., (2016) express the concern that the MLP over-focuses on the 'bottom up' niche-led innovations to bring about change but fails to adequately address powerful landscape and regime actors. There may be dominant groups that use their power (force, domination, control and exclusion) to protect their interests and compete with other groups that seek change (Geels, 2010). It is believed that politics 'plays a potentially powerful role' in a transition in a way that it is 'defining the landscape, propping up or destabilising regimes, and protecting or exposing niches' (Meadowcroft, 2011, p.73).

As a result, political economy, power and social relations need to be taken into account to better understand re-distributional impacts and assess who the winners and losers are within a socio-technical transition (Newell and Philipps, 2016; Patterson et al., 2017; Power et al., 2016). In relation to the carbon offset market, it consists of a transnational network of economic agents (economists, scientists, policy advisors, consultants, lawyers) (Pearse and Böhm, 2014) and appears to be vulnerable to capture by influential market actors (Paterson and Laberge, 2018; Ervine, 2013). It is therefore necessary to investigate discourses and power relations of these actors in the MLP.

Furthermore, scholars observe that the assumption of the MLP being 'monolithic' and 'homogeneous' in its structure is unrealistic (Jørgensen, 2012; Fuenfschilling and Truffer, 2014; McMeekin et al., 2019). In reality, there are persistent institutional tensions and contradictions (Fuenfschilling and Truffer, 2014). At the same time, the possibility of weak state capacity and institutions that are subject to elite capture are not adequately considered in the model (Lawton and Murphy, 2011; Power et al., 2016).

This situation applies to the South African political system which was in a period of so-called 'state-capture' for more than 10 years - ruled by wealthy elites (the Zuma-Gupta patronage network[17]), who influenced laws, policies, political appointments and regulations to their own advantage and controlled the country's coal and mineral resources (Bracking, 2018; Madonsela, 2019). A transition to renewable energies was perceived as a threat, and the state and corporate

[17] Zuma-Gupta patronage network is a close relationship between the former South African President Jacob Zuma with the wealthy Indian immigrant Gupta family, who managed to create in a tight partnership with the former President and convert political leverage into commercial gain (Bracking, 2018; Madonsela, 2019)

elites were reluctant to open the market to new players or cede control over the country's resources (Newell and Philipps, 2016; Baker et al., 2014).

Furthermore, Power et al., (2016) claim that the MLP is based on European energy systems and therefore less applicable to the context of low-carbon technologies in Africa or the wider reconfiguration of African energy systems. It does not explicitly consider multiple forms of energy provision operating concurrently in many Southern African countries - from large-scale hydroelectricity for heavy industrial use to burning firewood and charcoal for domestic use (Power et al., 2016). The model is rather based on European structures of energy provision - which are heavily regulated and one in which governments do not need to habitually deal with crises, such as blackouts or issues stemming from out-dated grids, substandard infrastructure maintenance, poor planning etc. (Power et al., 2016).

In the South African context, the energy sector is governed by the state-owned monopoly utility, Eskom. South Africa has suffered from an ongoing electricity crisis for more than a decade (Nhleko, 2021). This stems from insufficient forward-planning and provisioning, and a lack of funding to maintain Eskom's existing and aging system. This has been exacerbated by ongoing theft of electricity and vandalism of its infrastructure. As a result, there is a loss of generation capacity and regular blackouts (termed 'loadshedding' in South Africa - Baker, 2012; Masondo, 2022). This phenomenon provides a good opportunity to build on conceptual knowledge and study the MLP model in a less functional energy market.

Furthermore, it is believed that the MLP does not consider the agency of actors (Jørgensen, 2012). The model presents them as the rule-followers, whereas in practice they may move between different levels of the socio-technical transition. This argument is relevant to this research as carbon consultants in the carbon offset market can move between a sub-regime and niche. These actors are called 'hybrid actors' - they share knowledge with the regime, but also may create new requirements with which many regime actors may disagree (Elzen et al., 2012).

The authors indicate that these types of actors play a crucial role in the transition process and bring 'anchoring' between technologies, institutions and networks that may still be vulnerable and easily broken (Elzen et al., 2012). However, it is also understood that these actors may act in their own interest. It is not their primary concern to create connections between different groups of actors. Scholars observe that these actors still have not been widely studied for their role within the socio-technical transition. As a result, further research is needed to understand how hybrid actors influence the process (Elzen et al., 2012) – this is something that will be addressed in this study.

Gruber (2020) notes that technology adoption remains unexplored within the MLP. It is argued that transition and technology adoption are rarely evenly distributed across users, which can lead to inconsistent rates of change (Sovacool, 2016). As a result, we need to study technology adoption to deepen the knowledge as to 'how' and 'why' transitions occur (Gruber, 2020; Sovacool, 2016).

Furthermore, scholars state that users' everyday practices are inadequately represented in the MLP (Shove and Walker, 2010). The model mainly focuses on the 'vertical' intersections between the niche, regime and the landscape and less on households' social practices (e.g., habits, norms, daily routines and cultural context) (Shove, 2003; Whitmarsh, 2012). Other scholars add to this debate and highlight that the MLP insufficiently engages with households as the primary users of the low-carbon technologies in the socio-technical transition (Raven et al., 2021).

It is believed that knowledge on social practices is essential to gain insight into how users affect the socio-technical transition and vice versa (Shove and Walker, 2014; Geels 2018; Raven et al., 2021). Assessment of technology adoption related to users' initial and long-term use is therefore needed (Gruber, 2020). In order to address these limitations and improve the heuristic power of the MLP, this study combines the MLP with the Sustainable Livelihood Approach (SLA). This approach allows to explore the effects low-carbon technologies have on households and socio-technical transitions in an integrated manner. The next section will critically discuss the concept of the SLA.

4.3 The Sustainable Livelihood Approach

This research applies the SLA, as founded on the work of Chambers and Conway (1992) and adopted by the Department for International Development (DFID) - the government department of the United Kingdom responsible for administering foreign aid (DFID, 1999). The study defines livelihoods as 'means of living' that consist of capabilities, assets, resources and activities. The livelihood is considered to be sustainable 'when it can cope with and recover from stresses and external shocks and maintain or enhance its capabilities and assets both now and in the future' (Chambers and Conway, 1992).

The SLA focuses on households as the unit of analysis. Households and communities are considered as generally rational agents under constraints, who play an active and critical role, including in relation to project interventions (Meikle et al., 2001; Franks et al., 2004). This approach seeks to understand and address the complexity of livelihood characteristics and coping mechanisms of the poor (Farrington et al., 1999).

In the context of vulnerability, the SLA recognises that people have a range of assets and engage in multiple livelihood activities. A combination of assets and activities is mediated by institutions, social relations, policies and relevant authorities. The results of the strategies/activities can lead to desired outcomes, namely improved health, more income, social fulfilment, improved food security and reduced vulnerability (DFID, 1999– see Figure 3).

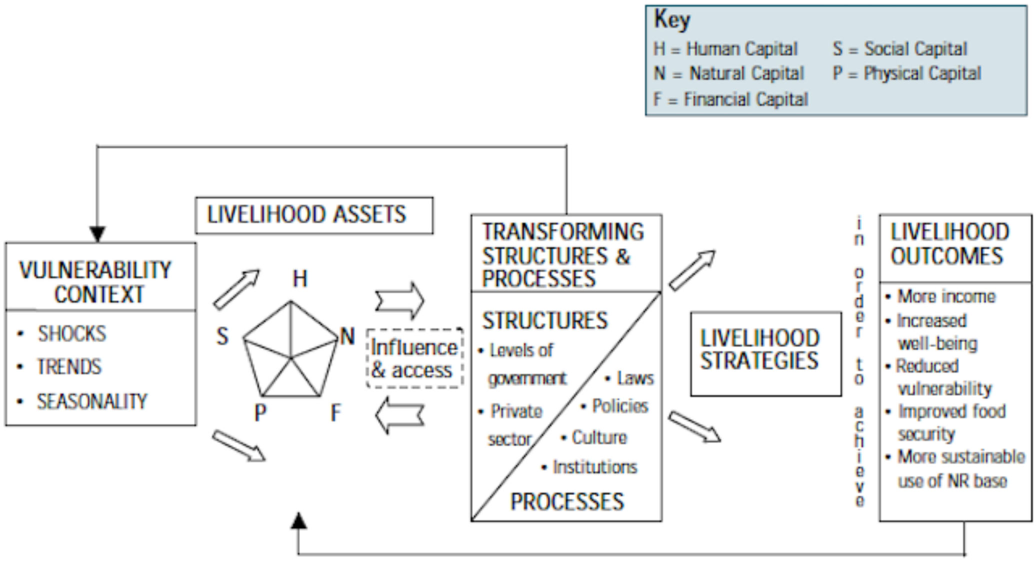

Figure 3: The Sustainable Livelihood Approach. Source: DFID, 1999

The household's choices and strategies (or activities) are conditioned by five types of asset holdings or access to resources (Babulo et al., 2008). The terms 'asset' and 'capital' are used interchangeably and are categorised into natural (use of natural resources: water, soil, air), financial (cash, financial assets such as savings, credit and debt, pension), physical (infrastructure, equipment, tools, roads), social (networks, social relations) and human capital (health, skills, training, education) (Scoones, 1998; Babulo et al., 2008; Jansen et al., 2006; Ellis 2000; Soltani et al., 2012). These assets and household strategies are dynamic and can be combined, substituted and switched over time by different people in different places (Scoones, 2009).

Barrett et al., (2001) identify that there are also some 'push' and 'pull' factors that trigger a household to change and expand the range of livelihoods. In the context of this study, the pull factors are low-carbon technologies that create opportunities to diversify assets. The push factors are the household's response to the reduced risk experienced as a consequence of technologies introduced by the carbon offset projects.

Scholars explain that access to resources is influenced by household demographics (gender, status, ethnicity and age), location and exogenous factors (external shocks, policies and technologies) (Blaikie et al., 1994; Babulo et al., 2008). Blaikie et al., (1994) note that access to resources varies between households and communities, and will ultimately affect their vulnerability to hazards. However, scholars also express concern with the SLA and find several methodological difficulties and limitations that are discussed in the next section.

4.4 Limitations of the Sustainable Livelihood Approach

One of the main limitations of the SLA is that the concept provides a simplistic view of poverty and reduces it to one component - economic deprivation - while in fact it is not clear who the poor are (Krantz, 2001). Poverty should be considered to be a multi-dimensional phenomenon, influenced by various factors, such as education, health, nutrition, gender, geographical location, living conditions and employment (Asselin, 2009).

Agrawal and Gibson (1999) observe that poverty is not uniformly distributed within an area. Communities[18] are not homogenous, hence access to resources influenced by informal structures of social dominance and power relations within communities, may not be visible to outsiders (Mosse, 1994). There is, however, a tendency to perceive poor people as passive victims. However, they typically have pro-active roles and diversify assets, income and activities to provide for their own sustenance despite their lack of access to services (de Haan and Zoomers, 2005).

Natarajan et al., (2022) explore this phenomenon further and argue that attention needs to be paid to the forms of globalisation and associated processes of production and exchange – historically stemming from colonialism to contemporary neo-liberal economics - that created marginalisation and opportunities (empowerment) at the same time. This argument is highly relevant to the South African context. The marginalisation of South African citizens was created by European colonial powers and further deepened and formalised through the government policy of apartheid[19] (Forde et al., 2021). While several opportunities were created (reparation grants, redistributive land reforms) as part of the reconciliation process, the country still faces ongoing divisions, economic and social deprivation, including social injustice (Forde et al., 2021).

This perspective leads to another re-occurring and pertinent critique of the SLA: that it fails to address structural issues and macro changes over the longer-term. For example, Scoones (2009) argues that the SLA does not engage with issues of rapid globalisation (the bigger shifts in world markets and modes of production), longer-term transitions in rural economies and agrarian

[18] A community is defined in this study as a group of individuals, who share identity based on location (village, town, neighbourhood, city) and/or social grouping (religious, racial, ethnic etc) (Agarwal, 1997). A person can be a member of several communities simultaneously. The essence of community is solidarity, which includes a feeling of belonging, a common identity and a set of shared norms and values (Bhattacharyya, 2004).

[19] See definition in Chapter 3, section 3.2

livelihoods, and alterations in environmental conditions as a result of drivers, such as climate change.

Although the livelihood analysis deals with structures, mediating processes and institutions, it is still excessively micro-focused and reduces actors to assets and capital (natural, financial, physical, social and human) ignoring power and politics (de Haan and Zoomers, 2005; Scoones, 2009; Ribot, 2014). Van Dijk (2011) argues that power relations between and within communities need to be understood to achieve more effective interventions. Natarajan et al., (2022) add to this debate and highlight that the SLA focuses more on the poor and their 'strategies' and 'assets' and diverts attention from issues of power and politics. Local livelihoods are likely to be influenced by political factors at the local, national and supra-national levels which may be biased, benefiting some and costing others.

Furthermore, van Hoeve and van Koppen (2005) claim that gender or intra-household inequalities (internal decision-making process, relationship to household head) influence livelihood choices and are ignored in the SLA. Livelihood activities are believed to be conditioned by gender differences in productive and reproductive responsibilities (e.g., looking after the children, cleaning, cooking) (Baden, 1998; Van Hoeve and van Koppen, 2005). As per Feldstein and Poats (1989), it is important to know 'who does what' in the household, especially when new technologies are introduced and targeted towards the actual users, e.g., those who make decisions, are involved in the tasks and responsible for the final outcome. This study therefore examines how low-carbon technologies influence gender dynamics and the allocation of time.

With regards to financial capital, Hulme and Mosley (1996) point out that it is a determining factor for raising income and diversifying livelihood activities. However, it is dominated by the available household budget. For example, the better managed the budget is, the more likely it is that financial capital is improved. Morse and McNamara (2013) add that the household budget is not explicitly represented in the SLA. Within the South African context, this study will therefore explore how the household budget changes within low-income households as a result of project interventions.

A study carried out by Twigg (2001) highlights that vulnerability is a complex phenomenon and cannot be confined within neatly drawn frameworks and categories, as described in the SLA. The scholar argues that enhancing a livelihood asset does not automatically mean becoming more resilient to hazards. Vulnerability is subjective and not only depends on the provision of better assets, but also the household's capacity to access and manage them, and consequently respond to changes (Moser, 1998). Scholars argue that vulnerability is also influenced by social relations that are far from harmonious (de Haan and Zoomers, 2005; Ribot, 2014). These issues are further explored in this study.

Despite all the weaknesses, this thesis regards the SLA as an indispensable model, which can effectively help analyse complex situations within households in South Africa. To minimise the model's shortcomings, Farrington (1999) welcomes the idea of combining the theoretical framework with other approaches, as long as it is meaningful and provides sufficient evidence necessary for the research.

Since the SLA does not address long-term structural and macro changes, it is a good opportunity to synthesise the model with the MLP, which explicitly tries to address long-term changes through different levels (macro, meso and micro). The SLA helps to analyse households' perspectives on adoption of low-carbon technologies. Using both models, the MLP and the SLA, this study will provide an understanding as to how a socio-technical transition can be facilitated in South Africa. The integrated framework is discussed and presented in the next section.

4.5 The integrated MLP-SLA framework

The concept of the MLP is similar to the SLA and allows for an efficient integration (El Bilali et al., 2017). For example, the landscape in the MLP is closely related to the factors in the vulnerability context (external shocks, trends) of the SLA. Both represent the exogenous environment that cannot be controlled by any actors. The regime in the MLP is equivalent to the structures and processes of the SLA. Both include established policies, institutions, rules and regulations that govern the specific system. Niches represent technologies and the effects they have on livelihood outcomes, strategies and assets of the end-users (El Bilali et al., 2017).

The integration of the MLP-SLA provides a systematic approach to analyse interactions of actors at different levels. The model takes into account the landscape (external environment), the energy regime, carbon market 'sub-regime', technological niches and households that adopt low-carbon technologies (see Figure 4). All elements in this model are inter-connected and dynamic. The model is based on the understanding that GHG emissions that drive anthropogenic climate change are a 'negative externality' caused by market failure.

The absence of costs imposed on polluters gives South Africa's coal-based energy regime an incentive to create high GHG emissions and other environmental and social problems (air pollution, human health, etc.). To correct for the market failure and internalise the 'negative externality', a market-based solution, such as carbon offsetting is introduced (see Figure 4).

This gives rise to the creation of the carbon market, which invites innovations in the technological niches and incentivises the development of low-carbon technologies, such as the Wonderbag, Solar Water Heaters, Basa Magogo and Wood stove (see Figure 4). As soon as these technologies are diffused, they are assumed to create impacts at the household level (see Figure 4). Actors in technological 'niches' are responsible for monitoring technology use. They estimate and verify GHG emission reductions of these technologies and issue carbon credits to be traded in the carbon offset market sub-regime. Since low-carbon technologies potentially reduce demand for fossil-fuel energy and GHG emissions within households, there is less pressure on the incumbent energy regime. This leads to an incremental socio-technical transition and partial correction of the market failure (see Figure 4). Each element of the model is examined in the next sections.

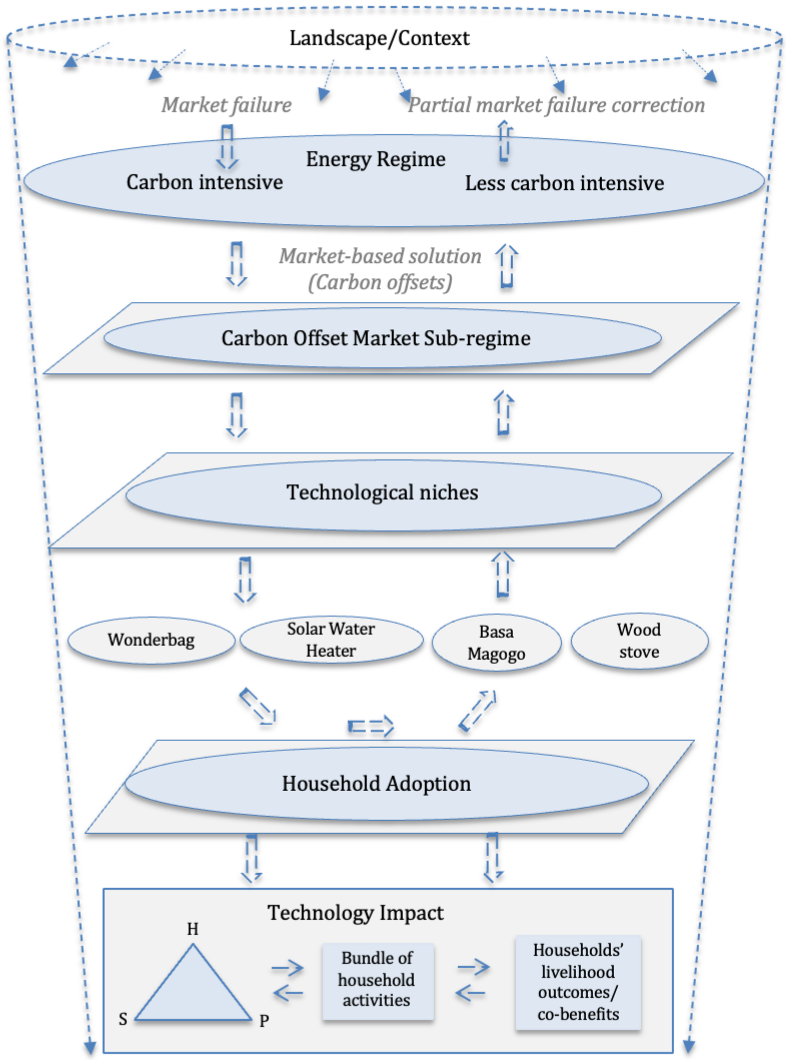

Figure 4: Integrated Multi-Level Perspective - Sustainable Livelihood Approach framework in the South African context. Source: Author's compilation

4.5.1 Establishing the 'landscape'

The landscape represents an exogenous environment and influences all levels of the integrated MLP-SLA framework. It is understood to apply pressure for action and creates opportunities for new ideas and solutions that can be implemented at the regime, sub-regime, technological niches and household levels (see Figure 4).

The landscape includes South African citizens' vulnerability to climate change, which one would hope would put pressure for a more rapid energy transition. There are persistent environmental problems, such as flooding, fires and heat waves that lead to fatalities each year (Hlahla and Hill, 2018; Tabi, 2013). Furthermore, socio-economic issues, such as poverty, unemployment, inequality and the racial legacy of apartheid create challenges and make many citizens even more vulnerable to the impacts of climate change. The landscape also includes several national and international policies that address the country's high emissions, including subsidies and carbon prices to encourage investments in new environmentally sound technologies to reduce vulnerability to climate change and GHG pollution. The landscape is discussed in more detail in Chapter 7.

4.5.2 Defining the 'energy regime'

South Africa's economy is largely driven by natural resource extraction. As a result, the energy regime is known as the 'Mineral-Energy Complex' (MEC) that is composed of mining and energy sectors, the constituent elements of which are the petrochemical industry, specifically coal and petrol, and other minerals like gold and diamond mining and the metal industry (steel, iron etc.) (Bell and Farrell, 1997; Baker, 2015) (see Chapter 7).

The regime is understood to have been mediated by the colonial and apartheid political systems, that included reliance on cheap black labour, persistent social and economic inequality, political repression (Marquard, 2006), privileged access to cheap energy, tax breaks and infrastructure (Roberts, 2007). The dominant actor of the regime is South Africa's state-owned monopoly Eskom, which is the sole transmitter of electricity in the country, responsible for generating 88% of the total electricity consumed in the country (Marquard and McCall, 2020).

Since the 1990s Eskom was at the centre of mega-project deals offering the cheapest electricity in the world to aluminium and steel plants (Baker, 2015). As a result, the heavy reliance on coal as the primary energy source has made South Africa one of the major contributors to carbon dioxide emissions in the world (Pressend and Lakhani, 2011) contributing to the aforementioned negative externality problem and market failure. Further details on the energy regime are discussed in Chapter 7.

4.5.3 Defining the carbon market 'sub-regime'

The carbon offset market operates as a 'niche' element of a bigger energy system and is trying to disrupt the fossil fuel regime and facilitate an incremental socio-technical transition (see Figure

4). However, it is also characterised as a complex sub-regime. It is safeguarded by several rules and structures to channel investments into nascent technologies at a lower cost (Fearnehough et al., 2020). The idea of the carbon market is to moderate the climatic effects of fossil-fuel technologies, while renewable energy technologies are being developed to replace them (Lohmann et al., 2005).

The market consists of various actors, such as carbon development consultants, project developers, auditors, banks, NGOs, brokers, national government, legal firms, academics and civil society. Actors in this sub-regime use carbon as a 'currency' with which to create 'routines', to govern and facilitate their carbon investments. All actors are interlinked; their relationships are continuously re-configured through their interests, national and local processes, wealth and power (Leach and Scoones, 2015; Marino and Ribot, 2012). The relationships can be contested by power and conflict of interests as well as ideology (Geels, 2010). The carbon market is constantly under landscape pressure, which includes international and national laws and regulations, socio-economic issues and a volatile carbon price. Once the carbon market is created, it valorises and opens up a commercial opportunity for low-carbon technological niches (see Figure 4).

4.5.4 Defining the role of 'technological niches'

The technological niches consist of a pool of small-scale carbon offset projects. The aim of these smaller innovations is to collectively create change within the residential sector and contribute to an incremental improvement in the larger energy regime facilitated through carbon offsetting. Technological niches consist of a 'plethora of actors', who create dynamic formal and informal networks and connect with the carbon market (Lovell and Liverman, 2010; Bumpus, 2011).

The formal network includes actors, such as project developers and their workers, business partners and carbon development consultants, who are directly and indirectly involved in the low-carbon technology rollout. The informal network consists of actors, such as artisan installers or plumbers that are not part of the project set up and implementation, but provide informal technical support to technology users in project areas.

Carbon development consultants are considered in this study as 'hybrid actors' (Elzen et al., 2012) or 'market enablers' (Phillips and Newell, 2013). They can move between technological niches and the carbon market sub-regime by using their existing network of clients to promote carbon project development, trigger debates on challenges experienced in the carbon market and subsequently influence investments towards particular sectors (Phillips and Newell, 2013).

Technological niches are characterised as 'innovative' household energy efficiency technologies. They are understood to be the fastest and least-costly mitigation option (Winkler and Marquard,

2009) that create change, influence behaviour of individual or a group of people (community) and facilitate a gradual transition to a low-carbon economy. As soon as technologies are developed – the Wonderbag, Basa Magogo, Solar Water Heaters, and the Wood stove – they are rolled out to communities in project areas.

The implementation process of these technologies is defined as a system which consists of a variety of actors involved in a project, and a set of actions that take place during the project implementation process (Alvial-Palavincino et al., 2011). These actions include the initial objective of a project, a schedule or a plan on how to reach this objective, community consultation and training of personnel to provide technical competency related to a new technology (Pinto, 1990).

A critical factor, which determines project success within this process is the users' adoption of a low-carbon technology. Project developers in the technological niches monitor technology use, estimate GHG emissions, verify and issue carbon credits in the carbon market. Similar to the carbon market sub-regime, the technological niches are exposed to landscape pressure. Uncertainties around carbon prices, subsidies or the fluctuations of the foreign exchange market may cause delays in project implementation or threaten the existence of carbon offset projects.

4.5.5 Defining the role of 'households'

A household is interpreted as a person or kinship-based group of people residing predominantly in the same dwelling, sharing meals, responsibilities and assets (Hosegood et al., 2005). A household is considered to be highly fluid and adaptable to domestic arrangements. There might be some frequent exchanges of individuals between households due to labour migration, financial insecurity, ill health and death (Hosegood et al., 2005). This research focuses on low-income households that reside in formal and informal, urban township settlements and rural villages with a monthly income of approximately of R1,500 or lower (Stats SA, 2011) – equivalent to R2,500 or at the 2021 prices[20].

Households often follow their own rules associated with their habits, established routines and culture that influence the adoption of low-carbon technologies (Thollander et al., 2010). As soon as low-carbon technologies are adopted, they create change in the flow of household assets, their activities and outcomes (see Figure 4). The effects may result in positive as well as negative outcomes. Positive outcomes relate to improved costs, disposable income and non-material well-being associated with health and spare time etc. (de Haan and Zoomers, 2005). Negative outcomes

[20] Source: Inflation rates in South Africa. WorldData (2022)

may include household resistance to change due to various reasons (culture, individual preferences and habits, influence of social networks, technical issues experienced with the new low-carbon technology) (sees Chapter 2 and 3).

If low-carbon technologies for any reason are not adopted or abandoned by households, it is argued that it will have an adverse effect on the technological niches and the carbon market sub-regime. It may result in insufficient or no reduction of GHG emissions and energy demand, contributing to limited or no incremental change towards the socio-technical transition. Based on the SLA, the study focuses on the three most relevant livelihood assets available to the household: Physical Capital (P), Human Capital (H) and Social Capital (S) (see Figure 4). The selection of livelihood assets is discussed in the methodology chapter (Chapter 5). Within household activities, the study specifically investigates gender time allocation and energy consumption that affect the household budget (energy costs).

In the South African context, women often spend substantial amount of time subjugating their individual preferences to household and family care activities (cooking, cleaning, looking after children). Due to unemployment among men, they have also become primary breadwinners and have more control over household budgets (Parry and Sagalo, 2017; Shefer et al., 2008). As a result, this research examines how low-carbon technologies may help them to allocate time to execute their multiple tasks.

Considering the high poverty and unemployment rates in South Africa (see Chapter 7), we seek to understand how the household budget may change as a result of technology adoption that may reduce households' financial vulnerability. Furthermore, household assets and activities are influenced by the external environment (landscape), over which the households have no control. As a result, the study considers if and how low-carbon technologies help reduce vulnerability to external shocks (such as water cuts, electricity blackouts), seasonal variations, poverty, inequality and unemployment.

The model assumes that there is a close interaction between project developers and individual households. As a result, households influence the technological niches by triggering discussions and providing feedback on new technologies. They can make project developers respond or adjust technologies to suit their needs. The model indicates that households indirectly influence the carbon offset market. Using low-carbon technologies, they reduce GHG emissions that are subsequently sold as carbon credits and traded in the carbon market sub-regime. The inclusion of households in the model provides a comprehensive understanding of the incremental socio-technical transition process.

4.6. Chapter summary

The chapter outlined the theoretical framework used in this study. The MLP is selected as the most suitable framework – one that assesses socio-technical transitions from 'multi-actor', 'multi-factor' and 'multi-level' perspectives. Although the model is used to analyse complex long-term radical socio-technical transitions, the chapter argued that it is not the only pathway to create change. Socio-technical transitions may also occur incrementally through different sub-systems that are less complex and easier to implement.

To advance the knowledge of the MLP, the chapter interpreted the model as a nested sub-regime that helps analyse a socio-technical transition. Since the model does not pay sufficient attention to energy systems in Africa and poorly conceptualises informal networks and structures of innovations, the chapter deepened the knowledge of the MLP by studying the model in the South African context.

In integrating the MLP and the SLA to provide a comprehensive understanding of a socio-technical transition in South Africa., I make a theoretical contribution to the field. Although the SLA does not focus on socio-technical transitions, it helps explain changes at the individual household level. This knowledge is infused into the MLP to provide a broader understanding of a transition.

Overall, the resultant framework plays an integral role in this study. It enables an analysis of the behaviour of actors in the carbon market and project implementation processes as well as users of technologies. The MLP-SLA is deemed to be a sufficient foundation for answering the research question in the study. The next chapter discusses the methodological framework used to conduct the study, and analyse and interpret the empirical results.

Chapter 5: Methodology

This chapter presents the research methodology used in the study. It first discusses the epistemology selected and explains the rationale for the multiple-case study approach. Then, it outlines the research design. It discusses the methods of data collection used to answer the research question. Third, the chapter presents and examines the data analysis techniques used to interpret the data. Finally, it discusses the researcher's positionality, ethical considerations and the limitation of the study.

5.1 Epistemology

Guided by the research question, in this analysis knowledge is constructed through a multi-faceted lens of different actors, based on their experiences and human interactions. The research adopts Murphy's (1997) argument that knowledge and reality cannot take an objective or absolute value, but is, rather, actively constructed through reflection, dependent on the network of things and relationships in our surrounding on which we rely (von Glaserfeld, 1995).

Critical realism (post-positivism) is another theory of knowledge that could be suitable for such research. It is developed from explanations based on 'closed or open systems ontology (reality/existence)' and positively applied through the use of criticism (Bhaskar, 2008). However, this school of thought still follows rational positivism, which is based on undisputable static facts and validations (Sousa, 2010), and on the notion of causality and replication of events (Mir & Watson, 2001; Geels at al., 2016). This theory is criticised as it does not account for any unobserved phenomena or any hidden structures that exist in the complex world, e.g., power relations, capacities, conflicts, external shocks (Fleetwood, 2001).

Since this research investigates actors' perceptions at different scales, followed by complex relations and behaviour patterns of local communities articulated through social and cultural norms, constructivism has been selected as the most appropriate epistemology. This theory of knowledge is 'interpretive' and allows for obtaining inter-subjective meanings through experiences based on real-life social context and local circumstances. It fits well with the Multi-Level Perspective, which also relies on interpretive assessments of interrelated actors, their visions and beliefs and any struggles they experience during such processes (Geels et al., 2010; 2016b). While positivism and critical realism mainly apply quantitative methods, such as regression analysis and mathematical formulas to explain changes, constructivists heavily rely on qualitative methods that are specific to the context and case study (Guba and Lincoln, 1982; Corbetta 2003); hence the methods of this research are qualitative in nature.

5.2 Multiple case study approach

This thesis adopts a multi-case study approach, based on the methodology described by Merriam (1998). It follows Merriam in defining a case study as a 'bounded system' that focuses on a particular situation, event or phenomenon. Since the carbon offset projects analysed in this study have defined project boundaries and finite timeline, this definition is deemed to be appropriate. While two other leading scholars – Yin (2014) and Stake (2006) – also explore case study research in depth, this thesis selects Merriam's method, because it reflects the constructivist epistemology, where 'knowledge is constructed by individuals interacting with their social worlds and the reality is not an objective entity, but based on multiple interpretations' (Merriam, 1998).

In contrast, Yin's (2014) case study design is based on positivistic epistemology, with no clear boundaries between the phenomenon and the context. It follows a tight and structured case study approach, based on 'how' and 'why' questions. The methodology is controlled, predictable and rationalist in nature (Boblin et al., 2013; Crabtree, 1999; Creswell and Poth, 2016). Stake (2006) offers a more flexible methodological approach and appears to fit well with this research. However, this case study methodology is highly interpretive and unstructured (Yazan, 2015). For example, the scholar explains that it does not include any sampling strategies or procedures for qualitative case study research. Merriam's (1998) pragmatic methodological approach includes useful elements of both the above: it allows for flexibility in design but maintains a well-defined and structured process for the case study research. It helps to elicit pragmatic, rigorous and credible knowledge (Harrison et al., 2017).

Merriam (1998) points out that knowledge is constructed based on multiple sources of evidence, e.g., triangulation and real-life settings, as a study unfolds. Since this study analyses different local perspectives of livelihoods provided by carbon offset projects, a multi-case study approach can develop richness, depth and complexity that can help one understand the phenomenon shared among multiple cases (Anaf et al., 2007). However, as Stoecker (1991) argues, multiple case studies are likely to reduce cases to a few comparable variables, resulting in the loss of the uniqueness of individual cases. To mitigate this risk, no more than four or five cases should be used to provide depth to the case studies, thus allowing individual cases to be properly represented and adequately analysed (Creswell & Poth, 2016; Flyvbjerg, 2006). This research therefore chooses four case studies.

5.3 Research design

In this research, the data is triangulated in order to obtain a greater depth and breadth of information. It also helps to confirm and identify anomalies. The mixed methods approach is used to combine qualitative and quantitative data. The research design for this study is summarised in

Table 4. To understand how South Africa's carbon offset market is integrated within each element of the conceptual framework of 'landscape' (external environment), 'regime' (energy regime), 'sub-regime' (carbon offset market) and 'niche' (carbon offset projects) discussed in Chapter 4, the researcher uses different research methods.

First, I conduct a literature review to understand the context of South Africa's energy regime, its sectors and the emission profile of the country. An extensive range of academic and grey literature sources is used to assess South African citizens' vulnerability to climate change (see Table 3). Policy documents and relevant academic literature sources are seeking to understand how South African government addresses climate change impacts (see Table 3). To provide background on the uptake of carbon offset projects and South Africa's participation in the CDM and the voluntary carbon offset market, I adopt a longitudinal analysis approach (see Table 3). This method provides context to all registered carbon offset projects, such as type, location in the country and their magnitude on GHG emission reduction in the country.

Second, to answer the first of (four) sub-research questions, I conduct semi-structured interviews with market actors. A snowball sampling approach was used. The target population is a representative selection of all market actors - in total 27 were interviewed. I analyse their storylines and map out discourse coalitions using a Discourse Network Analyser (DNA) (see Table 3).

Third, I conduct semi-structured interviews with 24 project actors to answer the second of (four) sub-research questions of this research. Since there is a limited number of participants who engage in the project implementation process, I identify all of them and interview them accordingly (more detail in section 4.4.1).

Fourth, to answer the third of (four) sub-research questions, I analyse project actors' and users' perceptions on adoption of the selected low-carbon technologies. I interview 24 project actors and 113 household participants ('project beneficiaries') in selected project areas (see Table 3) (more detail in section 4.4.1).

Lastly, to answer the fourth sub-research question I conduct interviews with 113 household participants that are randomly selected (more detail in section 4.4.1). To complement the household survey, I use observations to validate the data (see Table 3). To conclude, the next section will discuss the sampling of each target group in detail.

Table 3: Research design of the study

Do carbon offset projects contribute to livelihoods within communities in South Africa, and if so, how?					
Context and Sub-research questions		**Research Method**	**Data sources**	**Main Focus**	**Data Analysis**
Context	Review SA's carbon intensive regime	Literature review	• Academic and grey literature sources	• Review the South African energy sector	
	Review South African citizens' vulnerability context	Literature review	• Academic and grey literature sources	• Sever weather events • Effects of apartheid • Poverty/Inequality • Unemployment	
	Review South Africa's international and national actions	Literature review	• Policy documents and academic literature sources	• SA's engagement in international climate change policies • SA's national policies	
	Review carbon offset market as a 'sub-regime'	Literature review	• Academic and grey literature sources	• Governance of the CDM • Carbon offset market post-CDM	
	Analyse historical development of carbon offset projects in SA	Secondary data analysis (Longitudinal approach)	• UNEP (CDM/JI Pipeline Analysis and Database) – (CDM Pipeline overview and PoA Pipeline overview) • Ecosystem Marketplace • Verra & Gold Standard Impact Registry databases • Berkeley Carbon Trading Project database • National GHG Inventory Report South Africa	• Analyse SA's market share in the CDM and voluntary carbon offset market • Analyse project' types, size, location and their emission reductions and compare them with SA's sectoral emissions and national GHG emissions	• SA's market share (%) in the CDM and the voluntary carbon offset market • Analysis of 129 carbon offset projects registered with CDM (57) PoA (31), Verra (17), Gold Standard (24) using MS Excel software • Disaggregate and group data by project types, size, location and carbon credits issued by these projects
Research Question 1	How does the carbon offset market function in South Africa?	Semi-structured interviews	• Interviews with 27 market actors	• Analyse market actors' perceptions in the carbon market • Map out market actors' storylines a discourse coalition	• Thematic analysis using Discourse Network Analyser (DNA) • Visualisation of results using Visone, a JAVA-based software
Research Question 2	How are carbon offset projects implemented in South Africa?	Literature review	• Grey and academic literature sources, e.g., Design Documents (PDD); monitoring reports; news articles	• Select and familiarise with four carbon offset projects, their objectives, GHG emission reductions • Identify the main project actors	
		Semi-structured interviews	• Interviews with 24 project actors	• Analyse project implementation process, barriers and external factors that influence projects	• Thematic analysis using Atlas.ti software • Rank and summarise responses using Three-point Likert-Type scale
		Site visits	• Photos of a factory/technologies • Fieldwork diary	• Verify technologies and learn about projects' operation	• Researchers' observations analysed using Atlas.ti software

Do carbon offset projects contribute to livelihoods within communities in South Africa, and if so, how?					
Context and Sub-research questions		**Research Method**	**Data sources**	**Main Focus**	**Data Analysis**
Research Question 3	How are low-carbon technologies adopted in South Africa?	Semi-structured interviews	• 24 project actors	• Analyse project actors' perspectives on project users' technology adoption	• Thematic analysis using Atlas.ti software
		Household surveys	• 113 households in four project areas	• Analyse households' continued technology use and their integration within households	• Thematic analysis using Atlas.ti software
Research Question 4	How do livelihoods of households change as a result of carbon offset projects intervention in South Africa?	Household surveys	• 113 household in four project areas	• Analyse livelihood impact before and after carbon offset project interventions	• Qualitative data: • Thematic analysis and summative content analysis (keywords) using Atlas.ti software • Quantitative data analysed using MS Excel software • Use of indicators based on the Sustainable Livelihood Approach
		Observation	• 113 households in four project areas • Fieldwork diary Photos/Videos	• Main factors observed: Housing infrastructure; living conditions, indoor pollution (smoke); type and quality of stoves used; type of coal/firewood used; access to technology in the local area	• Thematic analysis using Atlas.ti software

Source: Authors 'compilation

5.4 Data collection

This section explains the sampling approach and the sample size of each participant group selected for the study. It then presents the methods used to collect the data. It explains the purpose of each method and how they related to each other. In total, data was collected over a two-year period. During this timeframe, three months were needed to collect the data from market actors in the carbon offset market. Six weeks were allocated for each case study to interview project actors, who implemented carbon offset projects, and end-users, who received and used low-carbon technologies in four project areas.

5.4.1 Sampling

Market actors are defined as 'key informants', who have 'specialised' (Tremblay, 1957) or 'expert' knowledge (Poggie, 1972). The researcher was looking for a spectrum of people involved in different activities in the carbon market. These activities include for example, carbon trading/brokerage, consultancy services, finance, project development, legal or policy and governance and so on.

The target population is based on a representative selection of all market actors. I adopted a snowball sampling, in which one interview led to another. As per Bryman (2016), I started with a small number of initial contacts, who fitted with the 'key informant' definition, who then in turn recommended other potential participants, and so on. To establish initial contacts I used my social networks with sampling developing from these I captured an increased chain of participants. Snowball sampling allowed me within a short span of time to cover what would ultimately be the 'main' actors within the space – those actors not covered were ultimately peripheral.

In total, 27 actors were interviewed (see Appendix A1). The actors included government officials, academics, employees from banking and legal institutions, carbon offset project developers, carbon advisors, local registry, NGOs, and civil society (see Table 4). To capture different actors' perceptions, more than one individual in the organisation was interviewed where possible. For example, at municipality level there were interviews of more than one government official involved in technical operations and the legal aspects of carbon offset projects. Each interview lasted approximately one hour.

Table 4: Number of interviews conducted with market actors

Market actor's category	Number of interviews
National government employee	1
Provincial government employee	4
Academics	1
Banking and legal institution employee	3
Carbon offset project developers	5
Carbon consultants	7
Local registry	1
NGOs	3
Civil society	2
Total	**27**

Source: Author's compilation

The questions in the semi-structured interviews are open ended, simple talking points designed around actors' perceptions on the functioning of the South African carbon market and the provision of co-benefits to communities in South Africa. An example of interview questions is given in Appendix A2.

Project actors

A sample of project actors were chosen, who were directly and indirectly involved in the project implementation. Since there was a limited number of participants who engaged in operation and management of these projects, all were identified and interviewed. Project actors include executives, senior and middle managers, installers, fieldworkers and factory workers, carbon consultants, business partners and community representatives. In total, 24 in-depth interviews were carried out. The number of participants interviewed in each project is summarised in Table 5. Detailed information on project actors and their roles in selected projects is provided in Appendix A3

Table 5: Number of interviews conducted with project actors

Project actor's category	Number of interviews
Project: Wonderbag	5
Founder	1
Senior manager	2
Middle manager	1
Factory worker	1
Project: Solar water heater	7
Manufacturer and Distributor	2
Carbon consultants	2
Financial institution	1
Business partner	1
Worker - Installer	1
Project: Basa Magogo and Brickstar wood stove	12
Executive	5
Middle manager	2
Fieldworker	1
Stove builder	1
Community representative	3
Total	**24**

Source: Author's compilation

Each interview lasted approximately one hour. It was carried out in person and in some cases via Skype. The interview questions were constructed around the intentions of project participants to set up carbon offset projects, project implementation processes, e.g., project design, employment, and any barriers they experienced during the rollout of selected carbon offset projects. An example of interview questions is included in Appendix A4.

Participant Households

The participant households were selected using random sampling. My intention was to get a full cross-section of households' experiences with the selected low-carbon technologies. I only surveyed household participants that received the technologies in project areas. In the Wonderbag project, I obtained a list from the project developer of all households, who received the technology. A list of participant households in the Solar Water Heater, Basa Magogo and the Wood stove projects, was not available. As a result, quasi-random selection of household participants (through walking around the townships) was applied.

A walking technique was based on the method provided by Birn et al., (1990). First, the boundaries of the project area were established on the map. Second, the interviews were conducted on every street selecting household participants at random intervals. Third, the method prescribed turning left and right into streets upon which the random selection of household participants continued. Data on the target population, who received the low-carbon technologies, was provided by project actors (see Table 6).

Table 6: Number of interviews conducted with household participants, saturation levels and target population

Carbon offset projects	Number of interviews	Saturation level	Saturation level (%)	Target population	Target population (%)
Wonderbag	19	11	57	39	49%
Solar Water Heater	28	17	60	500	6%
Basa Magogo	25	16	64	187	13%
Brickstar wood stove	41				
Burgersdorp	23	16	69	495	5%
Bonn	18	11	61	34	53%
Total	113				

Source: Authors' compilation

To determine the sampling size for each project, a widely used principle of data saturation was used. As per Miles and Huberman (1994) and Bowen (2008), data sufficiency was guided by continuously adding new respondents into the project until no new substantive information is gained. In other words, the data saturation was reached when redundancy and repetition of data occurred (Bowen, 2008) (see Table 6). However, since data saturation is regarded as an elusive concept and no sample guidelines are available, Marshall and colleagues (2013) point out that data saturation is likely to be reached using a sample size of approximately 15-30 interviews for the target group.

In total, 113 households were interviewed in the study. The number of interviews for each project has different levels of saturation (see Table 6). Upon reaching the saturation level, a sufficient cross-section of information on the variation of responses is gained. It is important to note that saturation levels provided in Table 7 refer to 'meaning' saturation. Given the richness of the data, the interviews needed to reach the 'meaning' saturation, to ensure that the researcher 'fully understood' the issues and no further nuances or insights could be found (Hennink et al., 2017).

5.4.2 Research methods

Secondary data collection

To understand the context of South Africa's participation in the compliance (CDM) and voluntary carbon offset market and to provide background on the historical development of carbon offset objectives in South Africa, the researcher collects secondary data from well-established data sources. The secondary data – originally collected for other purposes (Glaser, 1993) – provides an opportunity to do a longitudinal study, which allows the researcher to trace the development of carbon offset projects over time. Walliman (2010) argues that this kind of research is not possible to do with primary data collected in a short period time.

The researcher uses official statistical databases, such as CDM/JI Pipeline Analysis and Database, Verra and Gold Standard Impact Registry, and Berkeley Carbon Trading Project database (see Table 3). The carbon offset project data is collected from the period the first carbon offset project was registered in South Africa in 2005 until 2021. To provide a comparison of emission reductions claimed by carbon offset projects in SA with relevant sectoral emissions, the researcher makes use of the latest GHG National Inventory Report South Africa 2017 provided by the Department Forestry, Fisheries and Environment.

While this method covers the length and breadth of the data (Johnson, 2014), scholars point out that it can cause challenges, e.g. incomplete or missing data can impact the validity of results and potentially lead to spurious conclusions (Little et al., 2007; Fitzmaurice et al., 2011). To minimise this concern, the researcher does not use any random sampling nor deals with a large set of data. The analysis in this study is purely based on project specific information, e.g., project type, size, location and emission reductions claimed by carbon offset projects.

Furthermore, Walliman (2010) argues that research based on secondary data may miss the nuances of real-life situations. The researcher acknowledges this limitation and agrees that this method alone is not enough for this research to obtain accurate results and validate the data. The researcher therefore uses the secondary data in combination with other qualitative methods as part of the triangulation process.

Semi-structured interviews

Semi-structured interviews enable more extensive understanding of real-life scenarios and behaviour greater than that which could be gained through observation alone by a researcher (Merriam, 1998). In comparison to structured or unstructured interviews, semi-structured interviews make use of a dialogue and allows more flexibility to seek clarification and elaboration on answers that are deemed to be important for producing knowledge required for the research project (Leavy, 2020; May, 2011). This research makes use of ‘follow-up’ questions to check on the correct understanding of concepts and any specific wording used during the interviews.

For privacy and veracity reasons, in-depth individual interviews were chosen instead of group discussions. Breen (2006) suggests that although focus groups encourage self-reflection on the issues discussed, the results could be distorted due to social pressure placed on individuals. For marginalised people, in particular, individual interviews are most likely for them to feel confident to share criticism (Moose, 2001). Individual interviews have been extensively used in the South African context, examining actors' experience in the carbon market (see Chapter 3).

This method is particularly useful to analyse small-scale carbon offset projects. It helps to delve more deeply into social, cultural and personal perspectives to better understand and interpret the adoption of low-carbon technologies in selected project areas. Most interviews were conducted in person. However, 5 interviews were performed by Skype, to minimise transport costs and reduce the carbon emissions associated with travel. The next section explains the sampling technique and the target groups identified for semi-structured interviews.

Household questionnaires

Questionnaires are one of the key elements of the data collection tool in this study. I use questionnaires as a way to derive qualitative data in the context of households' technology and energy use. The mixed-method format of a questionnaire is a useful tool to tease out key themes and meanings necessary to answer the research question (McGuirk and O'Neill, 2016). It also allows for cross-case comparison.

The questionnaire is designed consistent with the Sustainable Livelihood Approach. It included the following components: demographic and socio-economic household characteristics, household energy use, impact assessment and adoption of technologies (see Appendix A5 for questionnaire examples). To measure changes in livelihoods, questions were created based on pre-determined indicators (see Criteria for indicator selection). Relevant questions were asked before (as a baseline) and after carbon offset project interventions. The questionnaire included closed, e.g. Yes/No, and open-ended questions. Closed questions helped to collect quantitative information on households' attributes and any changes in their livelihoods in numerical terms.

In contrast, open-ended questions were deployed to elicit in-depth responses and explore deeper meaning of households' behaviour and any changes observed within households as a result of technology use. The open-ended questions enabled free-flowing discussion and respondents were able to contribute their insight freely without narrowing restrictions. The questionnaire was conducted on a one-on-one basis and gave the respondents a feeling of safety to express themselves freely. When the questionnaire was administered, a free-flowing discussion transpired wherein the respondents gave examples and described their relevant real-life experiences on the subject matter. This information is presented in result Chapters (Chapter 10 and 11).

According to McGuirk and O'Neill (2016), open-ended questions also create an opportunity for participants to 'voice' any issues encountered with a new technology, debate and provide justifications to the subject matter. As per Marshall (2005), who advocates that the questionnaire must be checked for its reliability and validity, in this research questions were piloted with some participants in the project areas. During this process some questions were refined and words that caused confusion during the interview process were removed accordingly.

The interview base discussion was conducted face-to-face with respondents. The interviews were held in a range of languages (isiXhosa, isiZulu and Tsonga) using a translator depending on the preference of the respondent. The interviews lasted on average between 45 minutes and one hour. One individual from each household was selected for the interview.

Observations

The data for this research was also collected through observation, which is a rather unstructured method and is based on the researcher's impressions. This method allows the researcher to observe and analyse the behaviour and interactions as they occur without being a member of the study population (Ritchie and Lewis, 2003). The researcher applied a systematic approach by specifically observing housing infrastructure, living conditions, indoor air pollution (smoke), type and quality of stoves used, type of coal and firewood used, access to technology in the local area, social relations, current condition and adoption of technologies. These observed factors helped validate the data obtained through questionnaires or complement and better contextualise the research findings.

During observations, the researcher developed good relations with participants. This allowed the researcher to better understand the participants' day-to-day life. In some cases, I (as the interviewer) shared some meals prepared by participants using the wood stove or the Wonderbag. Furthermore, the researcher created photographic images and recorded videos with permission of participants and community members. These images helped to visualise researcher's experiences and daily life in project areas.

As per Guest et al., (2013), I positioned myself as an 'observer-researcher', meaning that participants were aware of my presence and purpose. This, however, can impose some risks where only positive comments are received and good behaviour is presented. The method might also include some degree of observer bias and prejudices that can shape the results of the study (Creswell and Poth, 2016). Taking this into account, observation notes were reviewed and consulted with the translators/research assistants on any variations in answers received from the respondents.

Site visits

Site visits allowed the researcher to verify technologies reviewed in project documents, and learn about project operations. For example, the researcher visited the Wonderbag factory and Solar Water Heater installation workshop to learn how these technologies were manufactured and observe the workplace dynamics. The researcher recorded her observations in the fieldwork diary and took photographs of facilities visited. Consequently, the results were triangulated with other data sources, such as semi-structured interviews conducted with project actors.

5.5. Analysis of data process

As per Merriam (1998) the data was analysed simultaneously with the data collection process, using a mixed method analysis approach. This approach ensures that extensive data is fragmented into a brief format, maintaining clear links between the research questions and the summary of findings derived from the collected raw data (Thomas, 2003). This section outlines in detail how the collected data for this research was analysed to obtain robust empirical results presented in Chapters 8, 9, 10 and 11.

Secondary data analysis of carbon offset projects

The analysis of the secondary data is a well-established practice in the quantitative social research (Fielding, 2004). The purpose of this analysis is to systematically re-analyse published data from a new perspective with a view to gain new insights. To analyse the uptake of the carbon offset projects in South Africa, the researcher downloaded the carbon offset project data provided by the UNEP (CDM/JI Pipeline Analysis and Database) as per June 2021. This database included all the projects in the CDM pipeline, e.g., registered, under validation, rejected and so on. Compared to the CDM compliance market, the information in the voluntary carbon market is more difficult to access as it less transparent. Only volume of carbon credits transacted by countries could be obtained and analysed.

To conduct a longitudinal analysis, the researcher analysed in total 129 carbon offset projects registered with the CDM (57), Programme of Activities (PoA) (31), Gold Standard (24) and Verra (17) (see Table 7). This investigation helped to contextualise the historical development of carbon offset projects in South Africa taking into account a number of carbon offset projects registered and carbon credits issued in the country. The full list of carbon offset projects analysed is provided in Appendix A6

Table 7: Number of carbon offset projects analysed

Carbon Standards	Total number of projects analysed
CDM	57
Programme of Activities (PoA)	31
Gold Standard	24
Verra	17
Total	**129**

Source: Authors' compilation

The project data was disaggregated and grouped by project type, size, location and emission reduction claimed by these projects during the carbon crediting period[21]. Subsequently, I compared these emission reduction claims with the relevant South African sectoral emissions, such as chemical, metal, mineral, waste, residential, agriculture, forest and other land use sectors. This information was needed to understand any effects carbon offset projects made on the economic sectors.

The secondary data analysis provides the first step into the analytical process to answer the research question. However, it remains descriptive and does not capture any market actors' experiences and perspectives. I therefore combine this method together with other research methods, such as semi-structured interviews, to obtain more rigorous and independent research findings for this study.

Thematic Analysis

To answer the first, second and (partially) the third sub-research questions, the researcher applied an inductive thematic analysis of the interview data received from 27 market actors and 24 project actors. This approach allowed the researcher to search for themes that emerge to form a pattern of the data collected (Fereday and Muir-Cochrane, 2006). This approach enabled the researcher to generate codes from the data itself to fully capture voices of actors.

As part of the analysis process, the researcher transcribed recorded interviews and adopted a rigorous, systematic and repeated reading approach to understand the meaning of the data collected (Creswell and Poth, 2016; Thomas, 2003). All questions asked during the semi-structured interviews were double-checked, separating those ones that the study seeks to answer

[21] Crediting period is defined as a period during which GHG emissions are verified and issued by the carbon offset projects. For the CDM, crediting period can be either 10 or 7 years with an option to renew twice for a total amount of 21 years. For Gold Standard projects the crediting period is 5 years, whereas Verra offers 10-year crediting periods that can be renewed twice (Michaelowa et al., 2019).

and the others that were simply included to understand the topic. As per O'Connor and Gibson (2003), these questions were necessary, but not essential to answer the research question.

To provide meaning to the data, the researcher coded the data received from market actors and organised it into themes using a Discourse Network Analyser (DNA). More details on the DNA are provided in the next section. Responses of project actors were coded and thematically analysed using Atlas.ti (The Qualitative Data Analysis and Research Software). Although some pre-determined codes were assigned, the data analysis was rather guided, but not confined by pre-determined coding. Instead, the researcher applied an iterative process by constantly refining coding and merging similar themes to avoid any duplication (Rivas, 2012). Alternatively, new coding was created for any emerging meaningful theme. To provide data integrity, the emerging themes were continuously examined for any similarities and differences within the dataset.

However, Roberts et al., (2019) argues that thematic analysis may be ambiguous and include researchers' projections. The author explains that the stronger the researcher's ideology, the more they are likely to project a judgement. Riessman (2011) adds that coding may cause 'detail and specificity to slip away in favour of general statements about the phenomenon of interest' (p. 311).

To overcome these issues, the researcher coded large sections of text instead of individual words to avoid any ambiguity and misinterpretations. To ensure consistency in the data, the researcher adopted Saldaña's (2021) systematic coding approach, which requires the researcher to identify a pattern that is 'repetitive, regular, or consistent occurrences of action/data that appear more than twice" (p. 5). Throughout the coding process, the researcher remained close to the raw information as prescribed by Boyatzis (1998) to avoid any impositions of interpretations on the dataset. The research findings presented in Chapter 8, 9 and 10 include the main themes that emerged from the data.

Discourse Network Analyser

To assess perceptions of market actors in the South African carbon offset market, the researcher uploaded the interview data into a DNA software program developed by Leifeld (2010). The DNA is a dynamic research tool that captures, evaluates and visualises arguments provided by actors (Leifeld, 2010). It is considered to be an effective tool for this type of research as it helps to map out market actors in the carbon offset market and cluster their arguments into discourse coalitions.

This tool is widely perceived to be reliable and has been extensively used to analyse environmental policies related to renewable energy and climate mitigation policy issues (Bulkeley

2000; Díaz and Gutiérrez, 2018; Rennkamp et al, 2017; Rennkamp, 2019; Wagner and Payne, 2017; Schneider and Ollmann, 2013) - including the political ecology of carbon offset markets (Lovell et al., 2009).

To analyse the data, each statement was coded with the following three variables: the name of the organisation that participated in the study, the issue addressed by the actor and a dummy variable to classify the actors' arguments on the issue as either positive or negative. The data was clustered at the organisation level with 'concepts' defined as storylines (Hajer, 1993) provided by an actor. Figure 5 presents an example of the dataset in the DNA.

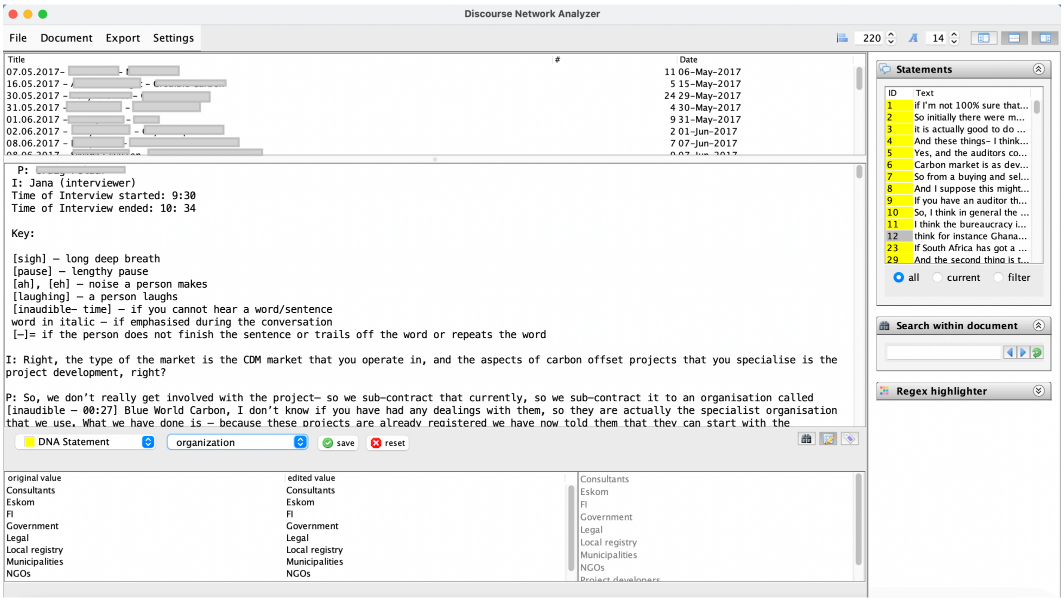

Figure 5: Example of the organised dataset for the coding process. Source: Authors' compilation

A discourse network structure is created as soon as actors share their storylines on a particular topic and their views either overlap or diverge, forming a discourse coalition. A discourse coalition is understood as 'the ensemble of a set of storylines, the actors that voice these storylines, and the practices that conform to these storylines, all organized around a discourse' (Hajer, 1993).

To analyse 'actor-concept' statements, the data is organised into a two-mode network (affiliation) (Leifeld, 2017 – see Figure 6). Each affiliation network includes binary statements – either positive or negative arguments about an issue. To visualise the network of competing coalitions, a bipartite graph is created using visone, a JAVA-based software. This representation enables the researcher to present various market actors in the South African carbon offset market and analyse emerging debates in a comprehensive manner (see Chapter 8).

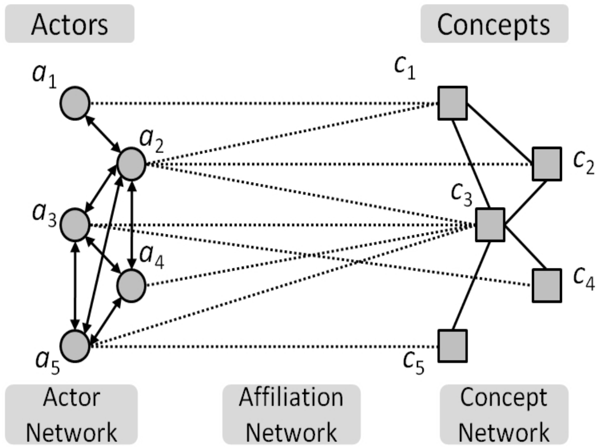

Figure 6: Structure of the discourse network analysis. Source: Leifeld, 2017

However, scholars identify a problem of transparency when using software packages for coding qualitative data (Bassett, 2004; Johnson 2015). For example, Johnson (2015) explains that a researcher can over-rely on coding, which may have been carried out in a mechanistic manner over a long period of time, thus losing sight of the broader context. To overcome this issue, coding is conducted through continuous detailed readings of raw data to derive themes and interpretations made from the raw data by the researcher (inductive approach) (Thomas, 2006). Despite the limitations, the DNA software remains the most suitable tool for this study. It allows the researcher to visualise the results in a comprehensive manner, represent actors with similar storylines and investigate who dominates the carbon offset market in South Africa.

Likert-Type Scale

To complement the assessment of project actors' responses, the study makes use of the Likert-Type scale (Robson, 1993). The Likert-Type scale, originally developed by Renis Likert in 1932, is a well-established tool, which helps to analyse attitudinal data (Dittrich et al., 2007). The purpose of this ranking scale is to understand complex phenomenon, such as opinions and perceptions, and capture them in an ordinal scale format (Likert, 1932). In this research, Likert-Type Scale helps the researcher categorise project actors' responses and evaluate how carbon offset projects are implemented.

As soon as project actors' statements are coded using the inductive thematic analysis technique mentioned earlier in this chapter, each response within a theme is assigned a numeric value based on the three-point Likert-Type scale: 'High' (3), 'Medium' (2) or 'Low' (1) (see Table 8). It is important to note that ranking is based on researcher's best ability to interpret project actors' responses. The results are therefore approximate and may change as time lapses. To determine the intervals that responses fall into, the researcher determines the range of the three-point Likert-Type scale as $2/3 \cong 0.66$. The boundary for each category is established as follows:

Table 8: Boundary values

Internal boundary value	1 - 1.66	1.67 - 2.33	2.34 - 3.00
Category	Low	Medium	High

Source: Author's compilation

Following this, the researcher establishes a composite score for each theme using parametric tests that include mean and standard deviation (Norman, 2010). The parametric test is based on the assumption that the sample obtained from the research data is normally distributed (Norman, 2010).

An important limitation of using Likert-type scale to investigate perceptions and attitudes is that the results are inherently numerical. Since the results are aggregated and measured by the mean, this method may include a loss of information between category thresholds (Glass, Peckham and Sanders, 1972). The researcher acknowledges this limitation and argues that the sample size in this research is relatively small and includes between 2 to 6 projects actors within a theme. This allows the researcher to have an overview of all responses. To avoid any loss of data, the researcher analysed the frequency of responses for each theme and supports arguments with relevant quotes where needed. This analysis is further triangulated with other methods, such as researchers' observations and household surveys.

Project costs and emission reduction analysis

To calculate costs of each carbon offset project, the researcher adopts the following approach. The information on total costs was obtained during the interview with the project developers. The information on emission reduction of each carbon offset project was obtained from the Monitoring reports of each project published by the carbon standards (Verra, Gold Standard). Approximate total costs per technology per tonne of CO_2e, is calculated:

$$Total\ costs_{\ technology/tCO_2e} = \frac{Total\ costs}{Total\ tCO_2e\ issued\ by\ carbon\ offset\ project}$$

Annual emission reduction per user per tonne of CO_2e is estimated as follows:

$$Annual\ emission\ reduction_{\ user/tCO_2e} = \frac{Total\ carbon\ emissions\ issued_{\ year}}{Total\ number\ of\ users_{carbon\ offset\ project}}$$

This information helps to understand how much investment is approximately needed to set up carbon offset projects versus the emissions reduced by a carbon offset project.

Questionnaire data analysis

To answer the fourth and partially third sub-research questions, the researcher conducted a total of 113 household surveys with participant households in four project areas (see Chapter 6 for details on project areas). The main focus of this analysis is to assess impacts on households' livelihoods of low-carbon technologies before and after carbon offset project intervention. The researcher used a combination of different techniques to ensure a rigorous analysis of data is achieved. They are presented and described as follow.

Deductive thematic analysis

Following the data collection process, the researcher transcribed all the household surveys. To ensure that the most accurate translation is provided, the researcher checked transcriptions of questionnaires with the translator two or three times. The data on demographics and socio-economic household characteristics, including energy use of households was entered and analysed using MS Excel software.

All transcripts were uploaded in Atlas.ti software and coded systematically using deductive thematic analysis, also called as a 'top-down' or a 'theory driven' thinking (Boyatzis, 1998; Wiltshire and Ronkainen, 2021). The researcher used a template coding approach outlined by Crabtree and Miller (1999). This process allows the researcher to use a template of pre-determined themes based on a set of indicators (see details on indicators in the next section). The researcher could evaluate the data in a structured and organised way that is in line with the Sustainable Livelihood Approach, the theorised conceptual framework chosen for this study (see Chapter 3).

Although this analysis is understood as a linear systematic step-by-step process (Fereday and Muir-Cochrane, 2006), the data analysis was iterative and reflexive. It allows the researcher to understand the authenticity and coherence of responses and interpret how well they 'fit' within the context of the study (Tobin and Begley, 2004).

During the analysis, the researcher looked for evidence in the data to identify a common pattern of responses that are in line with pre-determined themes (indicators). This involved repeated reading of the transcripts to absorb the details and check if experiences by the first respondents were also consistent with other respondents in the study. Following this, the researcher counted and clustered responses for each theme using MS Excel software.

Summative content analysis

During repeated reading of transcripts, the researcher detected that respondents in two carbon offset projects (Wonderbag and Wood stove) kept using specific words to describe the value of the received low-carbon technologies. As result, the researcher conducted a summative content analysis. To capture respondents' immediate reactions, the researcher inductively coded the keywords and counted the frequency of responses. This analysis provides a useful insight into how and what words are used in relation to technologies introduced in project areas.

Although this method may eliminate researcher's projecting subjectivity (Bryman, 2016) and provide an opportunity to study the phenomenon of interest in an unobtrusive and nonreactive way (Babbie, 1992), Bryman (2016) points out that it has a cognitive limitation. The method does not take into account any nuances of complex situations. Over-focusing on key words may lead to insufficient understanding of the data (Bryman, 2016). To overcome this limitation, the researcher uses content analysis as a complementary technique to the deductive thematic analysis to analyse households' responses. Its purpose is to enhance understanding of an issue and strengthen research design and empirical results.

Indicator selection process

The data obtained from household surveys for this study was analysed using indicators. The researcher performed an indicator selection process using a deductive approach, which is theory-driven and based on the Sustainable Livelihood Approach. Ashley and Carney (1999) advocate that there is no specific method or tool available that prescribes how changes in livelihoods should be analysed. A range of methods can be employed to evaluate projects' impacts, as long as the underlying principles of the Sustainable Livelihood Approach are maintained.

The use of indicators is considered to be an important assessment tool in this study. They are able to summarise, focus and condense complex situations to a manageable amount of context-specific information (Singh et al., 2009; Innes and Booher, 2000). However, Scerri and James (2010) argue that the use of indicators can fail to explain the nature of human relationships and present a relatively abstract view of things.

Taking this limitation into account, as per Scerri and James (2010), I combine and interweave a number of quantitative and qualitative indicators in the analysis of this study. They help to measure changes of livelihoods in absolute terms and assess qualitative claims about users' experiences with low-carbon technologies before and after carbon offset project interventions.

I developed project-specific indicators that can be broadly compared across all selected projects. The indicators are of qualitative and quantitative nature. The quantitative indicators include a measurable unit (kg, Rand, litres, time), whereas qualitative ones are analysed based on a frequency of households' responses. Data is triangulated with additional data sources, such as observations, relevant grey and academic literature sources, to provide reliable and credible results.

Carbon offset projects in this study have different project life cycles, hence changes in livelihoods occur and materialise at different times. For example, some carbon offset projects have been in operation since 2012, while others (Brickstar Wood stove) were only launched in 2016 (see Chapter 6). The 'time-related' boundary is set to measure the impact 'before' and 'after' carbon offset project intervention.

Each carbon offset project is assessed using five livelihood level impacts described in Table 9 focused on three capitals: physical, human and social capitals because they are the most relevant for this study. I did not focus on financial capital, e.g., people's savings, as it is not relevant. The same applies to natural capital, e.g., biodiversity, land changes or irrigation systems. However, there are also additional aspects of livelihood which are important and not related capital, e.g., energy consumption, household budget and gender time allocation.

Table 9: Overview of livelihood level impact criteria and indicators for the study

Livelihood level impact criteria	Indicator	Description	Unit
Physical capital	Perceived value of a technology	Perceived advantages of a new technology	qualitative
Human capital	Health and wellbeing	Perceived changes in smoke by households	qualitative
		Perceived changes in health and wellbeing (symptoms)	qualitative
	Hygiene and sanitation	Average water consumption per bathing facility per person	litres
	Perceived technology safety	Technical issues or accidents/burns experienced by households	qualitative
Social capital	Social relations	Social engagement and experiences shared among and within households	qualitative
Gender labour allocation	Cooking time	Average time spent on cooking a meal	hours
	Convenience	Convenience factors/activities experienced by a household	qualitative
	Time required to collect firewood	Average number of trips needed to collect firewood per year by households	number of trips
Energy consumption	Energy use	Average monthly amount of coal consumption per household	kg
		Perceived saving of fuel-based electricity per household	qualitative
		Average monthly amount of firewood consumption per household	kg
Household budget	Energy costs	Average monthly costs of coal per household	Rand
		Average monthly costs of electricity per household	Rand
		Average monthly costs of firewood per household	Rand

Source: Authors' compilation

The objective is to examine if identified indicators provide any explicit indication of any changes in livelihoods created before and after carbon offset project interventions. Livelihood level impacts are defined in this study as follows.

Physical capital refers to basic man-made infrastructure for the supply of energy, equipment, tools, roads available to the households (Scoones, 1998 – see Chapter 4). In this study, physical capital of a technology does not improve the infrastructure of an area, but is defined as a new object received and used by households. A technology can be also a skill or knowledge that improves the existing physical capital. Physical capital is measured using the indicator of 'Perceived value of technology'. This indicator examines households' perceptions on advantages of using the technologies and their importance within households (see Table 9).

Human capital considers indicators, such as 'Health and wellbeing', 'Hygiene and sanitation' and 'Perceived technology safety'. The indoor air pollution (smoke) and any changes in health and wellbeing are analysed using households' perceptions (see Table 9). To provide an indication of improved hygiene and sanitation, the researcher examines if there are any changes in water consumption as a result of SWH intervention. A 'Perceived technology safety' is assessed based on technical issues reported by households using the SWH and any accidents/burns experienced with the wood stove (see Table 9).

Social capital includes an indicator of 'social relations' that assesses social relations and experiences shared among households on low-carbon technologies received through carbon offset projects (see Table 9).

Energy consumption relates to the quantities of energy used by households as part of their household strategies. Households' fossil-fuel and firewood consumption are measured in kg, whereas the electricity consumption is assessed using households' perceptions. Due to multiple activities carried out in the house, it is not possible for households to allocate electricity consumption to various household devices (see Table 9).

Household budget includes energy costs of households using new technologies. It is measured in Rand and closely relates to household capital, e.g., the type and the amount of fuel used by a household (see Table 9).

Gender labour allocation refers to the amount of time women allocate to their daily chores. The researcher analyses if low-carbon technologies help reduce 'Cooking time' by assessing average time spent on cooking a meal. Furthermore, an indicator of 'Convenience' is used to assess any convenience factors experienced by households as a result of introduction of new technologies (see Table 9). An indicator of 'Time required to collect fire wood' assesses if households are able to reduce their number of trips to collect firewood as a result of project intervention (see Table 9).

These indicators are not intended to stand alone and the study does not analyse the nuances or any differences between individual households. In contrast, the indicators provide a snapshot of the collective outcome of livelihood changes as a result of carbon offset project interventions. The next section will explain how these indicators are analysed in more detail.

Analysis of indicators

To evaluate changes in livelihoods in a consistent manner, the researcher applies a Multi Criteria Assessment (MCA). It is the most prominent research methodology among academic assessments of carbon offset projects to date (Olsen 2007; Heuberger et al., 2007; Nussbaumer, 2009; Sutter and Pareño, 2007; Nussmauber, 2009; Crowe, 2013). This method is considered to be 'ideal' for capturing complex and multi-dimensional issues of livelihoods (Giampietro et al., 2006, Nussbaumer, 2009; Drupp, 2011). It permits the use of several quantitative and qualitative indicators and is elaborate (Olsen and Fenhann, 2008).

The MCA involves a process of assigning weighted scores for each indicator relevant to their importance and aggregating these scores to measure the overall impact (Sutter, 2003). The weightings are derived from the stakeholders' participation, who decide on the importance of each criterion (Olsen and Fenhann, 2008). However, Nussbaumer (2009) argues that the method of assigning weights by individuals may be arbitrary and judgement driven with possibly conflicting objectives.

Furthermore, using weights to embody magnitude of importance implies theoretical inconsistency (Nussbaumer, 2009). The author explains that sustainable development indicators are understood as trade-offs and not as importance factors. Another important weakness of this method highlighted by Giampietro et al., (2006) is that aggregation of scores can lead to technical 'incommensurability'. The author explains that scores cannot be reduced to each other as they may be defined in different units or at different scale (economic loss and loss of biodiversity over a century). Nussbaumer (2009) adds that scores can also be valued against each other (environmental degradation versus job creation) providing weak comparison and misleading results (Nussbaumer, 2009).

Despite these limitations, this method is still well suitable for this study and provides a consistent comparison of livelihoods changes created by carbon offset projects. The method was successfully deployed by using a desk-based analysis of project documents scholars mentioned above to evaluate 'potential' sustainable development impacts of the CDM projects. However, in this study, the researcher takes a slightly different approach and analyses 'actual' and 'realised' impacts created by carbon offset projects. This approach provides more accurate and authentic results, capturing realities at the local level.

As per Nussbaumer (2009), the researcher's objective is not to establish ranking, but to apply scores to primarily compare and discuss impacts created by carbon offset projects. To address limitation of this MCA method, the researcher does not aggregate any scores. As all changes in livelihoods are equally important, scores remain unweighted in this study. The analysis is derived from the data obtained using household surveys.

The data of indicators measuring quantitative impacts on livelihoods (energy use and energy costs) was estimated using MS Excel software (see Table 10).

Table 10: Overview of indicators' data analysis

Livelihood level impact criteria	Indicator	Unit	Analysis
Physical capital	Perceived value of a technology	qualitative	Count
Human capital	Health and wellbeing	qualitative	Count
	Hygiene and sanitation	litres	Count
	Perceived technology safety	qualitative	Count
Social capital	Social relations	qualitative	Count
Energy consumption	Energy use	Coal use (kg)	Estimated
		Electricity use (qualitative)	Count
		Firewood use (kg)	Estimated
Household budget	Energy costs	Costs of coal (Rand)	Estimated
		Costs of electricity (Rand)	Estimated
		Costs of firewood (Rand)	Estimated
Gender labour allocation	Cooking time	hours	Count
	Convenience	qualitative	Count
	Time required to collect firewood	number of trips	Count

Source: Authors' compilation

Since the study includes different incommensurate quantitative and qualitative impacts to livelihoods, the researcher came up with a simplified system to cluster responses provided by respondents in a meaningful way. For example, to evaluate quantitative indicators, the researcher applied the following scores:

Table 11: Overview of scores related to quantitative indicators

Indicators	Description	Score
Energy use	Significant improvement in energy saving (kg) when compared to the baseline	Positive
	No impact on energy savings (kg) when compared to the baseline	No impact
	Significant negative energy saving (kg) when compared to the baseline	Negative
Energy costs	Significant improvement in energy savings (Rand) when compared to the baseline	Positive
	No impact on energy savings (Rand) when compared to the baseline	No impact
	Significant negative energy saving (Rand) when compared to the baseline	Negative

Source: Authors' compilation

To measure impacts on livelihoods of qualitative indicators, the researcher adopts a counting approach (see Table 10). As soon as responses are counted and evaluated, the researcher applies the following scores:

Table 12: Overview of scores related to qualitative indicators

Indicators	Description	Score
• Physical capital • Human capital • Gender labour allocation • Social capital	Responses significantly outweigh negative responses that create a positive change in livelihoods when compared with the baseline.	Qualified Positive
	Responses provide mixed feedback (+/-5%) in relation to a particular livelihood impact when compared with the baseline.	Qualified Ambiguous
	Responses significantly outweigh positive responses that create a negative change in livelihoods when compared with the baseline.	Qualified Negative

Source: Authors' compilation

The results of livelihood level impacts measured through indicators are presented and discussed in Chapter 10. The next section explains how the data collected using researchers' observations is analysed and used in this study.

Analysis of observations

The researcher applied a thematic analysis approach to the data collected from observations. Although the researcher had pre-determined themes that she observed, the researcher read and re-read the fieldwork notes, coded statements and refined codes to avoid any duplication, to make gradual sense of the complex situation in project areas. The data was analysed using Atlas.ti software.

During the analysis, most researchers' observations were in line with data received from the household surveys. However, in some instances, researcher observations ran counter to the data of household survey. For example, in the BM carbon offset project respondents indicated 'less' or 'no' smoke when using the BM method (Chapter 11). In contrast, the researcher observed smoke in several instances, whilst collecting the survey responses. This was mainly due to the fact that some stoves were not properly cleaned and/or the majority of respondents used poor quality stoves (see Chapter 11).

Furthermore, the researcher found some contradictions in the household survey data reported by respondents in the BM carbon offset project. For example, the majority of respondents (64%) confirmed that people knew about the BM method in Wesselton. However, the analysis of researchers' observations shows that there was no awareness of the BM method in the project area. All these contradictions were accurately noted and included in findings presented in Chapter 11. To confirm impacts on smoke and visualise technical issues (plumbing issues and leakage), housing infrastructure and the types of stoves used, the researcher used photographs taken during the fieldwork. Research observations were triangulated with household surveys and presented in Chapter 11.

5.6 Positionality and reflexivity

Conducting fieldwork in South Africa requires some knowledge and understanding on the country's historical background and social local realities. For a researcher there was a constant need to assess positionality and fine-tune the objectives and the script of the research project in response to unexpected events (Jones et al., 1997). Throughout the fieldwork, I kept reflecting on my identity and maintained a position as an 'outsider'. This helped to avoid making any judgments and provide impartial results. I presented myself as a PhD researcher from the University of East Anglia in the UK conducting research in South Africa. This helped to set the scene for further discussions or questions and establish an 'outsider' relationship that is neutral and unbiased.

However, Jones at al. (1997) argue that a researcher's position can be affected by gender, race, ethnicity and political beliefs. Taking this into account, despite all the efforts to position myself as an impartial researcher, I was often seen as a white privileged individual, who brought 'hope' to the area and could resolve people's struggles. To avoid any wrong rumours in the areas and eliminate any biased results of the study, my presence was announced by area leaders. I constantly talked to people on the streets to reiterate and confirm my rightful position as a researcher.

During the fieldwork in the townships, some racial differentiations were noticed. For example, some people in project areas declined to participate in the study or interrupted the interviews, as they felt uncomfortable to be interviewed by a white person. This behaviour did not influence the quality of data but prolonged the time of data collection. Furthermore, some participants tried to involve me in discussions on socio-economic issues, their struggles and domestic politics. However, I continuously reminded them of my position as a researcher coming from a foreign country to avoid any conflicts and maintain neutrality. Despite all the challenges, the rigour of the data was always the top priority and relevant measures were immediately taken to overcome any challenges experienced during the data collection process.

5.7 Ethical considerations

This research was conducted according to ethical guidelines and approved by the University of East Anglia's Committee on Ethics on 26 January 2017. The confirmation of ethics clearance can be found in Appendix A8

The identity of all participants was protected and anonymised. Non-disclosure agreements were signed with project developers upon their request. Before conducting interviews and requesting any project documents necessary for this research, all participants were made aware of the research and its objectives. Informed consent was obtained orally or in writing prior to the interviews. All interviews were recorded with permission of participants. With participants' approval, videos were recorded and photographs were taken where necessary for this research.

Households that participated in household surveys were incentivised with a small gift to show appreciation for their time and willingness to be part of this research. Gifts were chosen in consultation with local research assistants, who were familiar with communities in project areas. Depending on the area, gifts ranged from an educational colouring book to personal care products, such as soap, toothpaste and snacks.

Prior to the data collection process, confidentiality agreements were signed with all research assistants, who helped with the translation during the household surveys. All research assistants were trained on how to conduct interviews and position themselves with households. All data collected was kept confidential. However, findings will be shared with all market and project actors that participated in this study. Results from household surveys will be disseminated to the leaders in the project areas, who will notify households that participated in the study. Findings will also be presented in form of publications to inform academic community, policy makers and industry.

5.8 Limitations of the study

Although the study unveils important results and checks were performed to verify the collected data, this research still contains some methodological limitations that should be considered when reading the results. The main limitation of the study is time constraint and a lack of resources. Under these circumstances, the level of sampling provides the best available data.

The results in this research are largely based on respondents' memories, perceptions and feelings. During the household surveys, some respondents could not remember certain aspects and tried to create stories that did not make sense. Some respondents were under the influence of alcohol, which could only be detected halfway through the conversation. As a result, these respondents were excluded from interviews and data was cleaned accordingly.

In this research information could only be obtained on what respondents regarded as true and valid in their opinion. There might be subjectivity in each respondent's response, which is beyond control of the researcher. However, since the research was triangulated using different data sources, a degree of verification and data confirmation was achieved.

Language barriers and some issues in translation were another limitation. Due to the fact that local languages have long and complex sentences, it was difficult for research assistants to provide the exact translation at the time of the interview. As a result, details during conversations were sometimes omitted. To minimise the risk of lost translation, interviews were transcribed and checked with translators, to capture any missing details. In situations where answers were unclear, follow-up visits were arranged with respondents to double check the information.

There were also some limitations in the data collection process. In some provinces, e.g., Mpumalanga and Limpopo, the process of data collection was often interrupted by extreme weather events, e.g., storms or unbearable heat, or street crime that caused delays and prolonged the fieldwork period. The walking street plan was sometimes amended due to an unsafe environment and the presence of gangsters in the area. To minimise any personal risks and those of the research assistants, the fieldwork was conducted in compliance with ethical considerations (see prior section). Before conducing any interviews with participant households, the project areas were studied in advance and interviews with community leaders were arranged to introduce research and gain awareness of any pertinent issues in the areas.

5.9 Chapter Summary

This chapter introduced the methodology of this study. This study is of a qualitative nature adopting a multiple case study approach. The study uses a mixed-method approach and combines qualitative and quantitative data. The chapter presented a number of methods to answer the research question. They include secondary data analysis (longitudinal approach), semi-structured interviews, household surveys, site visits and observations. The chapter explained the sampling technique and the target groups: market actors, project actors and participant households.

Data analysis is performed simultaneously with the data collection process. The research uses both an inductive and deductive approach to code and analyse the data. A discourse network analyser is deployed to evaluate perspectives of market actors in the South African carbon offset market. To evaluate and rank responses obtained from the project actors, the researcher uses a Likert-type scale. The chapter makes use of qualitative and quantitative indicators to assess changes in livelihoods after carbon offset project interventions. The impact of indicators is measured using scores based on the Multi Criteria Assessment.

To conclude, the chapter presented researcher's positionality, ethical considerations and some limitations of the study. It is hoped that having elaborated this method clearly, the valuable aspect could be replicated in the future. The following chapter (Chapter 6) will introduce the case studies and their selection process.

Chapter 6: An introduction to the carbon offset project case studies

This chapter explains the sampling process for the four case studies selected. Following this, the four case study projects are introduced. The details of each project are presented - including their locations including geographical context, households' conditions and livelihoods in the project areas.

6.1 Selection of case study projects

This research applies a purposive case study selection. As per Patton (2002), purposive selection helps to select information-rich cases that provide an in-depth understanding of an issue and offer an opportunity to learn (Denzin and Lincoln, 2008). Le Compte and Preissle (1993) point out that a criterion-based selection, e.g., a list of attributes, needs to be created to provide guidance for identifying and selecting the most representative cases.

Since this study focuses on small-scale household energy efficiency projects outlined in Chapter 2, I conducted a desk-based analysis of these projects registered with the CDM, Verra and the Gold Standard. In total there were 36 projects (see Table 13 and Appendix A7). The desk-based analysis reveals that all carbon offset projects under the Programme of Activities (PoA) and the CDM remained dormant due to the collapse of the global carbon price in 2012. Furthermore, projects registered under the Gold Standard were dominated by the Basa Magogo fire technique (n=13), followed by household lighting projects run by Eskom (n=2), wood stove projects (n=2) and others.

Since there was a limited number of functioning projects available, sampling became a matter of stratifying projects based on accessibility, project actors' willingness to participate and share information beyond self-reported, publicly available project documents. First, I established a target population of small-scale household energy efficiency carbon offset projects registered in South Africa with the CDM, PoA, Verra and the Gold Standard (see Table 3).

Table 13: Target population of household energy efficiency registered carbon offset projects and selected carbon offset projects

Carbon offset projects	Household energy efficiency projects	Selected carbon offset projects
Gold Standard	22	2
CDM Programme of Activities (PoA)	9	1
CDM	3	
Verra	2	1
Total	**36**	**4**

Source: Authors' compilation

Second, I contacted all project developers in the project target population and enquired as to their willingness to participate in the study. Thereafter, a number of researchable projects was subsequently narrowed down to four – all of which are studied in this research (see Table 14).

Table 14: Outcome of the selection process

Selected carbon offset projects
Wonderbag
Solar Water Heater PoA
Basa Magogo
Brickstar wood stove

Source: Author's compilation

The projects' context information is presented in Table 15. It shows diverse characteristics of the selected projects, such as the range of the four different carbon standards, different start dates, project locations and funding structures. Projects are so diverse that parameters cannot be controlled. As a result, case studies were required.

Table 15: Selected carbon offset projects in this research. (Collected in 2017)

Project context	Wonderbag	Basa Magogo	Solar Water Heater	Brickstar wood stove
Location	Cape Town	Ermelo	Johannesburg	Tzaneen
Province	Western Cape	Mpumalanga	Gauteng	Limpopo
Townships/ Villages	Langa	Wesselton	Cosmo City	Burgersdorp, Bonn
Carbon standard	Verra	Gold Standard	CDM	Gold Standard
Project start date	2010	2010	2012	2015
Project timeline	In operation	In operation	Inactive	In operation
End date	2020	2020	NA	2025
Type of technology	Cooking device	Fire technique	Solar water heater	Wood stove
Project funding	Private	Loan	Subsidy	Grant
Management structure	Private business	NGO	Private business	NGO
Community type	Urban	Urban	Urban	Rural

Source: Author's compilation

Based on the framework set out in this study, these niche innovations play an integral part in this study. They connect actors and create networks in a local industry (e.g., installers, business partners, carbon consultants and local communities) (Chapter 9). They create technological independency between all actors to facilitate change. However, they may also be vulnerable to actors' vested interests, landscape pressures and consumers' personal preferences.

Their characteristics, such as technology design, durability including seasonal changes, maintenance requirements, social relations and users' willingness to change, will influence the user's choice on whether to adopt or not and, therefore, help determine the magnitude of the overall GHG emissions reduced in the long-term. These factors are examined in detail in the empirical Chapter 9. The next section will explain the site selection within each project case study.

6.2 Field site selection

Each project has been implemented in several different locations – between 5-15 (see Table 16). Resource constraints prevented the researcher from visiting every location, and therefore different township and village locations were assessed for suitability. A primary concern was safety - sites were sought which, according to University Principles, presented a lower risk assessment (places with a lower crime rate). As a result, five location sites were selected: Langa, Cosmo City, Wesselton, Burgersdorp and Bonn.

In relation to the Brickstar wood stove project, two locations were chosen. The wood stove was rolled out at different timelines, e.g., Bonn in 2016 and Burgersdorp village in 2018 (6 months before conducting fieldwork for this study). To compare project users' continued technology adoption, it was necessary to choose both locations for the analysis. All selected research site locations are depicted in Figure 7.

The next section provides detailed description of each selected carbon offset project. It outlines the background of the selected site locations, living conditions and vulnerability context of residents in these locations.

Table 16: Carbon offset project sites

Selected carbon offset projects	Provinces	Townships/ Villages	Selected location sites	Approximate target population size
Wonderbag	Western Cape	Langa, Philippi, Lavender Hill, Crossroads, Nyanga	Langa	52,401
Solar Water Heater	Gauteng	Tembisa, Alexandra, Cosmo City, Tshwane, Diepsloot	Cosmo City	50,000
Basa Magogo	Mpumalanga	Sakhile, Duduza, Masetjhaba View, Bluegum View, Ermelo, Wesselton	Wesselton	28,154
Brickstar wood stove	Limpopo	Burgersdorp, Gabaza, Bonn, Myakayaka, Mangweni, Molati, Berlin, Ntsako, Sedan, Mafarane, Lefara, Rita, Ritakop, Sunnyside, Tikiline	Burgersdorp Bonn	6,347 2,752

Source: Author's compilation

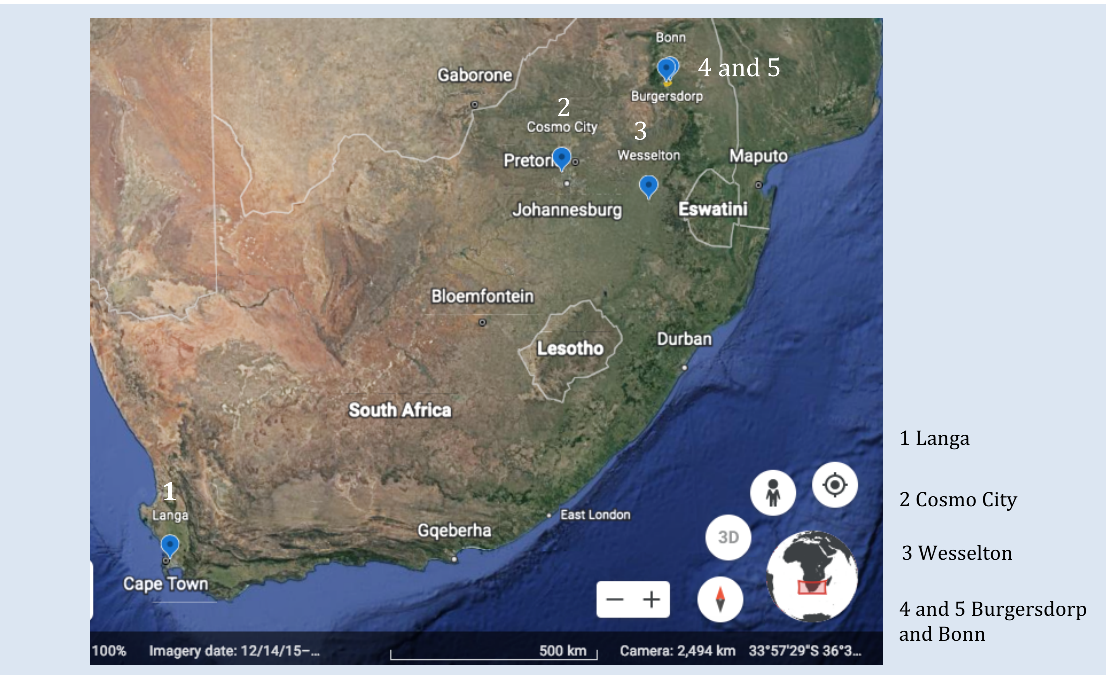

Figure 7: Map of South Africa, showing locations of selected sites. Source: Google Earth

6.3 The Wonderbag project

The Wonderbag (WB) project was registered as a carbon offset project in 2010. The WB is a thermally insulated bag, which helps low-income households to reduce consumption of coal-based electricity and other fossil fuels like paraffin and coal. The objective of this project was to reduce indoor pollution, improve health and save time on cooking (Natural Balance, 2012). Ingredients, especially samp (the traditional Xhosa meal consisting of corn kernels and beans) is typically brought to a boil and then transferred to the bag, where it continues to simmer for up to 12 hours without using any additional energy sources (Natural Balance, 2012) (see Figure 8). This project was funded mainly through private funds. The project developer distributed over 600,000 cooking devices between 2010 and 2019 across the country (Claassen, 2021).

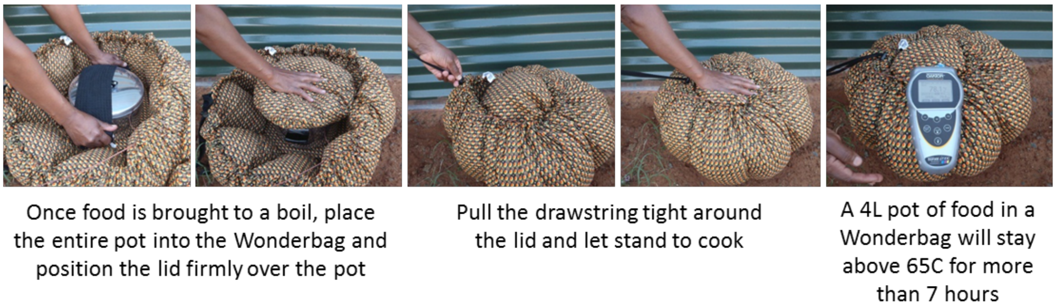

Figure 8: Illustration of the use of the 'Wonderbag'. Source: Natural Balance, 2012

6.3.1 Research location for the Wonderbag case field study: Langa Township

This study focuses on the community in Langa township, located 12.4 km from Cape Town (see Figure 9). Langa was one of many areas in South Africa that was designated for black people during the apartheid era. It was the oldest and most central township that was built on the periphery of the city (Powell, 2014). The settlement is occupied predominantly by black, isiXhosa-speaking South Africans, who mainly came from the Eastern Cape as migrant labourers (Powell, 2014; Ralphs, 2008). Langa has an estimated population of 52,401 (City of Cape Town, 2013). The majority of households received their WBs free of charge at the environmental workshop, called the Smart Living workshop, organised by the City of Cape Town, three or four years ago before this study was conducted. The workshop aimed to educate residents on energy saving, water consumption and biodiversity.

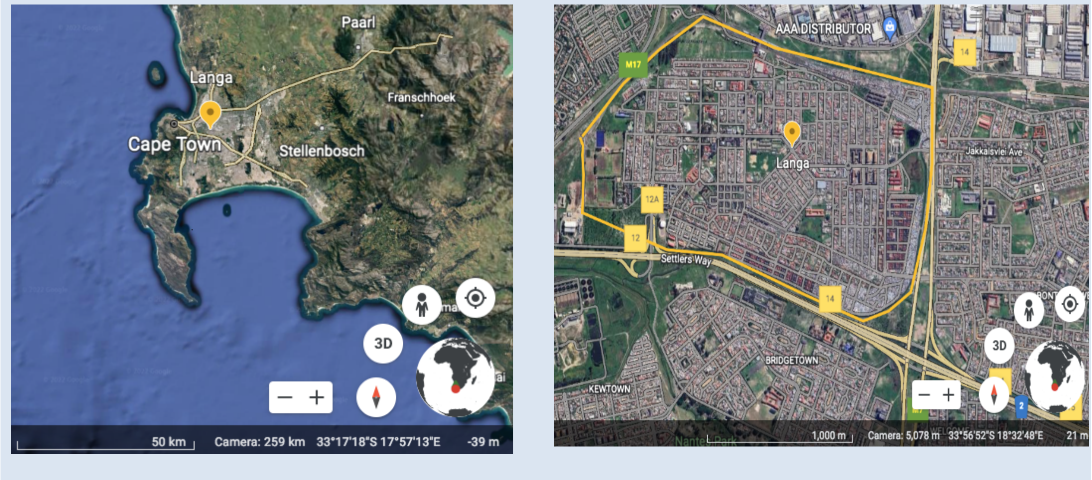

Figure 9: Location and map of Langa township. Source: Google Earth

6.3.2 Living conditions

The majority of people in Langa live in formal dwellings with access to adequate basic services, such as electricity, water, sanitation and refuse collection, known as Reconstruction and Development Programme (RDP) houses (see Photo 1). These houses were given free by the government to low-income families. However, there are also some households in informal housing, such as hostels and shacks in the backyard of an RDP house (see Photos 2–4). A backyard shack consists of a single room in which households undertake all their daily activities (Turok and Borel-Saladin, 2016; Observations, 2017).

Households that occupy hostels use them as a temporary accommodation, while being on a waiting list to receive an RDP house. Households typically rent a bed but share toilets and a kitchen with other hostel residents. Living conditions in hostels are very poor. The rooms are overcrowded, and hostel dwellers have little or no privacy and are exposed to inadequate sanitary conditions (Segar, 1991; Gontsana, 2019; Observations, 2017). Langa township faces various obstacles such as poverty, lack of education, high levels of crime, substance abuse, teenaged pregnancy and approximately 70% adult unemployment rate (St. Mary, 2020). The township is believed to be the area with greatest prevalence of HIV/AIDS infection in the Western Cape Province (Ndabula, 2008). The majority of residents depend on government pensions due to old age, disability or disease like Tuberculosis (TB).

Photo 1: Typical RDP House, Langa township. Source: Fieldwork, 2017

Photo 2: Shack in the backyard of an RDP house, Langa township. Source: Fieldwork, 2017

Photo 3: Hostels, Langa township. Source: Fieldwork, 2017

Photo 4: Flats, Langa township. Source: Fieldwork, 2017

All households living in RDP houses, hostels and shacks in the yard of RDP houses are electrified in Langa. However, since electricity is expensive, households try to combine its use with a variety of energy sources, such as paraffin and gas. For example, they often use electricity for cooking small dishes that require shorter cooking time. Gas is typically used for meals that need to be cooked for longer periods (e.g. meat, stews, beans). Since the majority of people heat their homes with paraffin in winter, they also use the heaters, the so-called 'Primastove', for cooking food at the same time (Observations, 2017).

6.4 The Solar Water Heater project

The SWH carbon offset project was part of the governmental SWH demand-side management intervention announced in 2009 (See Chapter 7, section 7.2.2). To take advantage of the revenue from carbon credits earned by saving greenhouse gas emissions through SWH installation, the project was set up as part of the POA under the CDM in 2012. The project was mainly funded through government subsidy and the private partnerships established in the Clean Development Mechanism. The objective of this project was to help reduce the consumption of coal-based electricity, uplift and improve living standards of low-income households, provide skills and knowledge of a new SWH technology and create employment (CDM, 2012). In 2012, shortly after SWHs were installed, the carbon price collapsed and it was not possible to monitor and maintain the carbon offset project, hence the project never issued any carbon credits and remained dormant.

6.4.1 Research location for the SWH case field study: Cosmo City Township

The study was conducted in Cosmo City, a township 25 km northwest of Johannesburg (Gauteng province) (see Figure 10). Cosmo City is a relatively new housing development, built from 2004 to 2012. It is home to some 12,500 families of two informal settlements that were situated nearby, called Zevenfontein and Riverbend (Haferburg 2013).

Cosmo City is one of the first South African urban developments to integrate low-cost and middle-class housing within a single suburb (Haferburg, 2013). It has a multi-cultural community pre-dominantly accommodating approximately 50,000 isiZulu-speaking black South Africans and some foreigners coming from other African countries, such as Malawi, Zimbabwe and Nigeria (Mosito, 2018). The carbon offset project distributed approximately 500 SWH units to households here.

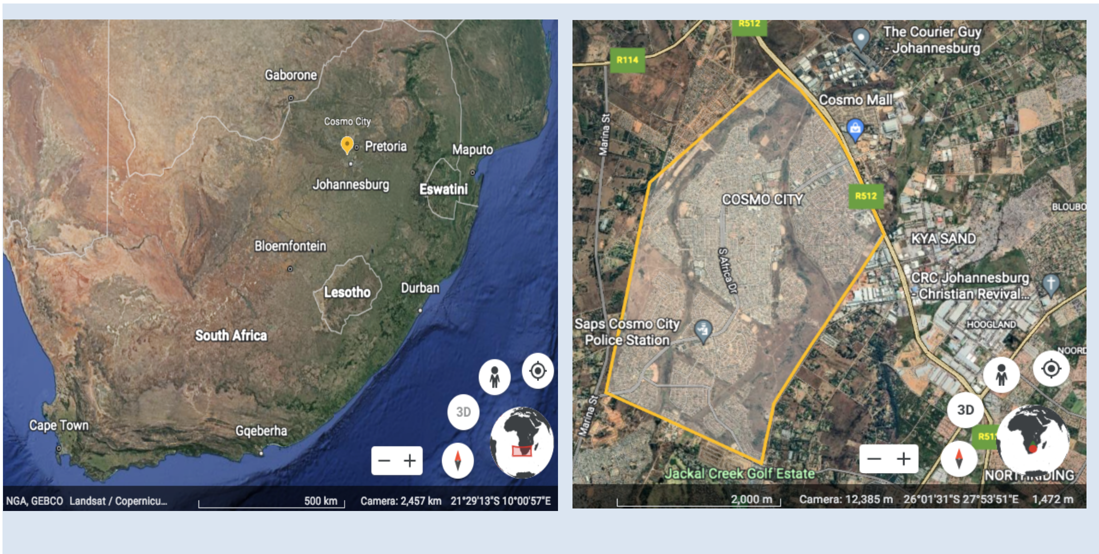

Figure 10: Location and map of Cosmo City. Source: Google Earth

The Johannesburg Metropolitan Municipality (JMM) also referred to as the City of Johannesburg was responsible for allocating SWHs to low-income households living in government-delivered RDP homes. Details on the decision-making process and the criteria how these households were selected could not be obtained due to changes in governmental officials.

6.4.2 Living conditions

All residents in Cosmo City live in newly built RDP houses (see Figure 11) and have access to basic services, such as piped water inside the dwelling, sewerage, and rubbish collection. All houses are connected to electricity and the majority of households use electricity for cooking. Similar to Langa township, they also make supplementary use of paraffin, electricity and gas (Observations, 2018).

Figure 11: Urban dwellings of Cosmo City township. Source: Fieldwork 2018

6.5 Basa Magogo project

The Basa Magogo (BM) project was registered as a small-scale carbon offset project with the Gold Standard in 2010 and implemented by Nova Institute (an NGO) with the aim of reducing air pollution in the area. The project was funded through a 10-year loan with ICCO-Kerk in Actie's Fair Climate Fund of the Protestant Church in the Netherlands and the Embassy of Denmark (Danida).

The BM project does not provide a technology as do other projects selected in this study. Instead, it is an alternative ignition fire technique, called the Basa Magogo (which translated from Zulu means 'Light up, grandmother') that helps residents to reduce smoke coming from the fire. In contrast to the traditional method of making fire (a bottom-up method) that follows the order of putting paper, wood and the coal, the BM method reverses the traditional ignition technique. It requires loading coal at the bottom, followed by paper and wood kindling, with some coal added on the top, hence it is called a top-down technique. The BM method causes less, or even eliminates, visible white and black smoke (see Figures 12 and 13) (Gold Standard, 2011). The BM project claims to have reduced a total of 200,000 tCO_2e between 2010 and 2020. Approximately 80,000 coal users across Mpumalanga, Gauteng and Free State were taught how to use the method (van Niekerk, 2017; Gold Standard Impact Registry, n.d.).

Figure 12: Imbaula stove using the traditional bottom-up ignition method

Figure 13: Imbaula stove ignited using the Basa Magogo method

6.5.1 Research location for the Basa Magogo case field study: Wesselton Township

The research is carried out in Wesselton township, which is located on the outskirts of Ermelo in Mpumalanga province. It is the most important area in the mining industry. The majority of South Africa's coalfield reserves are located in the so-called Central Basin, which includes the Witbank, Highveld and Ermelo mines (see Figure 14). Wesselton accommodates approximately 28,154 isiZulu-speaking black South African residents (Census, 2011a).

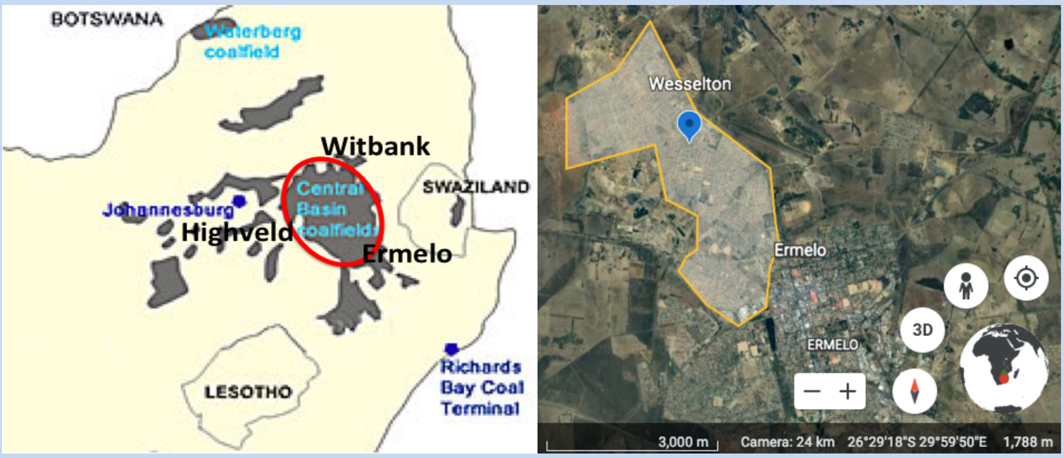

Figure 14: Maps of South Africa's major coalfields and Wesselton township. Source: Eberhard, 2011; Google Earth

The region contributes to most of South Africa's emission inventory industrial particulates, sulphur dioxide and nitrogen oxides (DoE, n.d.). The indoor air pollution in this area was reported to be 20 times higher than the World Health Organisation-recommended threshold (Masekameni & Mbonane, 2017). This imposes major health risks to the local population and is declared by the

South African Government as the National Priority in the Management Air Quality Act (DEA, 2012). The poor air quality results from a large concentration of industrial infrastructure, e.g. Eskom's coal-fired electricity generation plants, the use of low quality coal by households, waste burning, and mining activities (DoE, n.d.). The indoor and outdoor air pollution from domestic activities in the township is illustrated graphically in Photo 5.

Photo 5: Indoor and outdoor pollution in Wesselton township. Source: Fieldwork, 2017

6.5.2 Living conditions

Wesselton township has a mix of formal (RDP houses) and informal dwellings (see Photo 6 and 7). While the majority of dwellings are fully electrified, some households, especially in informal settlements, use illegal electricity connections due to high electricity prices. They also do not have basic infrastructure, such as water, sanitation and waste removal services (Observations, 2017). According to the councillor, many families in Wesselton township live in poverty due to high unemployment (70%) and low levels of education (Mnisi, 2017). Households use mainly coal and wood for cooking and heating (Observations, 2017). These fuels are much cheaper than electricity. Coal is the most attractive fuel source for households in this township, as it provides thermal energy for space-heating and cooking at the same time.

Photo 6: Formal dwellings, RDP houses, Wesselton township. Source: Fieldwork 2017

Photo 7: Informal settlement, Wesselton township. Source: Fieldwork, 2017

6.6 Brickstar wood stove project

The Brickstar wood stove was rolled out in 2016 across the greater Tzaneen area of Limpopo province. More than 60% of local communities in Limpopo use wood as their primary energy source for cooking. However, it is predicted that at the current level of firewood consumption, the forest around the villages will be depleted within 13 years (Wessels et al., 2013). Although all households in the greater Tzaneen area are electrified, they still traditionally cook their meals on an open fire outside their homes or in separately built kitchens. However, these cooking practices cause major health hazards, such as cough, asthma etc. As a result, the objective of this project is to reduce the consumption of fuel wood and improve the indoor air quality due to less smoke being generated by the wood stove (Gold standard, 2015).

Together with some residents, Nova Institute developed a more efficient cookstove suitable for residents' daily cooking practices and needs. The wood stove is made out of local materials, such as clay and cow dung (see Photo 8 and 9). The same mixture is used to create 25 bricks necessary for the stove's construction. The project developer agreed that households make and provide these bricks in exchange for the stove installation (Gold Standard, 2015).

The carbon offset project was funded by the overseas grant provided by the Energy and Environment Partnership Trust Fund (EEP Africa), which was hosted and managed by the Nordic Development Fund (NDF), with funding coming from Austria, Finland and NDF. Since the project is still at the beginning of its cycle, it has only distributed 2,655 wood stoves to households in greater Tzaneen.

Photo 8: *Brickstar wood stove. Source: Fieldwork, Burgersdorp village, 2018*

Photo 9: Brickstar wood stove in operation. Source: Fieldwork, Bonn village, 2018

6.6.1 Research location for the Wood stove case field study: Burgersdorp and Bonn

Burgersdorp and Bonn villages are located approximately 32-40 km south east of Tzaneen (see Figure 15). In total, Nova Institute distributed approximately 495 wood stoves to residents in Burgersdorp in 2018 and 34 wood stoves in Bonn in 2016 (Reyneke, 2018). Burgerdorp has a total population of 6,347 people (Wikipedia, n.d.), whereas Bonn has 2,752 residents (Census, 2011b). Most residents are from the Tsonga tribe, which originally migrated to South Africa from Southern Mozambique.

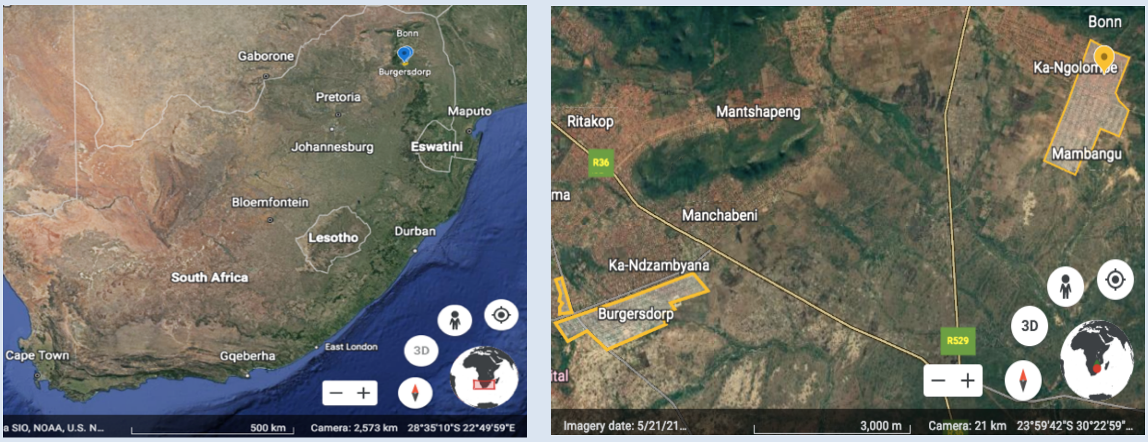

Figure 15: Location and map of Burgersdorp and Bonn village. Source: Google Earth

6.6.2 Living conditions

All residents in Burgersdorp and Bonn villages live in formal brick houses. Both villages are fully electrified. According to the ward councillors, the main challenges faced by households in these villages are the poverty, high levels of unemployment (40%), crime, early pregnancies and the water crisis e.g. drought (Lepulane, 2018; Phakula, 2018; Banyini, 2018). There is uneven access to basic services, such as water supply. While Bonn village has a communal borehole, in Burgersdorp the majority of residents are forced to buy water from neighbours or others who have a borehole (Observations, 2018). Most households in the villages primarily use wood for cooking. Since electricity is expensive, it is only used for warming up food or preparing small meals, such as eggs or oats for breakfast. Big meals, such as stews, meat or mealie meal (maize meal or pap) require long cooking hours, hence they are cooked using firewood (Observations, 2018).

6.7 Chapter summary

The chapter introduced the four case studies selected for the study – the Wonderbag, SWH, Basa Magogo and Brickstar wood stove project. Each case studies was purposively selected based on fulfilling certain criteria such as accessibility and willingness of project actors to participate and disclose information in the study. The selected carbon offset projects are all small-scale household energy efficiency carbon offset projects targeting low-income urban and rural communities in four different provinces of South Africa.

The formal purpose of these carbon offset projects is to reduce the use of unsustainable fuel sources within households, such as coal-based electricity, coal and wood, reduce indoor pollution and improve health. Although the selected carbon offset projects have different timelines, funding and management structures, these characteristics allow for the exploration of deeper insights and critically analyse outcomes of projects and their impacts on livelihood activities of selected communities. Detailed analysis of these projects are presented and discussed in Chapter 10 and 11.

Chapter 7: Background

This chapter presents the characteristics of South Africa's energy regime. Secondly, it examines the vulnerability of South African citizens to climate change and their socio-economic context (e.g., inequality, poverty, the effects and legacy of apartheid). Thirdly, the chapter analyses international and national climate actions as part of the South African government's response to climate change. It then briefly explains how the carbon market is structured and who the actors are that govern the market. Lastly, the chapter provides an analytical insight into carbon offset projects initiated in South Africa, taking into account their geographical location, project types and emission reductions.

7.1. South Africa's energy regime

South Africa has historically followed a development pathway which has been both capital- and energy-intensive, driven mainly by a concentration of commercial interests in the extractive sector, known as the 'Mineral-Energy Complex' (Fine and Rustomjee, 1996; Marquard, 2006). National economic activities have therefore been dominated by mining, mineral processing, and energy, as well as to a lesser extent finance and manufacturing (Winkler and Marquard, 2009; Scholvin, 2014). South Africa' s total energy production is comprised overwhelmingly by fossil fuels, such as coal (75%), oil (14%) and natural gas (3%). Together they make up 92% of the primary energy supply (as of 2019), followed by renewables including hydro (3%), nuclear (2%) and others (2%) (See Figure 16) (Marquard and McCall, 2020).

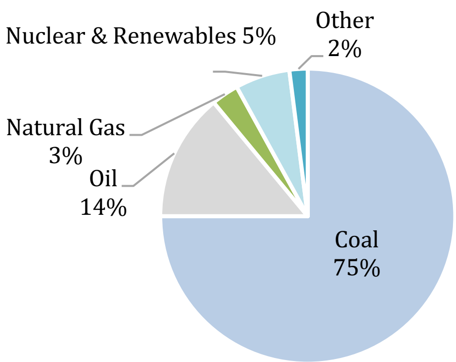

Figure 16: South Africa's total energy production by source in percentage in 2019. Source: Marquard and McCall, 2020

South Africa's GHG emissions in 2019 totalled 474 million tons of Carbon Dioxide equivalent ($MtCO_2$-e) (Enerdata, 2020). The country is the largest polluter on the African continent, accounting for 8.7 tCO_2e/person, compared to Africa's average of 1.1 tCO_2e/person (Statista, 2021). Coal is the key component in the energy mix, and although providing 75% of energy in total, it is used to generate 88% of South Africa's electricity supply in 2019 (Marquard and McCall, 2020). Eskom – South Africa's state-owned power utility – dominates the production, transmission and distribution of coal-based electricity to industrial, mining, commercial, agricultural and residential customers (DMRE, 2021). Scholars note that heavy reliance on coal as the energy source is the main reason behind South Africa's high emission profile (Winkler, 2007; Shikwambana et al., 2021).

Although the inclusion of renewables in the energy mix has been discussed since 2003 (DME, 2003), their share (5%) still remains relatively small (see Figure 7). It is claimed that the South African government is disinclined to move forward and endorse renewable energy generation, and instead makes decisions to expand the coal sector by granting approvals for the construction of new coal-generation plants (Lawrence, 2020).

Eskom is known for its resistance to change towards renewable energy within South Africa's electricity planning and policy arena (Baker, 2015). The utility never publicly blocks renewable energy programmes but employs a strategy of using its control over the value chain to delay the entry of renewable energy technologies. This tactic is called 'malicious compliance', where the company does not explicitly disagree with a government policy but will do what they can to impede it (Morris and Martin, 2015).

Winkler and Marquard (2009) point out that there are three mitigation options available in South Africa: (1) achieve energy efficiency (e.g., reduce demand for energy or use the energy services in a more efficient way), (2) change fuel mix (moving to lower or non-carbon intensive energy sources) and (3) create structural changes to lower the energy intensity of the economy. The scholars state that changing the fuel mix and achieving structural changes cannot be accomplished quickly due to power stations being locked into investments for several decades. As a result, the fastest and least-costly mitigation option would be to address the energy efficiency in industry and the residential sector (Winkler and Marquard, 2009; Aliyu et al., 2018). Scholars claim that household energy efficiency interventions could potentially save around R1 billion and reduce approximately 4 $MtCO2$-e by 2025 (Winkler and Marquard, 2009) as well as improve livelihoods, e.g., reduce energy costs and environmental pollution (Aliyu et al., 2018). How household energy efficiency interventions improve livelihoods in South Africa will be further explored in this thesis.

7.2 The 'landscape' pressure

This section reviews and critically discusses various factors that influence the landscape of the socio-technical transition in South Africa. These factors include citizens' vulnerability to climate change and their socio-economic context. The section describes the magnitude of climate change impacts on human life and the government's response to climate change.

7.2.1 Vulnerability of South African citizens to climate change

South Africa has experienced increasingly severe weather events that caused devastating effects on its citizens (primarily the poor). For example, increased rainfall in Western Cape, Mpumalanga, Limpopo, KwaZulu-Natal, Gauteng and Eastern Cape resulted in massive flooding, which especially threatened human settlements along the coast, informal settlements located on high or degraded slopes in urban areas, and marginal groups living in rural areas (Chikulo, 2014; Dube et al., 2021; Ngarava et al., 2021).

The history of apartheid makes some South African communities more vulnerable to climate change than others. Winkler and Marquand (2009) and Barnwell (2021) argue that their vulnerability is deeply rooted in racial oppression, which created extreme economic, infrastructural, health and geospatial inequalities. For example, due to the inherited spatial segregation of residential areas, the urban Black population mainly resides in townships and informal settlements that are situated on the periphery of urban areas along flood plains, riverbanks and wetlands with inadequate infrastructure. As a result of the poor housing structure (where inferior building materials are often used - such as corrugated iron) dwellings are easily damaged, become inhabitable or get simply washed away during storms and floods (Olorunfemi, 2011; Chikulo, 2014; Musungu, 2016; Satterthwaite et al., 2018).

The government has long recognised climate change not only as an environmental problem, but as a developmental concern (DEA, 2012). Evidence indicates that 55% of the population live in poverty, of whom 25% are in extreme poverty, where they cannot even satisfy their basic food needs (Stats SA, 2017). The unemployment rate reached 32.6% in the first quarter of 2021, with the rate of unemployed young people aged 15-34 amounting to 46.3% (Stats SA, 2021).

Almost half of the population (37-47%) had insufficient funds to buy food, which has led to widespread food insecurity, famine and reliance on handouts (Nwosu et al., 2021). Taking these aspects into account, Barnwell (2021) adds that especially families with children, who have low education levels, are unemployed and depend on government aid, have limited or no resources to adapt to extreme weather events and therefore are the most susceptible to climate change impacts.

Le Roux (2021) points out that heat waves have become more frequent, causing wildfires and creating a hazard for informal settlements. Due to extremely hot summer months, there is an increase in discomfort levels or heat stress that contribute to cardiorespiratory disease and death (Tabi, 2013). The WHO (2018) reports that approximately 23,000 people die in South Africa every year from stroke, heart disease, lung cancer and chronic respiratory diseases due to indoor air pollution. Furthermore, Marquard and McCall (2020) estimate that on average there are 44 fatalities and almost USD646 millions of losses (0.11% of GDP) that occur annually due to extreme weather events in South Africa.

Furthermore, Olabanji et al., (2021) predicts that changes in temperature – particularly in summer – will cause a decline in crop yields of maize, dry beans and soya beans, and will pose a serious threat to food security in South Africa going forward. Due to drought and land degradation, South Africa is experiencing an increased climate-related migration and displacement of people (Chikulo, 2014; Hermans and McLeman, 2021).

To conclude, Averchenkova et al., (2019) analyse the governance of climate change policies in South Africa and note that there is a mistrust between players in public and private sectors. Since the private sector is dominated by large emitters, who are wealthy white South Africans, this issue creates greater vulnerability for poorer communities to climate change and further exacerbates the inequality in the country (Averchenkova et al., 2019). Next section will review and critically discuss the government's response to climate change and the policies it has introduced to date.

7.2.2 South Africa's international and national actions

The South African government has been grappling with climate change since at least 1997 when it signed the United Nations Framework Convention on Climate Change (UNFCCC) (See Table 6). There is a long list of policies, plans and programmes that the government has introduced to reduce the country's emissions. Since this research focuses on household energy efficiency innovations, the researcher examines policies that relate to energy efficiency in the residential sector and sustainable development from the date the South African government signed the UNFCCC in 1997 to 2021. Before presenting and analysing South Africa's domestic policies, the next section discusses South Africa's engagement in the international climate change arena.

South Africa's international engagement in climate change

South Africa's engagement in climate change matters begun when it became a signatory of the *United Nations Framework Convention on Climate Change (UNFCCC)*[22] in 1997 (see Table 17). As a

[22] The UNFCCC was formed and adopted in 1992. The UNFCCC came into force in 1994 and there are 197 countries that ratified the Convention (UNFCCC, n.d.(a)).

member of the African Group[23], the South African government plays a leading role and represents a common voice of African countries in international climate change negotiations. The South African government has continuously emphasised climate change impacts and limitations African countries face in addressing them (e.g., limited financial resources). The South African government has been actively seeking financial support (aid, climate change funding) from developed countries for the African continent. For example, the government helped secure a $100 billion Green Climate Fund for developing countries to reduce emission (Nelson, 2016).

Table 17: Overview of key climate change international policies and South Africa's engagement

International climate change policies and South Africa's engagement	Date
United Nations Framework Convention on Climate Change (UNFCCC)	1997
SA Ratification of the Kyoto Protocol	2002
Copenhagen Accord	2009
2030 Agenda for Sustainable Development	2015
SA Ratification of the Paris Agreement	2016
SA Nationally Determined Contribution	2016
Revised SA Nationally Determined Contribution	2021

Source: Author's compilation adopted from Averchenkova et al., 2019

In 2002, the South African government signed the *Kyoto Protocol,* which entered into force in 2005 (see Table 17). However, as a non-Annex I country, the government did not set any targets under the Protocol (Steenkamp, 2017). The Kyoto Protocol is based on the UNFCCC objectives[24] and translates them into a specific action plan. More details on the Protocol's components are discussed in section 7.3.

Later in 2009, under the *Copenhagen Accord*, former South African President, Jacob Zuma, pledged to reduce the country's emissions by 34 percent below 'business as usual' (BAU) levels by 2020 and by 42 per cent below BAU levels by 2025, provided that financial and technical support is received from developed countries (The Presidency Republic of South Africa, 2009). However, no actions were indicated by the President on how to achieve this objective (Armeni, 2010).

The adoption of *2030 Agenda for Sustainable development* is an important step in the field of development. It provides a plan of action on how to achieve sustainable development. For the first

[23] The African group was formed in 1958. It is a regional grouping, which serves as a negotiation coalition and provides a collective platform to discuss on how to pursue the continents priorities on climate change (Chevallier, 2011; Masters, 2011).

[24] The objective of the UNFCCC was to set out a commitment to all Parties in accordance with Article 12 to develop national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol; implement measures to mitigate climate change and facilitate 'adequate adaptation; develop, diffuse and transfer low-carbon technologies to reduce greenhouse gas emissions, including in the energy sector; promote education, training and public awareness on climate change (UNFCCC, 1992; pp. 5-6).

time, developed and developing countries agreed to commit and align their national development priorities with 17 Sustainable Development Goals (SDGs) and measure their progress using 232 indicators (United Nations General Assembly, 2015). The South African government played a key role in the negotiations to ensure that SDGs could be used in complex interrelated development challenges (Croese et al., 2021). In addition, the government provided a strong political motivation to localise the SDGs in national policy agendas (Fourie, 2018).

Since the Kyoto Protocol's commitment period came to an end in 2020, after many years of negotiations, a new treaty, *the Paris Agreement*[25], entered into force in 2016. The South African government ratified the Paris Agreement and announced that it will follow the 'Peak, Plateau and Decline' (PPD) emission trajectory. The government submitted its *Nationally Determined Contribution (NDC)* confirming that it will commit to a total emission reduction in the range between 398 to 614 $MtCO_2$-e over a period between 2025 and 2030 (UNFCCC, 2015). In 2021, the South African government revised its NDC in September 2021 and is now committed to reduce GHG emissions between 398-510 $MtCO_2$-e between 2021 and 2025 and 398-420 $MtCO_2$-e in 2030 (Republic of South Africa, 2021). However, the study carried out by Climate Action Tracker (2020) classifies this climate target as insufficient. Uncertainty in implementation of national policies still remains very high and the government continues to provide mixed messages regarding the transition to a low-carbon economy. For example, to recover from the COVID-19 pandemic, the South African government mainly focused on carbon intensive investments, such as fossil fuel power plants, instead of prioritising and facilitating an effective 'green' recovery across all sectors (Climate Action Tracker, 2020; Chapungu, 2022).

South Africa's national policies

To be in compliance with international agreements, reduce energy demand and curb GHG emissions, the government put in place a number of domestic policies and legal measures. Policies related to energy efficiency in the residential sector and sustainable development are presented in Table 18.

[25] United Nations, n.d. Paris Agreement. Available at: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf [11 June 2022]

Table 18: An overview of South African energy efficiency and climate change policies, regulations and programmes

South Africa's national policies, regulations and programmes	Date
White Paper on the Energy Policy	1998
White Paper on Renewable Energy	2003
National Climate Change Response Strategy	2004
Energy Efficiency Strategy	2005 (revised in 2008)
Electricity Regulation Act	2006
Liquid Petroleum Gas (LPG) DSM programme	2006
SA National Energy Act	2008
National Framework for Sustainable Development	2008
Integrated Resource Plan for Energy 2010-2030	2010
National Solar Water Heater DSM Programme	2010
National Climate Change Response White Paper	2011
National Strategy for Sustainable Development and Action Plan	2011
SA National Development Plan	2012
Compact Fluorescent Lamps (CFLs) DSM Programme	2014
Carbon Tax Bill	2019
Carbon offset regulation	2019

Source: Author's compilation

The *White Paper on the Energy Policy* focuses on the pro-poor agenda to re-address inequality[26] caused by the apartheid regime (DME, 1998). It promotes energy efficiency awareness in households and encourages the use of improved combustion techniques and appliances for fuelwood and other traditional fuels (DME, 1998). Five years later, the South African government recognised the value of renewable energy technologies to diversify the energy supply and published the *White Paper on Renewable Energy* (2003) (See Table 18). The policy sets out a specific target of 100,000 Gigawatt-hours (GWh) of renewable energy contribution to final energy consumption by 2013 (DME, 2003). It states that approximately 4% renewable energy is to be utilised for power generation and non-electric technologies, such as solar water heating and bio-fuels. Assuming that 18% of urban residential electricity consumption could be replaced by solar energy, then the potential savings could come to 5,900 GWh (0.508 Mtoe), which to put into perspective is approximately equivalent to a large coal-fired power station (DME, 2003).

However, the major barrier to the deployment of renewable energy technologies was the availability of cheap electricity in the country. It is reported that South Africa experienced a long period of the lowest electricity prices in the world – on average at approximately R0.25/kWh or

[26] During the apartheid 'over 99% of white households had access to electricity, while more than 90% of black households did not. Electrification stood at 90% among Asians, and 64% among coloureds' (Murphy, 1993 p.53)

less (Edkins et al., 2010). The reason for the cheap electricity supply was the electricity surplus[27] due to overinvestment by the apartheid government in previous decades (Eberhard, 2007) and abundance of cheap coal used in the primary energy mix. As a result, it made it politically and economically difficult to change towards greater energy efficiency and introduce renewable energy technologies (Winkler and Marquard, 2007; Edkins et al., 2010).

After rectifying the agreement with the UNFCCC, the South African government released its first *National Climate Change Response Strategy* (2004) (NCCRS) to address vulnerability to climate change and suggest steps to reduce energy use in the industrial, transport, commercial and residential sectors etc. (DEAT, 2004). The Strategy includes several energy efficient activities - such as improved cooking technologies, the use of solar water heating, efficient lighting and the retrofitting of efficient heating etc. - and endorses the use of innovative financing mechanisms, such as the CDM, to respond to climate change in the medium and long term (DEAT, 2004). This strategy was believed to serve as the basis for South Africa's international negotiations and the development of further national climate change policies (Averchenkova et al., 2019).

Since there were no energy efficiency standards in the country, the government introduced the *Energy Efficiency Strategy* in 2005 (revised in 2008), which spelt out a target of a national final energy demand reduction of 12% and 10% in the residential sector by 2015 (DME, 2005). The purpose of this Strategy is to assist in providing energy for all residents of South Africa, by reducing energy consumption through energy efficiency practices. Similar to earlier policies, this strategy also propagates the use of energy efficient cooking technologies and solar water heating in the residential sector.

However, the implementation of the *Energy Efficiency Strategy* was reported to be challenging. Scholars report fierce resistance to change from the private sector, a lack of capital to implement measures and invest in energy efficient technologies, and a lack of monitoring and verification processes (Rosenberg and Winkler, 2011; Adom et al., 2020).

To regulate energy efficiency and the type of energy sources from which electricity is generated, the government introduced the *Electricity Regulation Act* in 2006. Although it regulates the energy efficiency of the electricity sector, it also includes measures related to consumers. For example, it is the first legislation to introduce a smart metering system[28] for customers with a monthly consumption of 500kWh (Angwe, 2014).

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[27] The term 'electricity surplus' does not consider the fact that until 1993 only one-third of the population had access to electricity in South Africa (Eberhard, 2007).
[28] Section 23 (i) of the Electricity Regulation Act 2006, p. 20 (RSA, 2006)

In contrast, the *National Energy Act 2008* regulates electrical devices as a means of enhancing energy efficiency. The act sets minimum energy standards for various technologies, such as low-smoke fuels, cooking, heating, lighting and other energy consuming household appliances, including motor vehicles and buildings (RSA, 2008). This is deemed to be an important legislation as it prohibits manufacturing, selling and importing electric products and fuel burning devices that do not meet the energy efficient standards[29].

The *Integrated Resource Plan (IRP)* is a key electricity planning document. It identifies the mix of generated technologies and establishes the capacity of renewable energies (wind, solar, hydro, solar photovoltaic panels (PV)) to be fed into the energy mix necessary to satisfy growing demand for electricity and reduce dependence on coal for the next 20-year period from 2010 to 2030 (DoE, 2011). The IRP stipulates that renewable energy will supply 42% of the new additional capacity over the 2010–2030 period, or 9% of the total generated electricity by 2030 (DoE, 2011). However, it also indicates that coal will remain the main energy source with renewable energy remaining on the periphery (DoE, 2013; 2019). To improve energy efficiency at the consumer level, the Plan includes energy efficiency and Demand-Side Management (DSM) incentive schemes.

Due to high poverty and unemployment rates many households in South Africa do not have the means to pay for improved energy efficiency technologies (Angwe, 2014). As a result, DSM programmes were introduced as a viable solution to modify and reduce households' energy consumption. One of the most attractive DSM interventions in the country was the *National Solar Water Heater Programme (2010).* The government aimed to roll out one million SWHs by 2014 and four million by 2030 across the country (DoE, 2009). The DSM programme was managed by the state-owned power utility Eskom and ultimately proved ineffective due to poor planning, challenges in installations and poor management (e.g., no verification, monitoring and quality control) (GIZ, 2015; Kritzinger and Covary, 2016; Netshiozwi, 2019; Mohabir, 2021). Another DSM initiative was the mass rollout of Compact Fluorescent Lamps (CFL) to replace incandescent light bulbs in households around the country. In total, 60 million efficient Compact Fluorescent Lamps (CFLs) were installed free of charge in 2014 and contributed to a verified demand reduction of 2 GW (Overen and Meyer, 2019).

Another DSM initiative headed by Eskom to reduce the electricity load and peak demand, was the introduction of the subsidised *Liquid Petroleum Gas (LPG) stoves* for cooking to at least 100,000 households in low-income areas of Cape Town (Mohlakoana and Annecke, 2009). Although 89%

[29] Section 29 (h) of the National Energy Act 2008 p. 35 (RSA, 2008)

of households successfully adopted the technology, they still used electricity during peak times and decreased their demand by only 20MW (rather than the targeted 40MW).

The *National Climate Change Response White Paper* (2011) is an overarching policy framework, which outlines how to reduce emissions using short-, medium- and long-term perspectives. It includes energy efficiency measures (solar water heating programme) and endorses the engagement in the CDM (DEA, 2011). However, Klausbruckner et al., (2016) criticises this policy for being too broad without any measures being formulated. It is regarded to be simply yet another policy with no concrete actions.

The *National Framework for Sustainable Development (NFSD)* (2008) presents South Africa's national vision of the sustainable development and outlines the development pathway towards sustainability, change in behaviour, values and attitudes (DEAT, 2008). It also emphasises the need for demand-side interventions (solar water heating) and fuel replacement from wood, coal and paraffin to Liquefied petroleum gas (LPG) in the residential sector. However, Rennkamp (2012a) argues that the NFSD never received the priority it deserved as a planning tool due to weak commitment towards sustainability from government departments. Cloete (2015) adds that no coherent action plan was developed to implement or integrate the framework with other governmental programmes.

The *National Strategy for Sustainable Development and Action Plan* (2011) (NSSD) provides a high-level overview of strategic sustainable development. It sets out collective actions on how to facilitate a transition to a green economy and reduce energy demand in all sectors. However, Gupta and Laubscher (2018) argue that the government needs to follow up on already well-established policies rather than introducing new ones. The scholars highlight that the awareness of the green economy is still limited, hence the need to promote it in order to implement initiatives highlighted in the strategy.

South Africa's *National Development Plan (NDP) 2030* maps out specific development priorities (eradicate poverty, reduce inequality, reduce unemployment by 6% by 2030 etc.) for the country (RSA, 2012). Although the NDP was developed before the SDGs were finalised, it is broadly aligned with the SDGs. However, Zarenda (2013) notes that there are no effective monitoring and evaluation systems set up to translate development aspirations and priorities into concrete results.

Although the *Carbon Tax Bill* (specified in Table 18) does not relate to energy efficiency in the residential sector but rather targets the industrial sectors (mining, construction, minerals processing), it is still important to briefly mention this regulation. The tax is set at a rate of

R120/tCO_2-e (€6)[30] per tonne of CO_2e and subject to increase by inflation plus 2% each year. It provides carbon tax-free allowances ranging from 60% to as high as 95% to allow emitters to adjust and transit their operations to cleaner technologies through investments in energy efficiency, renewables and other low carbon measures (National Treasury, 2019).

However, scholars argue that this rate is too low to incentivise the development of energy efficiency and renewable energy technologies. It is deemed to be ineffective in cutting country's GHG emissions unless it starts from R200/tonCO2-e and rapidly increases to R750/tonCO2-e thereafter (Winkler and Marquard, 2011). The carbon tax allows the use of carbon offsets to incentivise South African companies to reduce their carbon tax liability (*Carbon offset Regulation, 2019* – see Table 18). Instead of paying the carbon tax, companies may purchase carbon offsets up to a maximum of 5-10% of their total GHG emissions from projects registered under international carbon standards (CDM, Verra and GS) (National Treasury, 2019).

Summary

Having reviewed the policies above, it is evident that the government has formulated policies in an attempt to try to build up momentum to mitigate climate change and improve energy efficiency at the consumer level. However, the implementation of these policies remained a challenging task largely due to political uncertainty and turmoil caused by 'state capture'[31] over the past 10 years in South Africa, (Averchenkova et al., 2019). Scholars report that there was a lack of capacity in the public sector, limited financial resources and unclear high-level direction among governmental officials (Trollip and Boulle, 2017; Averchenkova et al., 2019).

While the government tries to improve energy efficiency, scholars note that it does not have a plan or a policy for the phase-out of coal power plants (Marquard and McCall, 2020). On the contrary, new coal power plants with a capacity of 1,000 MW are planned to be built by 2030, while already one coal power plant, with a capacity of 6,000 MW, has been commissioned (DMRE, 2019).

[30] The following exchange rate is used throughout the study: 1 Euro = 18.9307 ZAR as per 31 October 2020, Source: XE Currency Converter, available at: https://www.xe.com/currencyconverter/

[31] According to Transparency International (2014), state capture is defined as "a situation where powerful individuals, institutions, companies or groups within or outside a country use corruption to shape a nation's policies, legal environment and economy to benefit their own private interests".

7.3 Governance of the carbon offset market 'sub-regime'

7.3.1 Governance of the CDM

The carbon offset market was created by the Kyoto Protocol[32] in 2005. The Kyoto Protocol includes three market-based mechanisms, the EU Emission Trading System (EU ETS), Clean Development Mechanism (CDM) and Joint Implementation[33] (Hepburn, 2007). The EU ETS is the biggest carbon trading market, set up to reduce emissions in various industrial sectors using a cap-and-trade system[34] across all EU member states (Lederer, 2012; Guo et al., 2020).

The CDM was designed to allow industrialised (Annex I) countries to reduce their GHG emissions in a cost-effective way by purchasing carbon credits from carbon offset projects that avoid GHG emissions in developing (Non-Annex I) countries (UNFCCC, n.d. (b)). Such emission reductions projects include, for example, switching away from fossil fuel, energy efficiency, implementing renewable energy and other related projects. Carbon emission reduction credits created under the CDM are defined as Certified Emission Reductions (CERs).

The CDM has a dual objective, that is, to assist developing countries in achieving sustainable development and industrialised countries in meeting their emission reduction targets (UNFCCC, 1998). The CDM aims to promote and facilitate finance, technology transfer and access to environmentally sound technologies in developing countries (UNFCCC, 1998; Hyams and Fawcett, 2013; Kollmuss et al., 2010).

The CDM regulatory framework consists of several institutional actors, who follow strict and extensive rules and regulations to govern the CDM process (see Figure 9). For example, as per Streck and Lin (2008), the Conference of the Parties serving as the Meeting of the parties (CMP) is the governing body to the Kyoto Protocol. Its role is to make rules and take ultimate decisions of the CDM process. It appoints the CDM Executive Board (CDB EB hereafter). It is responsible for the day-to-day operation of the CDM. It consists of 10 members and 10 alternative members nominated by the CMP. It is responsible for all CDM methodologies, and reviews and approves applications of carbon offset projects. Expert Panels are the accredited UNFCCC experts that

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[32] The Kyoto Protocol is structured into two commitment periods. In the first commitment period 37 industrialised countries agreed to reduce their emissions to an average 5% emission reduction compared to 1990 levels over the five-year period 2008–2012. In the second commitment period, parties pledged to decrease their GHG emissions by at least 18% below 1990 levels in the eight-year period from 2013 to 2020 (UNFCCC, n.d. A).

[33] Joint Implementation (JI) is similar to the CDM, but quantifies emissions reductions from projects that are located in Annex 1 (developed) countries only (Kollmuss et al., 2008).

[34] Cap-and-trade system is a government regulated system where companies are obliged to trade emission reduction certificates to reduce their emissions due to an emission cap set by national governments or the EU Commission (Lederer, 2012).

advise the CDM EB on technical assignments, such as methodologies, registration, issuance, accreditation and appeal.

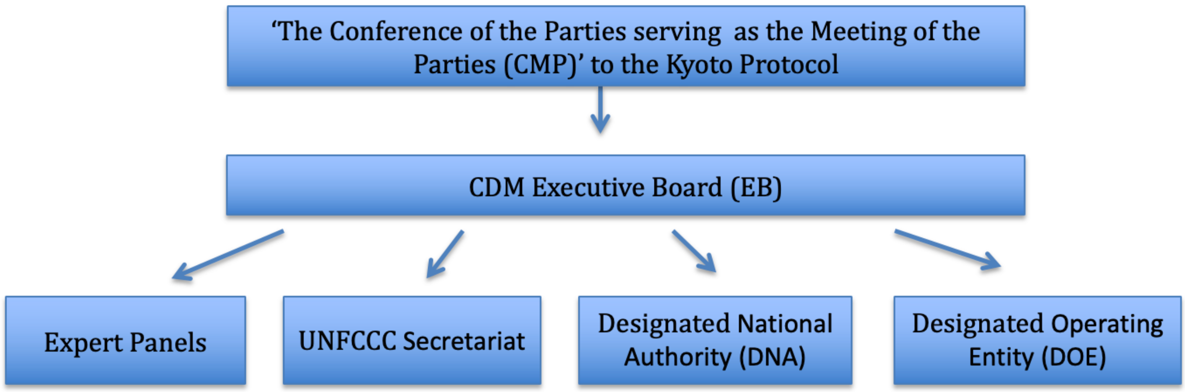


Figure 17: Institutional governance of the CDM. Source: Adopted from Streck and Lin, 2008

The UNFCCC Secretariat fulfils an administrative role for the CMP and the CDM EB. It prepares meeting notes, drafts decisions and guidelines. The Designated National Authority is the regulatory authority created in the host country. It is the first point of contact for the project developers before they can submit their project applications to the CDM EB. The DNA provides a Letter of Approval (LoA) and confirms that projects contribute to sustainable development in the host country. Designated Operating Entities are accredited entities by the CDM EB. They independently validate carbon offset projects and verify their GHG emission reductions before they can be submitted to and registered with the CDM EB (Streck and Lin, 2008).

Carbon offset market post-CDM

The future of the CDM appears to be highly uncertain, given that the second commitment period of the Kyoto Protocol came to an end on 31 December 2020 (UNFCCC, 2020). In fact, the outcome at the COP26 in Glasgow stipulates that carbon offset credits generated by the CDM projects after 2013 can only be used towards achieving the first NDC commitment (2020-2025) (UNEP DTU Partnership, 2021).

Overall, the international climate change regime changed its character from the top-down approach – based on mandatory emission commitments – to the bottom-up voluntary national mitigation targets as soon as the Paris Agreement came into force on 4 November 2016 (Michaelowa et al., 2019a). According to Lang et al., (2019), the nature of the carbon offset market has moved towards voluntary activities, whereby countries now increase their demand for carbon offset credits and are actively involved in the voluntary carbon offset market to achieve their domestic GHG emission targets (Lang et al., 2019; Schneider and Theuer, 2019). The characteristics of the voluntary carbon market is presented in the next section.

Comparison of carbon offset standards

The voluntary offset carbon market consists of different carbon offset standards. They are all based on the fundamental principle that the emission reduction must be real, verifiable, measurable and 'additional' to a business-as-usual scenario. This means that GHG emission reductions would not have occurred had the carbon offset project not been implemented (Bumpus and Liverman, 2008; Newham and Conradie, 2013).

Verra (formally known as Verified Carbon Standard) has adopted methodologies from the CDM and is the leading carbon standard in the voluntary carbon offset market (McFarland, 2010) that issues the majority of carbon offset credits (73%), followed by the Gold Standard (16%) and other standards with smaller trading volume, such as the American Carbon Registry (9%) and Climate Action Reserve (2%) (Berkley Trading Project database, 2022).

Both, Verra and Gold Standard were originally established by a range of different private sector organisations, such as NGOs and non-profit business organisations (See Table 19). The carbon offsets generated by these standards are primarily used for marketing purposes and to meet investors' corporate social responsibility objectives (Streck et al., 2009). Since the emitters do not have any binding emission limits, but still have an ethical reputational incentive, they buy carbon credits to reduce their emissions on a voluntary basis (Kollmuss et al., 2008; Karavai and Hinostroza, 2013; Steenkamp, 2018).

Table 19: Characteristics of carbon offset standards

	CDM	Gold Standard	Verra
Established by	UNFCCC Parties under the Kyoto Protocol defined in Article 12. The mechanism to be discontinued under the Paris Agreement	WWF, SouthSouth-North and Helio International	The Climate Group, the International Emissions Trading Association and the World Business Council for Sustainable Development
Established in	2001	2003	2007
Carbon emission reduction credits	Certified Emission Reductions	Voluntary Emission Reductions	Verified Carbon Units
Transaction volume[35]	2 billion tCO_2e 7,868 projects 100 countries	200 million tCO_2e 924 projects 60 countries (16% of market share)	924 million tCO2e 1,792 projects Over 100 countries (73% of market share)
Sustainable development contribution	No mandatory requirement	Stringent process to comply with UN SGD targets and indicators	No mandatory requirement – Sustainable Development Verified impact
Carbon price[36]	$0.4-$1/tCO2e	$3-$6/tCO2e	$2.71/tCO2e
Process[37]	Highly regulated, complex and strict rules	Complex and demanding requirements	Reduced administrative burden and costs relative to the CDM

Source: Author's compilation, adapted from Kollmuss et al., (2008)

Carbon offset credits that originate from Gold Standard are called Voluntary Emission Reductions (VERs) in comparison to Verified Carbon Units (VCUs) generated from Verra (see Table 19). There is no centralised marketplace for voluntary transactions. Carbon offset credits are traded Over-the Counter[38] (OTC) and are subject to price negotiations (Hamrick and Gallant, 2018). Prices for voluntary carbon offset credits depend on project types and buyers' perceptions of co-benefits delivered by these projects. The more co-benefits a project claims to produce, the higher the price project developers communicate in the voluntary carbon offset market (Karhunmaa, 2016).

[35] UNEP DTU Partnership (2021); Berkley Trading Project database (2022)
[36] Michaelowa et al., (2019a); Hamrick and Gallant (2018); UNFCCC (2017) https://unfccc.int/files/na/application/pdf/04_current_cer_demand_cdm_and_art_6_of_the_pa_nm.pdf (Accessed on 01 April 2020)
[37] Michaelowa et al., (2019b), Kollmuss et al., (2008)

[38] Over-the Counter transactions are direct private sales (e.g not through trading platforms) of carbon offsets to organisations and consumers who want to offset their emissions resulting from their own activities (Ristea and Maness, 2009).

The carbon price of the Gold Standard appears to be the highest among all carbon standards (see Table 8). It is reported that the certification of this standard follows a strict process and requires project developers to commit to deliver socio-economic and social co-benefits to local communities in project areas (Michaelowa et al., 2020). This assures a higher quality of a carbon credit but makes it more expensive than registering with the CDM or Verra carbon standards. The latter two are claimed to be less stringent on requirements to provide sustainable development impacts (Taiyab, 2006).

While scholars criticise CDM for being complex, bureaucratic, highly regulated and expensive (Lövbrand, 2009; Karavai and Hinostroza, 2013; Andonova and Sun, 2019) (see Table 19), Verra was originally created to reduce administrative burden and costs of CDM and bypass bureaucratic government control (Kollmuss et al., 2008; Benessaiah, 2012). However, Betz et al., (2022) argue that over the years the Gold Standard and partially Verra have become stricter with their processes than the CDM. To maintain the integrity, the carbon standards reviewed the guidelines and excluded large-scale grid-connected renewable electricity projects previously accepted by the CDM. They classified them as being non-additional, which meant that these projects were not eligible for carbon finance (Michaelowa et al., 2022).

7.4 Uptake of carbon offset projects – 'technological niche'

7.4.1 CDM projects

The 'technological niche' in this study constitutes carbon offset projects registered under the CDM, Verra and Gold Standard in South Africa. This section analyses and critically discusses current carbon offset projects registered with the CDM, Verra and Gold Standard. In South Africa, the majority of carbon trading was executed through the CDM (IETA, 2015). China and India have hosted the majority of CDM projects (UNEP 2021 - see Table 20), with China having registered 3,764 projects during the 2012–2021 period, accounting for 48% of the total registered projects, followed by India with 1,686 (21%) and Brazil 344 (4%). In contrast, South Africa had only registered 57 CDM projects, accounting for 0.73% of the total (UNEP DTU Partnership, 2021). However, within the African region, South Africa appears to be the leading CDM host country (see Table 21).

Table 20: Total number of CDM projects registered during 2012–2021.

Countries	Number of CDM projects registered	Share of registered CDM projects (in %)
China	3,764	47.89
India	1,686	21.45
Brazil	344	4.38
Vietnam	258	3.28
Mexico	192	2.44
Indonesia	150	1.91
Thailand	144	1.83
Malaysia	143	1.82
Chile	110	1.40
South Korea	91	1.16
Philippines	72	0.92
Columbia	66	0.84
Peru	61	0.78
South Africa	57	0.73
Argentina	46	0.59
Egypt	21	0.27
Rest of the world	675	8.59
Total	**7,859**	**100%**

Source: UNEP DTU Partnership, 2021

Table 21: Top 10 African countries in the CDM market

Countries	Number of CDM projects registered	Share of registered CDM projects (%)
South Africa	57	25.2
Egypt	21	9.3
Kenya	20	8.8
Uganda	19	8.4
Morocco	16	7.1
Nigeria	11	4.9
Senegal	8	3.5
Mauritius	8	3.5
Côte d'Ivoire	7	3.1
Tunisia	6	2.6

Source: UNEP DTU Partnership, 2021

Gauteng is the leading province for registering CDM projects in South Africa having 12 projects (20%), followed by Kwazulu-Natal 8 projects (KZN) (14%), Western Cape 9 (16%) and Eastern Cape 9 projects (14%) (UNEP DTU Partnership (2021) (see Figure 18).

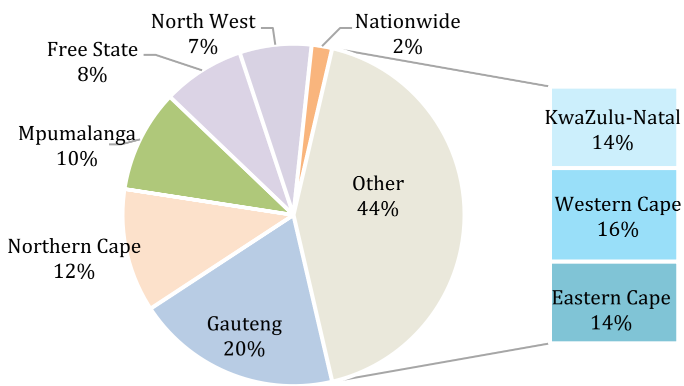


Figure 18: Distribution of registered CDM projects by location in South Africa.
Source: UNEP DTU Partnership, 2021

Being the economic hub for industrial activities, Gauteng mainly attracted large-scale projects, such as landfill site projects, fossil fuel switch, N_2O reduction projects and energy efficiency projects. Similar to Gauteng, the province of Kwazulu-Natal, which plays a leading role in addressing climate change risks in South Africa (Roberts, 2008; Cartwright et al., 2013), hosted a variety of large-scale CDM projects, such as landfill site, energy efficiency and methane avoidance projects. The Western Cape and Eastern Cape provinces mainly introduced CDM wind projects, due to their favourable climate conditions. In contrast, the Northern Cape mainly registered large-scale CDM solar projects due to abundance of sunshine in the province (see Figure 19).

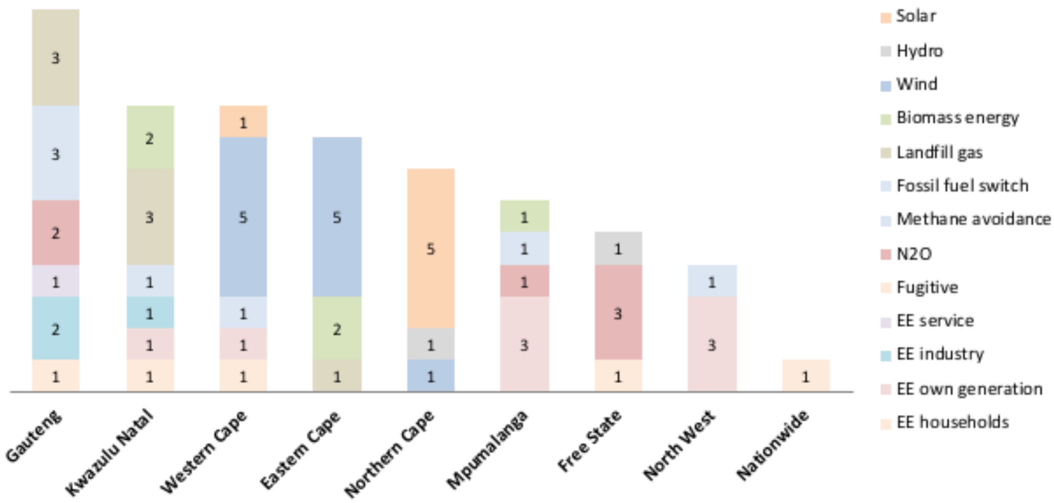


Figure 19: Geographical distribution of registered CDM projects by project type in South Africa Source: UNEP DTU Partnership, 2021

Renewable energy technologies, such as solar and wind, have dominated the CDM market in South Africa. They accounted for more than half of the total projects registered under CDM (26%) and Programme of Activities (48%) together, followed by industrial energy efficiency projects (21%), N_2O, methane avoidance & fugitive projects (16%) and landfill site projects (12%) (see Figure 20).

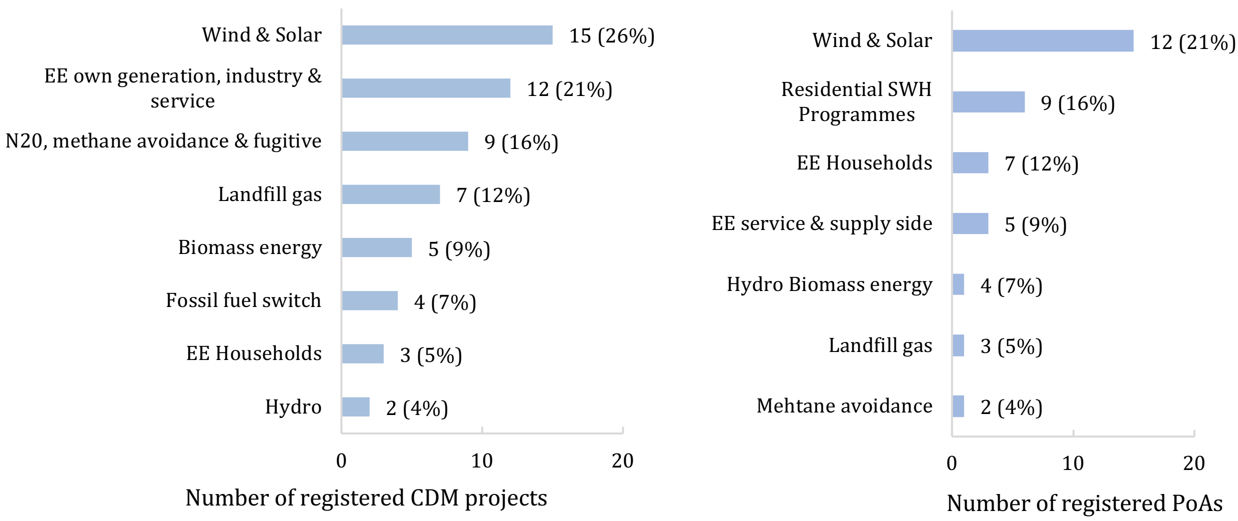


Figure 20: Number of registered CDM projects and PoAs by project types in South Africa Source: UNEP DTU Partnership, 2021

However, the statistical data shows that of 57 registered CDM projects, 19 of them (33%) issued total credits of 17 $MtCO_2$-e during 2012 and 2021 (UNEP DTU Partnership, 2021), whereas the rest remained dormant or stopped operating due to the collapse of the carbon price. Projects registered under PoA generated a total of 1.4 $MtCO_2$-e of carbon offset credits during the same period (UNEP DTU Partnership, 2021). The collapse of the carbon price in 2012 was mainly driven by a deterioration in economic conditions which contributed to a decline in emissions in Europe and an oversupply of carbon credits in the EU ETS (Kossoy, 2012). The carbon price eventually fell from €10 per tonne of CO_2e to €0.50 per tonne of CO_2e limiting the development of all carbon offset projects (Kainou, 2022).

7.4.2 Carbon offset projects in the voluntary carbon market

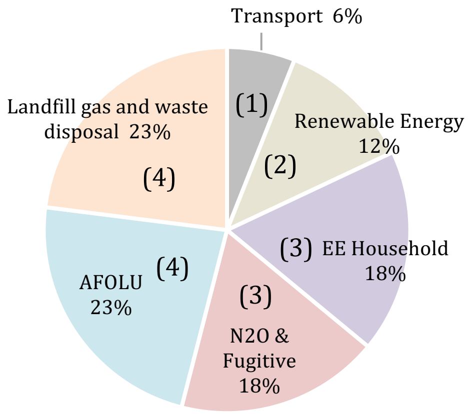
The voluntary carbon offset market in South Africa remains very small in relation to the CDM. In 2018, South Africa only transacted 43,602 tCO_2-e, which appears to be marginal in comparison to the rest of Africa, where Kenya (5.5 MtCO_2-e), Uganda (2.2 MtCO_2-e) and Zimbabwe (2.1 MtCCO_2-e) dominate this market (Donofrio et al., 2019 – see Table 22). These countries mainly host energy efficiency carbon offset projects, such as cookstoves, and forestry projects (Karanja and Gasparatos, 2019; Lietaer et al., 2019; Fisher et al., 2018).

Table 22: Top 10 African countries in the voluntary carbon offset market

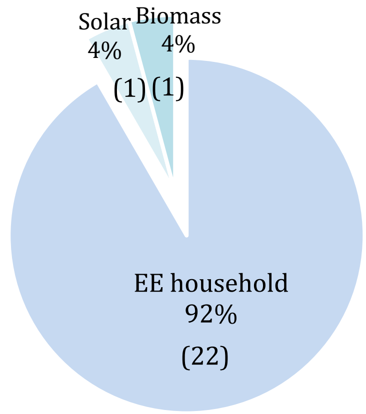
Country	Total Volume (MtCO_2e)	Share of carbon emissions transacted (%)
Kenya	4,997,818	47.49
Zimbabwe	2,246,408	21.35
Uganda	1,089,230	10.35
Ghana	921,757	8.76
Zambia	559,631	5.32
Malawi	462,421	4.39
Ethiopia	156,609	1.49
South Africa	43,602	0.41
Rwanda	25,603	0.24
DRC	20,421	0.19
Total	**10,523,500**	**100**

Source: Donofrio et al., 2019

As at autumn 2021, there are only 17 carbon offset projects registered with Verra and 24 with Gold Standard in South Africa (Gold Standard Impact Registry, n.d.; Verra, 2021) (see Figure 21). Similar to the CDM, the voluntary carbon offset market is dominated by large-scale industrial carbon offset projects, e.g., landfill gas/waste disposal (23%) and N_2O, fugitive (18%) carbon offset projects. The statistical data shows that there are also other projects, such as Agriculture, Forestry and Other Land Use (AFOLU) (23%) or a transport project (2%). However, these projects remained dormant and did not generate any carbon offset credits, due to the collapse of the carbon price in 2012. 23 projects registered with the Gold Standard mainly consist of small-scale household energy efficiency carbon offset projects, the so-called Basa Magogo fire technique, improved cook stove projects and lighting projects (see Figure 21).



No. of projects registered with Verra



No. of projects registered with GS

Figure 21: Total number of projects registered with Verra and GS. Source: Verra, 2021; Gold Standard Impact Registry, n.d.

South African carbon offset projects under Verra issued approximately 4 $MtCO_2$-e of carbon credits from 2012 to 2021 (Verra, 2021), whereas projects under GS claim to have only reduced a total of 0.24 MtC_2Oe between 2010 and 2020 (Gold Standard Impact Registry, n.d.). When comparing the emission reductions achieved by carbon offset projects with the relevant sectoral emissions[39] of the country, it is evident that these projects hardly made a dent in reducing emissions in these sectors (see Table 23). Carbon offset projects in the CDM, PoA, Verra and Gold Standard collectively reduced approximately 20 $MtCO_2$-e between 2011 and 2021 – when compared to the emissions of the relevant industry sector, these reductions pale into insignificance.

[39] The sector classifications and their emissions are obtained from DFFE (2021, p.115). The sector emissions dated as of 2017 are the latest emissions available in these sectors in South Africa.

Table 23: Comparison of issued carbon credits by all carbon offset projects with SA's sectoral emissions between 2010 and 2021

Sectors	Total emissions in 2017 (GgCO2-e)	CDM ($MtCO_2$-e)	VCS ($MtCO_2$-e)	Gold Standard ($MtCO_2$-e)	PoA ($MtCO_2$-e)	Total carbon credits issued per sector ($MtCO_2$-e) (2011-2021)
Chemical Industry	893	12.20	1.94	0.00	0.0	14.14
Metal industry	20,889	1.02	0.01	0.00	0.0	1.03
Mineral Industry	20,389	0.18	0.22	0.00	0.0	0.41
Residential	17,997	0.01	0.29	0.23	0.10	0.62
Waste	6,257	3.53	0.67	0.00	0.00	4.20
AFOLU				0.01	0.00	0.01

Source: DFFE, 2021; Verra, 2021, Gold Standard Impact Registry, n.d., UNEP DTU Partnership, 2021

However, most carbon credits generated by the CDM projects were sold to developed countries, e.g., United Kingdom, Norway, Switzerland, Germany etc. (see Figure 22) and consequently do not generally get accounted for as emission reductions for the associated South African sector. The buyers in the voluntary market could not be determined as the sale of carbon credits is confidential ('Over-the Counter').

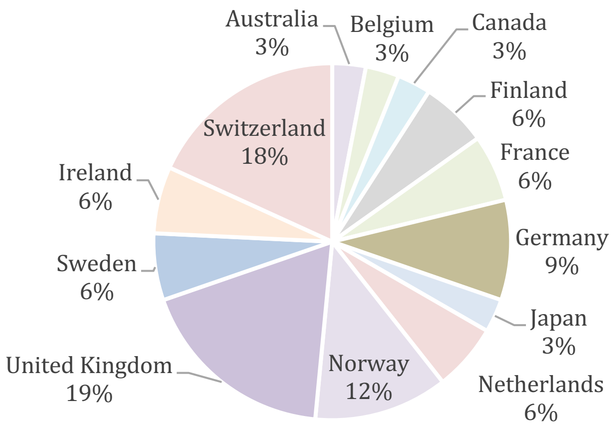


Figure 22: Buyers of CDM projects Source: UNEP DTU Partnership, 2021

7.4.3 Local carbon offset projects

There have been some unique developments in the South African carbon offset market. A local carbon registry called Credible Carbon was set up in 2007 to address the reportedly slow cumbersome process experienced in the CDM, reduce transaction costs and allow small-scale projects to enter the local carbon offset market (Newham, 2013). Credible Carbon is reported to be using the CDM methodology to register the projects. The projects are then independently audited by recognised entities, e.g., the University of Cape Town's Energy Research Centre, the Green House, SouthSouthNorth, Urban Earth and Carbon Calculated (Credible Carbon, n.d.) to ensure that emissions reductions are correctly recorded, and projects make a "discernible impact on poverty" (Credible Carbon, n.d.).

To successfully achieve the poverty alleviation impact, Newham (2013) claims that the local registry emphasises the need of acknowledging workers and employees as equitable stakeholders in carbon offset projects. As part of the project registration process, project developers are required to outline how poverty alleviation benefits will be delivered. Project developers apparently made a commitment to the Credible Carbon registry that at least 60% of the net carbon revenue is returned to the project beneficiaries, e.g., workers and employees, in the form of cash (Credible Carbon, n.d.). It was reported that some AFOLU projects, in this case the Spier Mob Grazing project, paid out as much as R100,000 (€5,282) from carbon revenue to a single employee, who used this money to put down a deposit on his first house (New24, 2020). In total, Credible Carbon registered 10 small-scale carbon offset projects in waste handling, agriculture and energy efficiency sectors (Credible Carbon, n.d.). However, as it is not recognised by any international association in the carbon market, carbon credits cannot be sold on the international market, hence they are mainly purchased by local South African firms.

7.5 Chapter summary

This chapter set out the context of the carbon offset market and carbon offset projects implemented in South Africa, through detailed literature review and the analysis of carbon offset projects data. South Africa is a highly energy-intensive economy dominated by coal mining and heavy processing industries. It is the largest polluter on the African continent. The country is also experiencing the effects of climate change – with the poor being the hardest hit and most vulnerable to its impacts. To reduce emissions, poverty and inequality, the South African government introduced several climate change and energy policies. While a number of policies were formulated, the implementation of these policies was found lacking. The government still does not have any plans nor commitments to phase out coal in the long-term.

The carbon market follows strict rules and regulations. While the CDM is governed by a rigid structure, it is claimed that carbon standards in the voluntary carbon market reduce the administrative burden and costs of the CDM. The uptake of carbon offset projects and innovative technologies in South Africa seemed to be very slow and mainly dominated by large-scale renewable energy, landfill gas, industrial energy efficiency, N_2O and methane projects.

Only 19 out of the 57 registered CDM projects actually generated carbon offset credits and contributed to a total emission reduction of 17 $MtCO_2e$ between 2012 and 2020. Many carbon offset projects (66%) in the country remained dormant and have not realised their potential due to the collapse of the carbon price in 2012. When comparing emissions reductions achieved by carbon offset projects with South Africa's relevant sectoral emissions, it was evident that these emission reductions were almost negligible. To conclude, this chapter provided a general understanding on how elements, at the landscape, regime, sub-regime and niche interrelate within South Africa's carbon market. The next chapter presents the first of four sets of findings generated by this study.

Chapter 8: Analysing actors' perceptions in the carbon offset market in South Africa

This chapter presents the first of four sets of findings from the research project. It addresses the first research question as to how the carbon market functions in South Africa based on interview data from 2017. The results reveal that on balance actors are critical of the legitimacy of the South African carbon market. The study shows an emerging consensus around the limitations of the carbon market and the difficulties in overcoming various barriers to deliver co-benefits of carbon offset projects.

The chapter is organised as follows. First, it discusses the methodology applied to analyse the responses obtained from the interviews. Second, it presents the results on the functioning of the carbon offset market and the perceived livelihood provision of carbon offset projects.

8.1 Data generation and analysis of market actors' perceptions

As highlighted in Chapter 5, the researcher identified and interviewed 27 market actors based on a snowball sampling technique. The transcripts were coded into a Discourse Network Analyser (DNA)*.* In total, there were 376 statements. Using discourse network analysis, the data generated from the interviews provided several benefits. The researcher was able map out the complexity of the situation, visualise clusters and better understand the differences between actors' perceptions.

A discourse network is based on narratives or a set of storylines provided by actors (see Chapter 5). This analysis is similar to the Advocacy Coalition Framework developed by Sabatier and Smith (1993). However, instead of focusing on the actors themselves, this research focuses on the narratives. To connect actors who provide similar narratives, a weighted bipartite or affiliation (two-mode) discourse network was used (Borgatti and Everett, 1997).

Since the DNA programme could only capture binary statements (Leifeld, 2010), the researcher categorised statements as being either 'supportive' or 'critical'. Depending on the context, the same actors could use critical and/or supportive views, in both discourse networks. However, it may seem to be surprising, but the discussions on the functioning of the carbon market were quite polarised and therefore this categorisation deemed to be legitimate.

In the situation where actors provided ambivalent views, the researcher used her judgement to establish an overall (either supportive or critical) sentiment. Where this was not possible, the researcher excluded these views from the further analysis and discussed them separately. In total, there were four actors (carbon consultant, a project developer, municipality and an NGO), who provided ambivalent views. These views related to the functioning of the carbon market introduction of the carbon tax and technology transfer. During interviews actors provided more than one response that were captured and analysed. This chapter summarises the findings and data on central topics and networks is included in the Appendix A9.

'Concepts' are interpreted as storylines discussed by one or more actors. A storyline is defined as 'a generative sort of narrative that allows actors to draw upon various discursive categories to give meaning to specific physical or social phenomena' (Hajer, 1995, p. 56). To analyse the importance of individual actors and their storylines, a measure of 'centrality'[40] was used. Since the discourse networks are bipartite, the degree of centrality is based on the number of statements each actor makes or the number of times a 'concept' is mentioned by an actor (Haunss, 2017).

There are four measures of centrality – namely degree, closeness, betweenness and eigenvector (Borgatti and Everett, 1997). Since this research not only focuses on individual nodes and their direct connections to others, but on their indirect connections too, eigenvector centrality seems most appropriate as it provides a comprehensive and nuanced perspective of centrality within a network (Borgatti and Everett, 1997).

Eigenvector centrality is based on linear algebra/matrix eigenvector analysis[41]. It allows us to identify which nodes (storylines/actors) are more 'central' than others in a network. 'Centrality' in this context relates to commonly expressed storylines or cited actors when analysing the collective views of the carbon market and co-benefits provision. If the eigenvector centrality of a particular actor or storyline is relatively high, it indicates it is 'more central' to the network or, equivalently, more widely discussed among actors. If the value of the eigenvector is relatively low, the actor or storyline is peripheral. The cluster of storylines and the explanation of the roles of actors in this study is discussed in the next section.

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[40] Centrality is defined as a notion which 'encompasses a number of different aspects of the 'importance' or 'visibility' of actors within a network' (Faust, 1997). Actors are central when they are active in the network; have the potential to mediate flows of resources or information between actors and have ties to other actors that are themselves central (Faust, 1997).

[41] The matrix here is the one formed to capture the connections between the actors/concepts. Eigenvector centrality focuses on the eigenvector associated with the largest eigenvalue of this matrix (the Perron-Frobenius theorem) (Pillai et al., 2005)

8.2 Market actors' supportive and critical perceptions of the carbon market

This section firstly presents the actors and discusses their roles within the carbon market. Secondly, the section introduces the narratives[42] revealed by these actors and then discusses the results.

8.2.1 Overview of narratives and market actors participating in the study

Actors interviewed for this study range from carbon development consultants[43] (n=7), financial (n=2) and legal (n=1) institutions, private companies (n=4), Eskom (n=1), municipalities (n=4), NGOs (n=3), civil society (n=2), academic institutions (n=1), the local registry (n=1) and national government (n=1). They are depicted in white squares in Figure 23 and 24. As discussed above, the study analysed two underlying discourse networks: one formed of the supportive perceptions and another of the critical ones.

These discourse networks are not active networks. Instead, they are created by common narratives in relation to an issue. Different actors with similar views were clustered together and create an apparent network. The central actors with critical perceptions are the municipalities (with an eigenvector centrality (EV 8.6%) followed by carbon consultants (EV 7.1%) and financial institutions (EV 6.2%) (see Figure 23 and Table 24).

Table 24: Overview of the network coalition with critical perceptions on the functioning of the carbon market in South Africa

Discourse network with critical perceptions		
Main market actors	Frequency of responses	Eigenvector (%)
Municipalities	43	8.6
Carbon consultants	58	7.1
Financial institution	21	6.2
NGOs	26	6.0
Project developers	25	5.5
Local registry	12	4.4
Legal	10	2.5
Academia	12	2.5
Civil society	15	2.5
Eskom	3	1.8

Source: Authors' compilation

[42] storylines and narratives are used interchangeably
[43] in short carbon consultants

The high eigenvector centrality of municipalities indicates that they are more strongly related via deployment of storylines that are common to other actors. To reflect on municipalities' role in the carbon market, they are directly involved in the design and set up of large-scale carbon offset projects, hence possess knowledge that they share via storylines that resonates with many actors.

Carbon consultants (EV 7.1%) are the second most important actor in the network. They relate to many actors via similar narratives. They appear to be knowledgeable as they possess technical know-how on the registration of carbon offset projects (e.g., project documents, liaising with auditors etc). The role of financial institutions (EV 6.2%) in the network is to assist project developers with raising and providing finance to make carbon offset projects commercially viable. As for the local registry (EV 4.4%), it is less 'central' to the actors in the network. This could be explained by the fact that the local registry is only involved in registering small-scale carbon offset projects, and hence shares storylines that are less common to other actors in the network.

Legal institutions, academia and civil society have the same eigenvector centrality of 2.5%. Since they are not involved in any project implementation processes, they provide narratives that are less common to other actors (e.g., governance of the carbon market) and play a less central role in the overall network. Eskom has the lowest eigenvector centrality (EV 1.8%). It is not related to many actors and remains a peripheral entity in the carbon market space. While Eskom participates in the carbon market by setting up carbon offset projects, it maintains its status quo of being a major GHG emitter in the country.

This research used visone, a JAVA-based software to provide a visual representation of apparent critical and supportive networks (see Figure 23 and 24). This visualisation enables us to see how actors and their storylines are positioned in the network in relation to their eigenvector centrality. In comparing Figure 23 (critical all actors in the networks are connected with yellow lines via storylines they share. Storylines discussed by actors are depicted in blue circles. The most central and frequently expressed storyline among market actors with critical perceptions is the 'Immature market' with an EV of 6.3% (n=43), followed by the narrative that 'the carbon market is not credible' (EV 6.1%) (n=32) and 'a profit maximising activity' (EV 5.7%) (n=20).

In Figure 24 (supportive views), it is clear that less enthusiastic views are more prevalent than supportive ones. There is a very thin network of actors and supportive narratives. Not many actors had any positive narratives to share. For example, the National Government has the highest eigenvector centrality (EV 35.5%), followed by Eskom (EV 3.8%), two project developers (EV 3.6%) and an NGO (EV 3.3%) (Table 25).

Table 25: Overview of the network coalition with supportive perceptions on the functioning of the carbon market in South Africa

Discourse network with supportive perceptions		
Main market actors	Frequency of responses	Eigenvector (%)
National Government	12	35.5
Eskom	4	3.8
Project developers	2	3.6
NGOs	2	3.3
Carbon consultants	9	0.3
Financial institutions	4	0.2
Local registry	1	0.1

Source: Authors' compilation

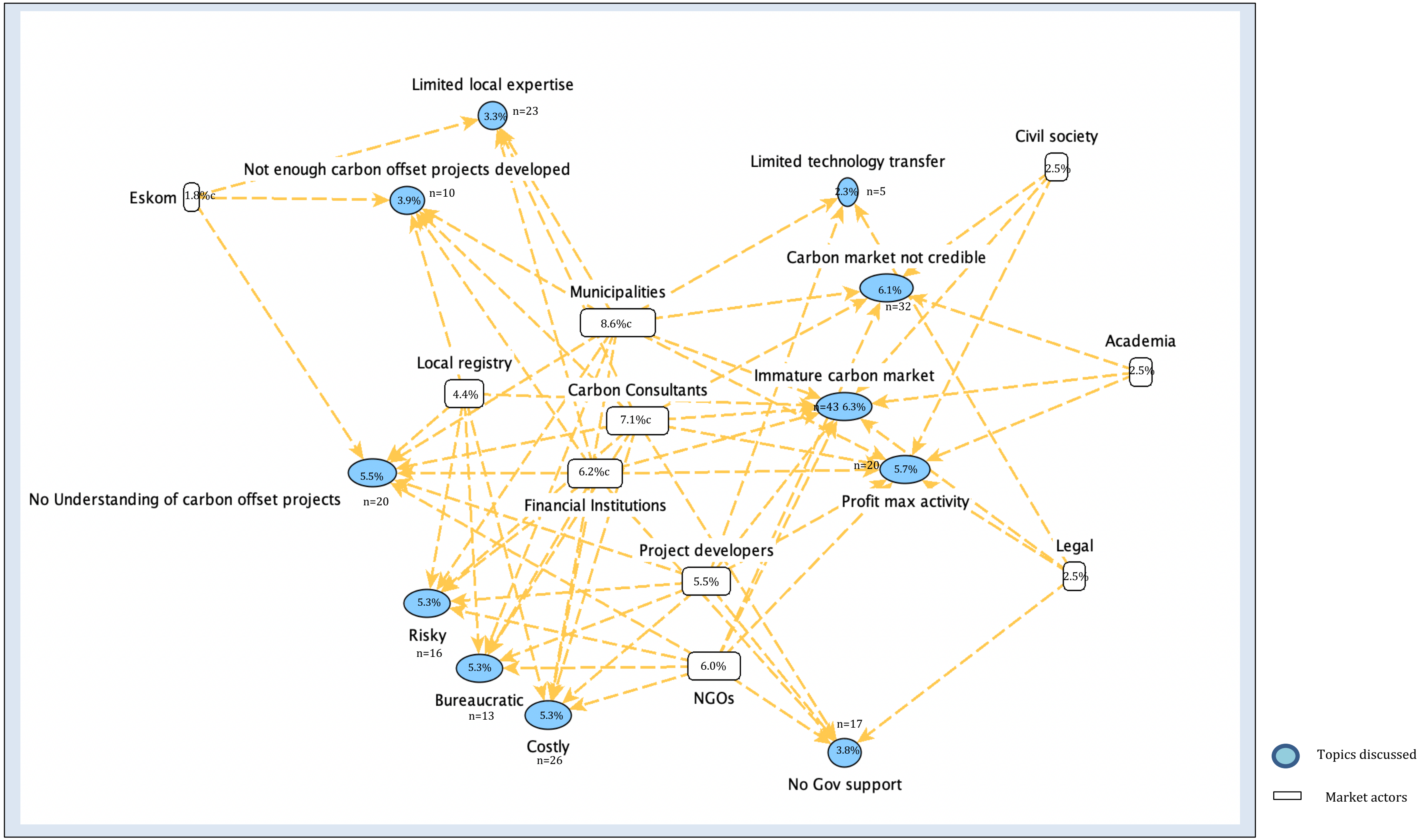


Figure 23: Overview of market actors with critical narratives of the carbon offset market

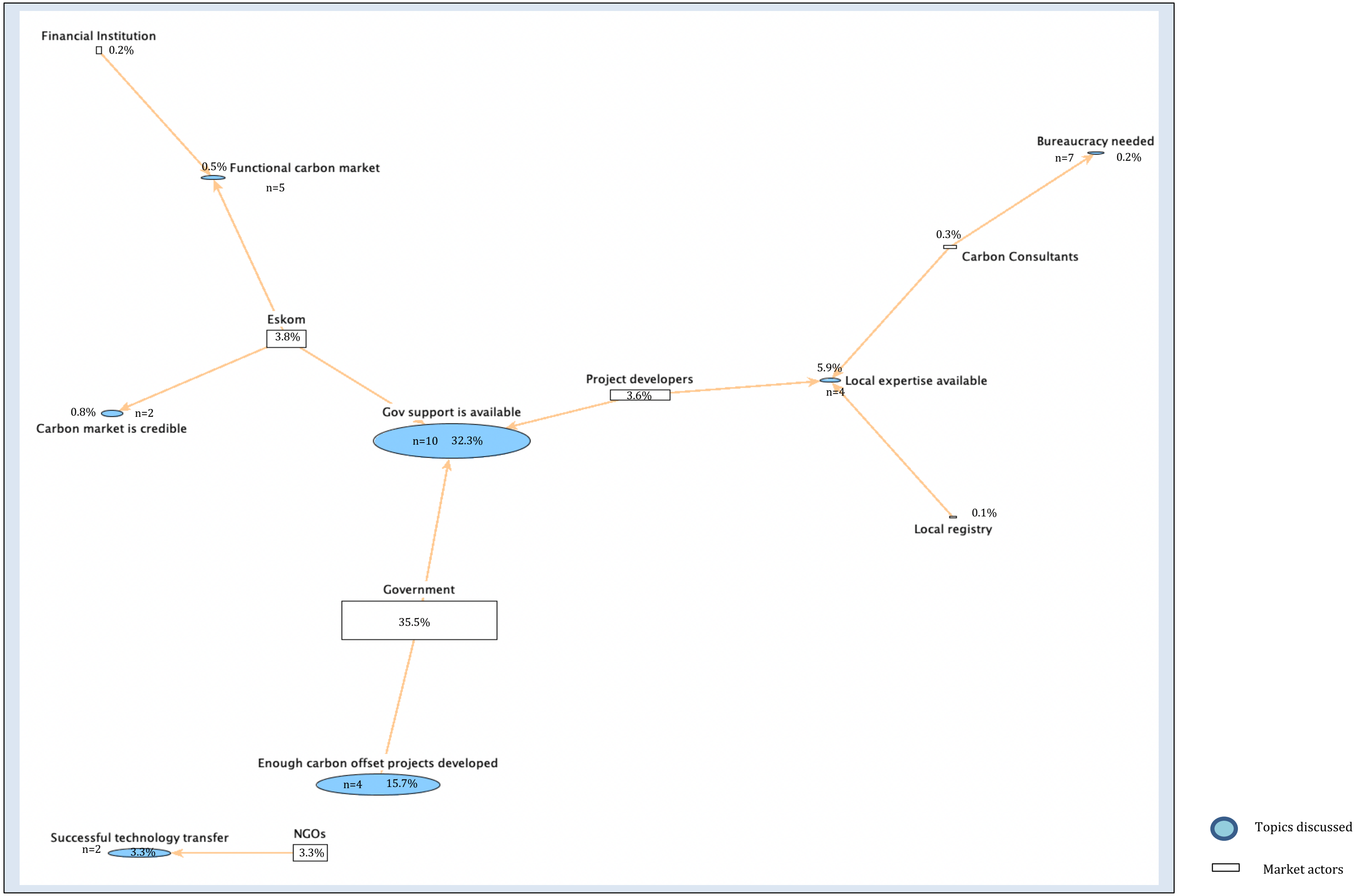


Figure 24: Overview of market actors with supportive narratives of the carbon offset market.

8.2.2 Perceptions of the functioning of the carbon offset market

The results show that 55% of respondents (n=15) in the network agreed that the market was 'immature'. The term 'immature' was used as an umbrella to summarise different narratives provided by actors that had common meaning (see Table 26).

Table 26: Summary of market actors' perceptions on the functioning of the carbon

Immature market		
Actor's perceptions	Frequency of responses	Number of actors
Carbon market poorly developed	19	13
Insufficient demand and supply for carbon credits	15	7
Carbon market dominated by a few player	5	3
Carbon offsetting is a voluntary activity	4	3
Total	**43**	**26**
Grand total		**15**

Source: Interviews with actors, 2017

The debate revolved around the carbon market being poorly developed, under-capacitated and almost 'non-existent'. For example, a municipal official and a carbon consultant observed that a number of CDM programmes were replicated, but remained dormant as no one joined them (22M, 6CDC) due to the collapse of the CDM and the low price in the compliance market (see Chapter 7).

Seven actors reported that there was insufficient demand for, and supply of, carbon offset credits (see Table 26). Carbon offsetting was perceived to be a voluntary activity due to the absence of any obligation to reduce emissions in the country (8,9CDC,1A). The carbon market was understood to be driven by marketing activities whereby small companies chose to offset their flights or conferences to differentiate themselves from their competitors (7,9CDC). A respondent quoted:

> *'There is no liquidity in the market. I think the flow of money isn't consistent. The market is driven by marketing. But predominantly, if people can get any kind of differentiation, it's definitely – general small companies. It's all voluntary market in South Africa at the moment' (9CDC).*

To add to this debate, ten actors in the sample argued that not enough carbon offset projects were implemented in the country (see Table A9.1). Although the CDM mechanism existed, municipal officials and carbon consultants pointed out that it was not worthwhile to engage or develop any carbon offset projects (8,9,11CDC, 19, 21M) as it did not make any financial sense due to the prevailing low carbon price.

Furthermore, a carbon consultant admitted that supporting the carbon market was not a top government priority as it was overshadowed by the more looming challenges faced in the country, e.g., economic recession, poverty, social unrest, inequality and high unemployment. This meant that the market was not as well developed as in other emerging economies (e.g., China or India) from a supply and demand side perspective (10CDC). However, the carbon consultant also added that it would be incorrect to assume that there was no carbon market as South Africa still remained a player in the global market and carbon credits were issued in the country (10CDC). The actor stated:

> *'The market in South Africa is not being as well-developed as in other parts of the world. But it's also because there are other challenges that this country faces, e.g., social unrests, poverty. It moved down the priority ladder, because other more urgent things' (10CDC).*
>
> *'But I don't think there is no market at all, because still South Africa is a player also in the global market. I mean there are carbon credits generated in this country, very much though' (10CDC).*

Nevertheless, three actors - a carbon consultant, the local registry and an NGO - perceived the carbon market as 'distorted' and dominated by a small number of large players (9CDC,13LR, 23NGO). The local registry added that these players held intellectual control by providing know-how (advisory and trading services) and took advantage of the less functional or 'immature' state of the market (13LR). An NGO characterised these players as '*risk takers'* or '*carbon offset price setters'*, who dictated the price and made it difficult for small-scale projects to compete and get off the ground (21NGO).

Furthermore, the results show that there were only two actors in the discourse network, who indicated that South Africa's carbon market functioned as well as any other countries' that were trading carbon offset credits under the CDM (2FI,18Eskom) (see Table A9.2). The government official believed that there was a big appetite for setting up carbon offset projects in the country. Sufficient government resources had supposedly been directed to support project developers during the registration process of carbon offset projects (12G). An official from Eskom reported that there was a well-established institutional and regulatory infrastructure in place with a relatively robust registration criteria and government support, allowing project developers to initiate projects and participate in the market (18Eskom). The respondent stated:

> *'In Africa certainly, we are the biggest participant. We have a lot of project developers, we have a lot of involvement, we have the registry system set up, we have DNA [Designated National Authority], we have Sustainable Development Criteria. From all of that perspective – from an institutional and regulatory perspective, it is pretty well developed and from the participation in the market' (18Eskom).*

This statement seems to confirm the results obtained from the statistical analysis carried out in Chapter 7. South Africa indeed showed leadership in registering CDM projects and managed to register the highest number of CDM projects on the African continent. Overall, the Eskom official felt supported by the government and had a positive experience when setting up carbon offset projects in the country. The process was described as being efficient and fast (18Eskom).

However, 33% of respondents (n=9) in the sample held an opposing view (see Table A9.3). An actor from the financial institution, for example, reported limited support from government. The respondent felt disappointed and experienced long delays in approval of their projects due to unnecessarily strict rules created by the Designated National Authority (DNA) (2FI). Other respondents reported that the government department experienced high staff turnover (5CDC) and perceived it as rather dysfunctional (4L). The Department of Environmental Affairs (DEA) played an active role in international negotiations; however, it remained silent at the national level and did not engage nor support the uptake of carbon offset projects (4L,6CDC). Apparently, the government did not have any visionary leadership (25NGO) nor political will to engage in carbon offset projects (14PD).

It seems that this was partly due to ideological views the Department of Environmental Affairs (DEA) has adapted. People, who joined the DEA as governmental officials came from the civil society and opposed the notion of carbon offsetting. As a result, they simply rejected or blocked carbon offset activities without following due process (4L). The actor provided the following insight:

> *'The Department of Environmental Affairs refused to take responsibility for carbon and the reason it did that was because it was ideologically opposed to carbon. Quite a lot of them [governmental officials] came from the civil society' (4L).*

Overall, it seems that there were several uncertainties that impeded the carbon market. The main unsettling factor was the low carbon price and insufficient progress on climate actions at the international level. As a result, actors felt hesitant to set up carbon offset projects (2,3FI,14-16PD). Municipalities adopted a *'wait and see'* approach (22M) and shifted their focus to other projects, such as adaptation type projects (21M). Other actors, such as financial institutions, withdrew their participation from the South African carbon market all together (3FI).

8.2.3 Summary

The results included positive and negative perceptions in relation to the functioning of the carbon market. While some actors provided supportive views, it seems like negative perceptions were in the vast majority. The study suggests that the carbon market in South Africa did not have a chance to develop fully and stagnated due to the low carbon price.

Reasons cited for the poor functioning of the carbon market were insufficient liquidity in the market (supply and demand for carbon offset credits) and the low priority placed on reducing GHG emissions. Inefficiencies at the governmental level and uncertainties created hesitancy and an unwillingness among actors to participate in the market. Lastly, ideological beliefs at the governmental level impeded carbon offset activities in the country and constrained the development of carbon offset projects.

8.3 Perceived issues with the carbon offset market

To continue with the debate, actors shared different issues experienced in the carbon offset market. The following narratives emerged and are discussed in the following sequence: (1) carbon offsetting being a 'profit maximising activity', (2) credibility of the carbon market, (3) understanding and availability of local expertise, (4) bureaucracy, (5) project risks and (6) technology transfer.

8.3.1 Profit maximising activity

The results showed that 41% of respondents (n=11) in the sample agreed that carbon offsetting was purely a profit maximising activity. The debate around this topic was dominated by municipalities, civil society, project developers, carbon consultants and legal firms etc. (see Table A9.4). Carbon offsetting was viewed as another business opportunity to generate additional revenue and maximise shareholder returns (14PD).

An actor from a legal institution explained that there were too many speculators rather than social entrepreneurs[44], who tried to mislead the market with the purpose of simply making profits (4L). The general consensus of project developers was that *'money is going to rain from the sky'* (4L) without understanding any rules, requirements and risks involved in the carbon project development process (4L,5,7CDC,21M).

Furthermore, a municipal official pointed out that funders had unrealistic expectations of the potential returns of carbon offset projects. They were not interested in protecting the environment, but rather *'chasing dollars'* (21M). While consultants and polluting industries apparently made money, the actor from the civil society highlighted that the situation of affected communities did not change and they still remained in poverty. Actors continued with their debate criticising the integrity of the carbon market which is analysed below.

8.3.2 Credibility of the carbon market

During the interviews, 22% of respondents (n=6) in the sample heavily criticised carbon offset activities as an inappropriate policy tool. The network mainly consisted of municipalities (n=1), civil society (n=2), academia (n=1), NGOs (n=1) and a carbon consultant (n=1) (see Table A9.5).

[44] Social entrepreneurs are defined as companies that pursue social and business goals. They incorporate social aspects in a financially sustainable way (Lambe et al., 2015).

Overall, actors characterised carbon offsetting as a *'perverse'* (n=4) and *'false solution'* (n=4), which apparently distracted (n=2) from dealing with the real issue of reducing emissions (20M, 26-27CS). An actor from the civil society quoted:

> *'Carbon offset projects are a false solution, like moving the deckchairs around on the Titanic' (26CS)*

Furthermore, it was claimed that carbon offsetting provided an *'artificial'* platform for dishonest behaviour that seemed to divert pollution from one source to another, allowing emitters to continue to pollute without taking any meaningful actions (20M). Furthermore, this policy was referred to as a *'bottomless activity'* and a *'flawed strategy'* (see Table 27) allowing the Global North to pollute, while offsetting its pollution against projects in the Global South (9CDC). Comments made by market actors on credibility of the carbon market are summarised in Table 27.

Table 27: Summary of market actors' comments on the credibility of the carbon market in SA

Market actors' comments	Frequency of responses
'Perverse'	4
'False solution'	4
'Carbon offsetting is a distraction'	2
'Bottomless activity'	2
'Unethical practice'	2
'Not sustainable activity'	2
'Biased towards overestimating of credits'	2
'Fictitious carbon'	2
'Projects create fictional stories'	2
'Legitimised corruption'	2
'Flawed strategy'	1
'Artificial platform'	1
'Dishonest behaviour'	1
'Scammer's paradise'	1
'Cowboy market'	1
'Includes fake projects'	1
'Offset indulgence for your climate sin'	1
'A fun fair/game run by the white elite'	1
Total responses	**32**

Source: Interviews with market actors, 2017

An actor from academia linked carbon offsetting to systemic racism. It was perceived as '*a fun fair/game run by the white elites*', who polluted without changing their behaviour (1A). The actor elaborated:

> *'If you are a white South African you just pollute, commit racism and apartheid, you commit corruption – does not matter. That is the ethics in this country' (1A).*

During the interviews, an NGO and an actor from civil society described some unethical practices in the carbon market. Apparently, projects were packaged with some fictional stories to satisfy the required tick-boxes for the carbon registration process. However, they turned out to be fraudulent, biased and containing an overestimated amount of carbon credits (9CDC, 24NGO).

Only one actor in the sample, namely Eskom, expressed a positive sentiment about the credibility of the carbon market (see Figure 24). The respondent perceived the market as highly credible, which included stringent rules and requirements to ensure high quality of carbon offsets (18Eskom). To conclude, it seems that there is a strong consensus that carbon offset activities are not credible, generate profit maximising activities and compromise on the environmental integrity.

8.3.3 Understanding and availability of local expertise

The results showed that 41% of actors (n=11) in the network acknowledged that there was poor understanding of carbon offset projects in South Africa. Carbon consultants were the leading actors in this debate and provided most of the responses (see Table A9.6). Actors agreed that the business community did not understand the basic principles of carbon offsetting (19M, 9CDC,18 Eskom), which involved a reduction or removal of emissions of carbon dioxide or other GHG emissions made in one sector to compensate for emissions made in another (Matemilola and Salami, 2020). A carbon consultant stated:

> *'It is a complicated world. Even for very well-educated people, it's a concept that most people don't understand (9CDC).*

It was reported that buyers and sellers (e.g., brokers) of carbon credits did not have much knowledge on how carbon offsets originated (23NGO,13LR). As there was no transparency in the market, it was not possible for the buyers to differentiate between a 'good' or bad' carbon credit (13LR). A respondent explained:

> *'Buyers do not know what a 'good' carbon credit and what a 'bad' carbon credit is. They are not familiar with methodologies - and sellers aren't familiar with what constitutes a carbon credit project' (13LR).*

Carbon consultants observed that project developers in general struggled to engage in the carbon market as they did not fully understand all the nuances and requirements needed to develop the projects (5,7CDC). It was like studying 'a new science', that required specialised knowledge and skills to register these projects (10CDC,15PD).

During the interviews, 30% of actors (n=8) agreed that there was no – or only very limited - expertise available in South Africa on how to develop carbon offset projects (see Table A9.7). Actors pointed out that skills (from data management to issuing carbon credits) remained limited and created a challenge for project developers to participate in the market (19,21M) (see Table A9.8). A municipal official confirmed:

> *'We don't have the skill set in South Africa and the number of people that you need to do those type of things. The skill sets in South Africa are very limited - so you haven't got many people that really know what they are doing – e.g. to expand the number of projects in the country' (19M).*

Furthermore, it was apparent that carbon practitioners were inexperienced and went through a learning process themselves, pretending to be experts and blaming the system if they failed to register carbon offset projects (22M,11CDC). Other actors (financial institution, carbon consultant and a municipal official) argued that there was insufficient knowledge at the governmental level (see Table A9.8). The Designated National Authority was perceived to be technically 'incompetent' to deal with carbon offset queries (5CDC). Only a few actors in the network were of the opinion that sufficient technical experts were present in the country, e.g., universities and local auditors, that could assist with developing carbon offset projects (9CDC,13LR).

The results seem to be in line with studies carried out by Du Toit (2006), Wilson (2007) and Ntuli (2012). Carbon offset projects were perceived to be constrained not only by insufficient government support and a low carbon price, but also by poor understanding and insufficient technical expertise available to get projects off the ground.

8.3.4 Bureaucracy and Costs

In the discourse network, 33% of respondents (n=9) strongly agreed in describing their involvement in carbon offset projects as 'highly bureaucratic'. The debate revolved around the contingent and arbitrary authority of the UNFCCC, the overly admin intensive process and high transaction costs. Project developers and financial institutions provided the most frequent responses to this debate (see Table A9.9).

Actors perceived the CDM project registration process as 'painful', 'tedious' (2,3 FI, 16PD) and 'admin intensive' (13LR). It seemed that project documents were too complicated and lengthy to complete (17PD) followed by endless repeated requests for information from the UNFCCC (16PD). A project developer revealed that South African carbon offset projects were apparently treated as fraudulent transactions by the UNFCCC (16PD). A project developer explained:

> *'It was extremely painful, very difficult, the experience. The default was that projects that presented to the UNFCCC were fraudulent and they needed to try and examine each project to see if there is no fraud involved there. It was an extremely negative process….I think at that stage there was a lot of credits coming to the market from China. Maybe there wasn't*

such a good system behind it, but the experience from the UNFCCC was that 'you were guilty before you were innocent' (16PD)'.

Furthermore, actors (NGO and project developer) claimed that auditors endorsed by carbon standards did not understand the local context nor had practical experience on how projects originated and operated in Africa. They just followed a tick-box exercise to fulfil the requirements prescribed by the CDM (25NGO;17PD). Overall, actors agreed that the function of an auditor did not add any real value to the carbon development process (13LR, 15PD, 25NGO).

However, three carbon consultants with supportive perceptions argued that bureaucracy was indeed necessary to ensure the integrity of the projects (see Table A9.10). Since *'money is allocated to something that is intangible'* (10CDC), a rigorous process and a robust bureaucratic system was needed to provide confidence to the actors in the carbon offset market (8CDC). It was believed that strict requirements of carbon standards only helped project developers become better and more efficient in their overall day-to-day operations (11CDC).

Furthermore, 55% of actors (n=15) in the network agreed that the registration process of carbon offset projects was costly (see Table A9.11). It included hiring consultants and auditors to monitor, validate and verify projects. Depending on the project, the auditor cost alone was reported to be between €20,000 and €30,000 (2FI). It was stated that these costs could be easily absorbed by large-scale industrial and renewable energy type projects, but not small-scale ones, where the budget was tight and uncertain (13LR). Considering a low carbon price, actors claimed that such high transaction costs nullified the incentive to implement carbon offset projects (3FI, 19,21M,24NGO). A municipal official noted that they were often excited about carbon mitigation projects, but as soon as they heard about the fees, they would lose their enthusiasm (22M).

In summary, it seems that the administrative burden of project registration and the high costs inhibited actors' willingness to engage in climate mitigation projects and attract CDM projects in the country. This empirical insight echoes the findings of other studies carried out by several authors, such as Steenkamp (2018), Little et al., (2007), Wilson (2007) and Nkusi et al., (2014) in South Africa.

8.3.5 Project risks

Continuing with the discussion, 37% of actors (n=10) in the network identified various risks experienced with carbon offset projects. Project developers, NGOs and carbon consultants provided the most frequent responses related to this narrative (see Table A9.11). The debate among actors was dominated by climate-related and financial risks (see Table A9.12).

For example, Agriculture, Forestry and Other Land Use were considered highly risky (17PD,23,24NGO), as South Africa is suspectable to extreme weather events, such as droughts and wildfires (Davis-Reddy et al., 2017). These projects apparently required long-term land management commitments, e.g., 5-10 years. There was no certainty that farmers would commit to these timelines and keep the land untouched during the required period unless suitably incentivised (17PD).

Results revealed that projects implemented on traditional, communal land were generally perceived to be high risk due to the complex and sensitive land tenure and land claims issue stemming from forced evictions during apartheid (7CDC). Since carbon consultants could not preclude inappropriate land use and illegal developments within project areas, implementing projects on communal land was therefore too risky (7CDC).

Financial risk (e.g., low carbon price) was considered to be a big challenge (15,16PD) and a limiting factor on project viability (2FI) (see Table A9.12). Since the carbon price was perceived to be politically determined (8CDC,16PD), a carbon consultant admitted that there was a deficit of trust in the market. Due to a perceived unwillingness to resolve climate change issues at the international level, the perception was that there would be no carbon price again (8CDC). The carbon consultant explained:

> *'The link between the carbon market and political systems is strong and it has done the market a lot of damage in the past. The biggest deficit in the market is the deficit of trust. People do not believe that there will be a carbon price again' (8CDC).*

Since South Africa was in a recession in 2017 (at the time of the fieldwork), the economic situation created unfavourable conditions to roll-out carbon offset projects (24NGO) This was further exacerbated by policy uncertainties at the international level (e.g., limited life of the Kyoto Protocol) (22M). Together with all the other aforementioned issues experienced by actors, these risks created additional bottlenecks which limited involvement in carbon offset projects.

8.3.6 Technology transfer

Technology transfer was the least discussed topic in the discourse network (with the lowest EV of 2.3% - see Figure 23). There were only three actors (project developer, municipal official and legal) in the network, who were of the opinion that technology transfer was limited under the CDM (see Table A9.13).

A municipal official observed that new technologies under the CDM were generally perceived as the *'nirvana of reducing pollution'* (21M). However, the actor highlighted that the technology transfer alone was not the endgame of the mitigation solution. It was, rather, a complex process and required strategic planning, infrastructure, skills and the availability of local industry to achieve meaningful results (21M). Due to a shortage of skills in South Africa large-scale waste management carbon offset projects often required overseas expertise. As a result, these projects became expensive and unsustainable over time (21M).

Only one of 27 actors in the network argued that successful technology transfer could be achieved using carbon finance. For example, carbon finance and subsidies helped boost the SWH industry in South Africa (25NGO). The respondent explained:

> *'We helped develop the industry… I thought it was fantastic that the Ministry of Trade and Industry, who set the minimum standards under the South African Bureau of Standards. They introduced energy and thermal efficiency standards for all housing. We eventually helped to develop local geysers; those are still up and are still functioning very well. We've got 700 or 800 geysers that will last for 10, 15 or 20 years with no problems – the imported ones are disaster (25NGO).*

However, this actor also admitted that some mistakes were made and public funds were invested in bad quality geysers imported from China (25NGO). Kritzinger (2011) highlight that the SWH technology had a potential to become a dominant technology and make a positive impact on the country's electricity capacity crisis. However, these results confirm that the full potential of this opportunity was never realised. Instead, the South African government did not pay sufficient attention to the niche development – exemplified by the fact that the SWH technology was imported from China. The penetration rate of the technology remained relatively low (less than 2%). This was due to high upfront costs, low consumer awareness and a lack of regulation (Pasad and Visagie, 2006; Kritzinger, 2011).

8.3.7 Summary

Actors with critical perceptions created tightly connected clusters, providing similar storylines on issues experienced in the carbon market. As a whole, the section identified and highlighted several inefficiencies (e.g., bureaucracy, limited understanding, no local expertise) and even raised some concerns about the integrity of the carbon market itself. Evidence suggests that carbon market is fragmented and susceptible to fraudulent transactions and manipulation (overestimation of GHG emissions). Actors experienced various risks (climate-related, financial, political etc.) that created challenges in fully embracing carbon finance. The results indicate that the transfer of technologies was limited and not enough attention was paid to the technology niche.

8.4. Regulatory environment

At the time of the fieldwork (2017), carbon tax was still in the design phase. However, during the interviews actors frequently cited this topic. As a result, it was important to capture, analyse and present their perceptions.

8.4.1 Carbon tax

The results show that 15 actors were supportive of its introduction. The leading actors on this topic were carbon consultants and NGOs (see Table A9.13). Actors perceived a carbon tax as a step in the 'right direction' to push the South African energy-intensive sectors to reduce GHG emissions. Actors seemed convinced that a hybrid pricing mechanism (carbon tax combined with carbon offsetting) was likely to revive the carbon market and increase demand for domestic carbon offset credits (see Table 28).

Table 28: Summary of market actors' comments supporting the introduction of the carbon tax

Market actors' comments	Frequency of responses
Stimulates the domestic carbon market	11
Provides a legal obligation to reduce emissions	7
Provides certainty in the domestic carbon market	4
Helps develop innovative low-carbon technologies	1
Carbon tax revenue can be used to set up environmental projects	1
Total	**24**

Source: Author's compilation

Furthermore, the introduction of the carbon offset regulation could encourage investments in innovative clean energy projects (24NGO), whereas a municipal official suggested that carbon tax revenue would be used to assist with educational and environmental projects (20M) in the country. There were only a few actors in the network who were sceptical about the introduction of the carbon tax. The network included a carbon consultant (n=1), financial (n=1), and academic (n=1) institution and a municipal official (n=1) (see Table A9.15).

Actors agreed that the carbon tax will have no impact on the environment (see Table 29). It was perceived a 'smokescreen' or just another tax to generate more revenue (9CDC). Since there was no ring-fencing of the carbon tax income, it remained unclear how the revenue would be used (9CDC). Furthermore, the tax-free allowances – e.g., up to 95% of emissions remaining untaxed – were undoubtedly too high. This could diminish the incentive to reduce emissions and transition to a low-carbon economy (15PD).

Table 29: Summary of market actors' perceptions criticising the introduction of the carbon tax

Market actors' storylines	Frequency of responses
Carbon tax has no impact on environment	7
Carbon tax will not revive the carbon market	3
No ring fencing of carbon tax revenue	1
Not enough carbon offset project to satisfy the demand	1
Carbon tax is a tokenistic approach	1
Bureaucracy of carbon projects remains unchanged	1
Total	**14**

Source: Interview with market actors, 2017

Although the carbon tax regulation would create a compliance carbon market and make it easier for carbon credits to be traded in the local market, the municipal official believed that there would be no change in the tedious bureaucratic process of registering carbon offset projects (21M). An academic accused the government of 'talking green and walking dirty' (1A). While implementing the carbon tax, the government approved the construction of a big coal-fired power plant in Limpopo (Musina-Makhado – Special Economic Zone), which defeated the intention of this regulation and brought into question the government's commitment to addressing climate change (1A).

8.4.2 Summary

The carbon tax policy was seen as a step in the 'right 'direction. Since the carbon tax was not yet gazetted at the time of the fieldwork, the effectiveness of the carbon tax still remains unknown and further research is needed into this topic.

8.5 Analysis of co-benefits provision

This section analyses actors' perceptions on co-benefits provided by carbon offset projects. Co-benefits are defined as monetary and non-monetary incentives ranging from human health, food security, biodiversity, air quality, energy access and other changes in livelihoods (IPCC, 2014, p. 5 – see Chapter 3).

The results reveal that within the network, carbon consultants are the most 'central' of all the supportive actors (see Table 30). They are strongly related via storylines that are common to many other actors. In total, actors focus on three storylines – namely, co-benefits provision (direct/indirect), job creation and skills, and revenue sharing.

Table 30: Overview of the network coalitions with supportive and critical perceptions on the co-benefits provision of carbon offset projects in South Africa

Discourse network with supportive perceptions		
Main market actors	Frequency of responses	Eigenvector (%)
Carbon Consultants	11	15.0
Municipalities	24	7.9
NGOs	8	7.9
Project developers	7	7.9
Local Registry	13	7.9
Eskom	4	6.0
National Government	3	6.0
Legal	1	2.4

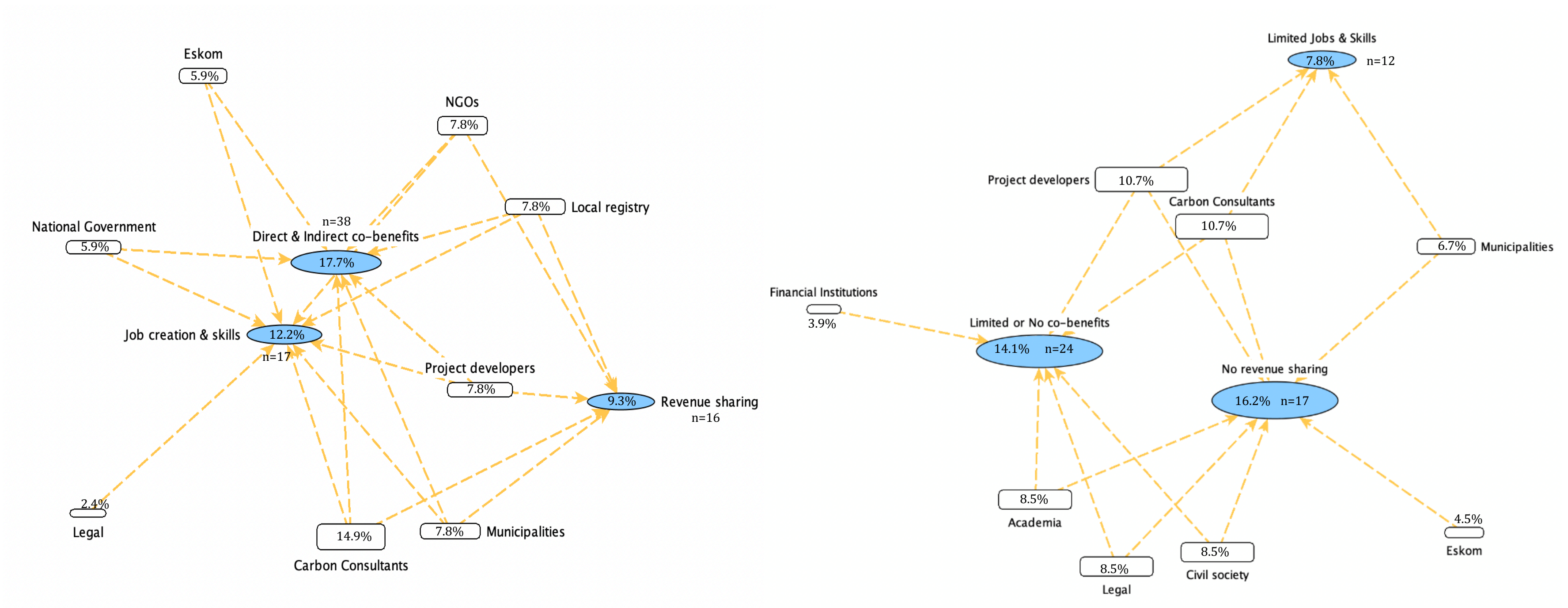
Discourse network with critical perceptions		
Main market actors	Frequency of responses	Eigenvector (%)
Carbon Consultants	15	10.7
Project developers	8	10.7
Legal	7	8.5
Academia	2	8.5
Civil Society	6	8.5
Municipalities	11	6.7
Eskom	1	4.5
Financial institutions	3	3.9

Source: Author's compilation

The most 'central' narrative discussed by actors with supportive perceptions was the provision of 'indirect/direct' co-benefits (EV 17.7%) (see Figure 25). Indirect co-benefits are understood by actors as benefits that create an overall environmental improvement (air pollution, eco-system). In contrast, direct co-benefits are associated with receiving a physical artifact (low-carbon technology), improved health, financial incentives (reduced fuel costs) and knowledge and others.

The overall sentiment of actors associated with the provision of co-benefits is positive. To evidence this, 56% of actors in the network (n=15) believed that carbon offset projects generated co-benefits in project areas, whereas only 30% of actors (n=8) were less enthusiastic and argued that projects provided limited or no co-benefits at all (see Table A9.16).

The most ‘central’ narrative discussed among actors with critical perceptions was ‘No carbon revenue sharing’ (EV 16.2%). This narrative provided insights into how carbon revenue was distributed and who benefited from it (see Figure 25). The sample also included ambivalent perceptions. Three actors argued that the provision of co-benefits was not explicit and depended on the type and size of carbon offset project. This view was excluded from the measure of eigenvector centrality and discussed separately. All narratives are analysed in the next sections.



Critical perceptions

Supportive perceptions

Figure 25: Overview of actor networks with critical and supportive perceptions on the provision of co-benefits of carbon offset projects.

Topics discussed

Market actors

8.5.1 Provision of co-benefits

15 actors in the network agreed that carbon offset projects had direct and indirect impacts on local communities (see Table A9.17). For example, actors stated that large-scale carbon offset projects, e.g., landfill gas or reforestation projects, typically created indirect impacts associated with reduced air pollution or eco-system restoration (see Table 31).

Table 31: Market actors' storylines on co-benefits provided by carbon offset projects

Market actors' storylines	Frequency of responses
'Improve air pollution'	14
'Create financial incentive'	8
'Households benefit from a physical artifact'	4
'Improve eco-system'	2
'Create social change'	2
'Create network and build knowledge on climate change'	2
'Contribute to Corporate Social Responsibility (build schools)'	2
'Help small business to grow'	1
'Improve standard of living'	1
'Reduce indoor pollution'	1
'Improved health'	1
Total	**38**

Source: Interviews with market actors, 2017

The government official believed that project developers, who set up large-scale nitrous oxide (N_2O) abatement projects, created an indirect impact on communities by building schools as part of their Corporate Social Responsibility (CSR) programme (12G). Schools in impoverished areas would often receive help in form of the provision of desks and chairs (15PD). However, a carbon consultant dismissed such behaviour and perceived it as ineffective and superficial. The actor cynically believed that it primarily served the project implementer's objectives to provide a '*feel good*' factor and create nice pictures for public relations (8CDC). The actors explained:

> *"People love to talk about and say 'This project built a school or they did this or they did that', but if you look at the bigger scheme of things then those contributions are always very small, they almost always aim towards being able to take nice photographs for the benefit of the project implementer. And the amount of benefit that it really gives to the community are not that high (8CDC).*

The carbon consultant perceived those co-benefits typically placed a burden on carbon offset projects. They were apparently not practical and hampered the development of projects. Instead, the actor was of the opinion that project developers should focus on implementing projects that create meaningful economic activities from which everyone can benefit (8CDC).

An actor from an NGO observed that projects that involved fruit tree planting in townships created social change within communities. Households would apparently create their own gardens around these trees and change the strategy of their existing livelihood approach by growing their own food and becoming more resilient and self-sufficient in the long term (24NGO). A respondent described the situation as follows:

> *'I think social change is really exciting for me. Often what would happen is, with this specific programme that is VCS registered Trees…we plant trees in these houses and then what will happen is they [households] will start growing their own gardens around those trees; they start growing their own veg. From the tree you start seeing how livelihood is kind of changing and the way that they care for their garden is which is quite exciting' (24NGO).*

However, carbon consultants (n=2) highlighted that the provision of co-benefits depended on the type and size of the project. While large-scale projects (e.g., landfill site or renewable energy) focused more on technology and less on communities, other projects, such as the household energy efficiency, often contained some aspect of community upliftment (5,10CDC).

Other actor confirmed that small-scale household energy efficiency projects created impacts that were related to the physical artifacts that households received and used to reduce their fuel costs, improve health and their standard of living. It was believed that it was necessary to create an extra financial incentive for workers in carbon offset projects to reward them for their everyday work. This approach seemed to recognise workers as equal players and help improve their life (13LR). The actor elaborated:

> *'Financial benefit from the carbon must go to poor people and the funny thing is that it's actually worked. When you don't know how you going to feed your family, having an extra hundred Rand in your pocket really helps. People, who are generating carbon credits – everyday waking up at 6 o' clock, going to work at 7 o'clock - these are the people who need to be rewarded for their work' (13LR).*

A municipal official explained that reforestation projects provided on average higher income to employees, compared to any other jobs carried out elsewhere. This type of project also helped communities build resilience, create networks, share knowledge and adapt to extreme climate events (26M). However, nine actors in the network perceived that carbon offset projects created very limited or no impacts on communities (see Table A9.18).

The aspect of co-benefits provision was apparently lost over years due to the low carbon price (4L). Since buyers of carbon credits did not pay attention to co-benefits, project developers did not take them seriously (4L). Co-benefits were typically under-emphasised in project documents and promises were never fulfilled. It was believed that once carbon offset projects were registered, project developers forgot what they stated in the papers (4L).

Actors from the civil society provided strong views against co-benefits by pointing out that project developers created false promises (26CS) and benefits 'are short-term window-dressing at best' (27CS) (see Table 50).

Table 32: Market actors' critical perceptions on co-benefits provided by carbon offset projects

Market actors' storylines	Frequency of responses
'No benefits from carbon projects'	6
'Large-scale carbon offset projects do not provide co-benefits'	4
'Co-benefits create unrealistic expectations'	3
'Co-benefits from Corporate Social Responsibility are ineffective'	2
'Benefits are short-term window dressing'	1
'Benefits go to the investor'	1
'We won't just create co-benefits, unless there is an obligation'	1
'Benefits are a false promise'	1
'Co-benefits is the last thing on people's mind'	1
'Do not care about the sustainable development'	1
'Co-benefits are not effective'	1
'It is a burden on the project'	1
'It is a climate change mechanism, not aid'	1
Total	**24**

Source: Interviews with market actors, 2017

Since the objective of carbon offset projects was to mitigate emissions, providing co-benefits simultaneously was not realistic (5CDC, 16PD). It was claimed that carbon offset projects needed to generate some revenue and not to provide 'a donation' in the name of so-called sustainable development (8CDC). However, the actor from the local registry explained that any carbon offset project can have a poverty alleviation component. It solely depends on the project developer's interest and willingness to share carbon revenue (13LR).

8.5.2 Carbon revenue sharing

During the interviews, five actors in the network agreed that it was possible to share carbon revenue with all participants in the project including workers and beyond (See Table A9.19). For example, projects registered with the local registry claimed to pay their workers up to R12,000 (€633) in cash as a one-off payment after the sale of carbon offset credits (13LR).

A municipal official stated that 5% of the carbon revenue of a landfill gas carbon offset project was allocated to a trust fund that could be used to help local companies create environmental projects, such as recycling, green infrastructure and schooling (19M) (see Table A9.20). However, the actor admitted that due to a low carbon price this initiative never materialised because insufficient revenue was received from carbon credits, (19M).

Furthermore, carbon revenue was apparently distributed to citizens in the form of reduced service rates charged by the council (e.g., refuse and solid waste collection, libraries, police etc.) (19M). However, other municipal officials were less enthusiastic about this perception. They confirmed that carbon revenue was lost in the municipal centralised accounting system as there was no ring-fencing of carbon revenue. Instead, it was used to cover shortfalls (deficits) faced by the provincial government (21,22M).

In total, there were twelve actors in the network that provided critical perceptions on carbon revenue sharing (see Table A9.21). Project developers and carbon consultants, were of the opinion that the main objective was to make carbon offset projects profitable, just like any other business, and use the revenue primarily to cover costs, pay taxes and satisfy the investors (8,10CDC, 15,16PD) (see Table A9.22). At the same time the revenue of carbon offset credits was so small due to the low carbon price that it barely covered the expenses (15PD).

While project developers struggled to cover the costs of carbon credit certification, the researcher's own professional experience indicated that carbon consultants in South Africa purchased carbon credits at a relatively low price and re-sold them with extortionate mark-up in the international carbon market.

Actors from civil society, academia and legal institutions stated that carbon revenue was distributed in the form of higher salaries and annual bonuses to senior employees of NGOs, government departments and private companies (1A,4L,27CS). Respondents explained:

> *'Most revenue goes to dishonest banks, crooked project consultants and corrupt government officials' (27CS)*
>
> *'People were so excited about the annual bonus payment– salaries of senior people in the department were going to be increased quite significantly because of the revenue that was being brought in by that project' (4L)*

However, no further evidence could be found to confirm these allegations. To summarise, this section provides examples that it is possible to share carbon revenue with others via different mechanisms, such as workers' reward schemes or trust funds. However, it seems that it was not a common practice and workers or community members remained marginalised as the carbon revenue was primarily used to cover costs and satisfy the investors.

8.5.3 Creation of employment and skills

17 actors in the network were of the opinion that carbon projects created employment opportunities in project areas (see Table A9.23). A project developer provided an example that a hydropower project successfully employed approximately 70 people over two years to construct

the plant (16PD). Others set up enterprise development programmes to uplift communities and help them compete against other businesses (14PD).

It was reported that carbon offset projects in the AFULO sector apparently employed over 200 people (20M) or as many people as possible (7CDC) during planting operations. However, it was claimed that these were often the most 'arbitrary' of jobs that in reality were not needed (7DCD). The actor explained:

> *'They get quite silly and employ as many people as they can initially and then the most arbitrary jobs to manage the forest, you actually don't need to manage it. You bring professional foresters and they just look at this and think this is mad. Just bring tractors and plough it and plant it using machines you can do it at a fraction of the cost and 10 times as quick as - but they are just trying to employ people' (7CDC).*

Other actors in the network provided critical perspectives (see Table A9.24) and believed that carbon offset projects created limited or no employment in project areas. Actors pointed out that employment was typically temporary, unskilled and laborious and only paid minimum wage (11CDC, 17PD).

Since large-scale landfill gas projects followed strict funding rules, a municipal official claimed that technical expertise needed to be imported from overseas, thus creating no employment opportunities for locals (21M). A carbon consultant reported that project developers often oversold employment benefits in project areas (11CDC). For instance, in renewable energy projects most employment was only generated during the construction phase of the plant. Thereafter, only a few people could be employed. However, communities were often not aware of this. As soon as the construction process was completed, they often felt disappointed and unhappy about the process (11CDC).

This finding indicated that project developers may have created asymmetric information in the employment market by taking advantage of the labour force without fully explaining and managing expectations around the hiring process during the project operation and maintenance phase. Although carbon projects created jobs, the findings suggest that they were temporary, unskilled, low paid and, in some cases, superfluous.

8.6 Chapter Summary

The chapter presented and analysed supportive and critical actors' perceptions on the functioning of the carbon market and the co-benefits provided by carbon offset projects. A discourse network analysis was used to summarise actors' perceptions in a systematic manner and visualise the results.

Actors with critical perceptions created tightly connected clusters, providing similar storylines on issues experienced in the carbon market. The findings suggest that the carbon market as a 'sub-regime' was sensitive to various factors (low carbon price, insufficient institutional capacity, limited understanding and insufficient local expertise). Actors recognised that carbon offsetting was not a good fit for reducing GHG emissions. Concerns were expressed around credibility of the carbon market, and the profit maximisation activities pursued by many actors.

The perceptions on co-benefits were positive overall. Actors claimed that small-scale carbon offset projects provided direct co-benefits, whereas large-scale carbon offset projects provided limited or no co-benefits at all. Carbon revenue sharing remained limited due to a low carbon price and depended on actors' vested interests. Although carbon projects created jobs, they were generally low paid and temporary.

While actors' perceptions were valuable and informative, they still remain subjective. To generate in-depth knowledge, it is therefore necessary to analyse the details of carbon offset projects instead of relying on perceptions. The next chapters (Chapters 9, 10 and 11) examine the reality of carbon offset project implementation processes, technology adoption and changes in the livelihoods of communities impacted by these projects.

Chapter 9: Implementation of carbon offset projects in South Africa

This chapter presents the second (of four) sets of findings from the research. It addresses the sub-research question as to how the carbon offset projects[45] are implemented. The findings presented are based on the project actors' experiences involved in the project implementation process of carbon offset projects. The chapter firstly explains how the interviews with project actors were analysed. Then, it examines the factors which influenced the project implementation process. Lastly, it identifies barriers that threaten the existence of some carbon offset projects and have even led, in some cases, to their collapse.

9.1 Assessment of project actors' responses

The study is based on the data obtained from semi-structured interviews with 24 project actors. Project actors are defined as individuals who are directly and indirectly involved in the project implementation of the selected carbon offset projects (see Chapter 5). The interviews were coded and analysed using a thematic analysis described in Chapter 5. When coding the responses, three key themes emerged: (1) partnerships, (2) project implementation approach, (3) employment and skills development.

Partnership is understood in this study as a strategic cooperation between private firms to help launch a low-carbon technology into the market. The project implementation approach refers to the way in which technologies are distributed to households in project areas (bottom-up or top-down). A bottom-up approach often involves the local community in the decision-making process, whereas the top-down is implemented without any a community consultation (Bell and Morse, 2013).

Employment and skills development include the number of jobs created in project areas and specific skills (technical, entrepreneurial or managerial) acquired as a result of a project intervention. Furthermore, project actors reported several barriers that were categorised into the following themes: (1) understanding and awareness of a technology, (2) project costs and (3) external shocks. To evaluate the responses, the researcher used a three-point Likert-Type scale (1-3). The methodology underlying this is explained in Chapter 5. The following three categories were established:

[45] Carbon offset projects and projects are used interchangeably

1 – Low: includes actors' statements that provide only negative/pessimistic perspectives in relation to the project implementation process

2 – Medium: includes actors' statements that provide mixed perspectives (positive/negative) in relation to the project implementation process

3 – High: includes actors' statements that provide only positive/optimistic perspectives in relation to the project implementation process

The composite scores for each theme across the four projects are explained in the next section and presented in Table 15. It is important to note that these scores are subject to change and only apply to the context of the projects analysed in this study.

9.2 Overview of Likert-score results

Each response from a project actor was assigned a score by the researcher based on the 1-3 Likert scale defined above. For each project, all scores within a particular theme are averaged to produce a single aggregate Likert score for each theme. These Likert scores and their standard deviation are summarised in Table 33. The number of responses (denoted by N) for each theme varies because respondents only provided answers to questions that were relevant to their roles in the projects.

The standard deviation is included to help further understand and contextualise the results. It is defined as a measure of dispersion and evaluates how tightly clustered responses are around their mean (Bhardwaj, 2013). The smaller the standard deviation, the tighter the response cluster is around its mean. A standard deviation of zero means all responses provided by project actors were assigned the same score (see Table 33) - indicating a high degree of consistency in respondents' comments. In contrast, a high standard deviation indicates that there is a relatively high dispersion around the mean – meaning there was relatively less consistency in the feedback received from project actors.

Table 33: Categorisation of project actors' responses according to Likert scores (1-3)

Projects	Partnerships				Implementation approach				Employment				Skills Development			
	Mean	StDev	N=	N = actors	Mean	StDev	N=	N= actors	Mean	StDev	N=	N= actors	Mean	StDev	N=	N= actors
WB	2.89	0.19	14	3	3.00	0.00	6	2	3.00	0.00	4	3	3.00	0.00	11	2
Wood Stove	3.00	0.00	2	2	2.71	0.33	20	5	2.00	1.41	2	2	3.00	0.00	2	2
SWH	2.08	1.02	18	6	1.33	0.47	14	4	1.25	0.35	5	2	3.00	0.00	2	2
Basa Magogo	1.17	0.29	7	3	1.67	0.85	12	5	2.00	0.82	4	4	2.50	1.00	4	4

Source: Author's compilation

Figure 26 shows the Likert scores per theme stacked on top one another across the four projects. The results provide evidence that the Wonderbag project, followed closely by the Wood stove project, appear to be on average the most effectively implemented in comparison to the other two projects (SWH and Basa Magogo). Both the WB and Wood stove projects received high scores across all themes (see Figure 26 and Table 33).

Figure 26: Stacked Likert scores related to themes in project implementation of each carbon offset project. Source: Authors' compilation

Table 34 below summarises the results in more detail and shows the assigned category (High, Medium, Low) of each score. It is evident that all carbon offset projects successfully created skills in project areas (see Figure 26 and Table 34). However, scores on employment vary across projects.

While the Wonderbag project received the highest score for the 'Employment' theme, respondents in other projects provided less optimistic perspectives and reported issues of low sentiment among workers due to the perceived hard nature of the work, the temporary nature of the contracts and a general unwillingness to follow project rules (See Table 34). The themes are analysed in more detail in the next section.

Table 34: Overview of factors cited by project actors that influence the effectiveness of projects' implementation processes and summaries of points made

Project	Partnerships	Implementation approach	Employment	Skill Development
WB	**2.89 (High/n=3)**	**3.00 (High/n=2)**	**3.00 (High/n=3)**	**3.00 (High/n=2)**
	• Partnerships with schools, refugee camps, soup kitchens	• Governmental initiatives, educational and skill development programmes and direct sales platforms	• 24 permanent factory workers • Over 10,000 self-employed 'Wonderpreneurs' • Favourable working environment.	• Hire unskilled workers and train on the job • Cutting and measuring skills; entrepreneurial skills
Wood stove	**3.00 (High/n=2)**	**2.71 (High/n=5)**	**2.00 (Medium/n=2)**	**3.00 (High/n=2)**
	• Partnership with churches and international funding organisation	• Deep respect, trust and strong integrity among church leaders, indunas, chiefs and households • Mismatch of expectations between NGO and community • Reluctance to engage due to personal reasons and frustrations	• 68 people installation and monitoring process between 2015-2017 • Employment directed to the "poorest of the poor" • Builders do not take the project seriously and compromise on the quality of the stove	• Trained to be a brick master and quality controller • Training on how to use building tools
SWH	**2.08 (Medium/n=6)**	**1.33 (Low/n=4)**	**1.25 (Low/n=2)**	**3.00 (High/n=2)**
	• Strong consortium of SWH installers, carbon consultants, financial institution • Mismatch of expectations and interests among actors	• No control over households' eligibility criteria • Mistrust, resentment towards the local government	• 1,000 SWH installers temporarily employed during the installation process (2-3 months • Biased recruitment process • No interest in learning about the technology; hard work	• Trained on the job • Technical SWH installation skills
Basa Magogo	**1.17 (Low/n=3)**	**1.67 (Medium/n=5)**	**2.00 (Medium/n=4)**	**2.50 (High/ n=4)**
	• Initial enthusiasm received from national government • No interest from polluting industry; perceived as additional tax	• Strong relationships and trust with civic structures of the community, such as street and zonal committees • Reluctance to engage in live demonstrations due to blame game	• 385 temporary fieldworkers between 2008-2018 • Fieldworkers do not take the project seriously and cheat	• Management skills: trained to be area leaders and field managers

Source: Author's compilation

9.3 Project implementation process

9.3.1 Partnerships

The study revealed that the Wonderbag (WB) and Wood stove (WS) projects are the two carbon offset projects that received the highest local and international support in terms of funding and corporate endorsement. For the WS project, the respondents pointed out that they successfully created a 17-year long relationship with communities through churches in the rural areas of Limpopo (R14,19).

This apparently helped project actors develop a good understanding of community needs and secure international funding for the project (R19). Respondents in both projects claimed that their aim was to address the poverty status quo of communities in urban and rural areas (R1,19)[46]. Carbon finance was seen as an innovative funding tool to help roll out such types of projects (R1). A respondent explained:

> *'I wanted to look at a financial model that could support a social enterprise. And so that's why I looked at carbon financing because it was a new and unusual model that I really thought could support' (R1).*

During the interviews, it quickly became apparent that project actors in the WB project managed to establish various partnerships with institutions, such as schools, refugee camps, soup kitchens and the private sector (R1,2,3; News24, 2016). The respondents strongly believed that women and girls in particular, who spend most of their time at home carrying out domestic chores, could be better educated (R1,2). As a result, they attracted sponsors to help facilitate events on educational topics, such as environmental issues, health, domestic violence and access to micro-finance. The respondent reported that they created interactive events and often donated WBs to participants, who were unemployed and could not afford the technology (R2).

To make the WB project commercially viable, project actors managed to establish a long-term partnership with the world's largest consumer goods company, Unilever. The respondents perceived this partnership as an 'instrumental game changer', which helped spread the cooking technology across low-income households nationwide. The respondent called it 'the perfect carbon project' at the time (R1).

In the case of the SWH project, findings show that the project was created through a consortium of different partners (R6). The project included two SWH installers, two carbon consultants, one

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[46] R stands for Respondent. This abbreviation is used throughout this chapter.

international funding institution and one commercial partner (Unilever). A respondent perceived this consortium as a 'perfect model', which guaranteed a stable stream of income in form of a subsidy for the SWH installation and a high carbon price to generate long-term profits (R9).

However, the results show that this partnership encountered challenges during the project implementation process. This was primarily due to a mismatch of expectations and intentions among actors. For example, while one SWH installer viewed the technology as a way to address a humanitarian need (R6), other actors (carbon consultants and financial institutions) viewed the project more as a 'stepping stone' to generate profits (R9,11).

Another installer believed that the technology was introduced purely for political reasons and not out of an environmental concern to reduce household GHG emissions. A respondent explained that the government announced the programme shortly before the general election and viewed it cynically as a way to garner public support (R7).

As a result, the rollout was regarded as a short-lived strategy, which subsequently failed. SWH installers explained that it neither included any feasibility assessments nor long-term maintenance plans (R7,9). One installer described the situation as follows:

> 'You see the government basically had this rollout to say look what we are doing for the community. But that's where it's left. They did not think further to say who is going to keep the thing going…that's what they do just before elections… They come and they put these things on the roof and everyone says 'oh the government is great', *they vote for them, after that nobody worries' (R7).*

Furthermore, a carbon consultant and a financial institution pointed out that there was a lack of understanding of the carbon development process at the installation level (R9,11). No matter how many times the installers received instructions on specific CDM rules, they apparently could not grasp them, causing frustration among actors (R11). A respondent explained:

> *'But to be honest most of these companies were not actually very good at monitoring if I could put it politely. … And even as far us telling them exactly where they had to put it; and training them and training them again, training them again' (R11).*

A carbon consultant highlighted that installers were hesitant to commit to any long-term carbon contracts (in this case 10 years[47]) due to uncertainties in the domestic market. A respondent elaborated:

> *'None of the guys were overly keen… most of these guys were just: 'I do not know what is going to happen in 2 years time or 3 years time. I've got the money from the government to implement the solar water heater. And now I want to move on' (R9).*

Referring to the Basa Magogo (BM) project, it was evident that it received the lowest support from the public and private sectors across all the projects analysed in this study. The intention of this project was to reduce domestic air pollution in heavily polluted industrial areas, e.g., the Highveld, eastern and southern Gauteng and the Vaal Triangle area (R13).

A respondent explained that in the beginning the Department of Minerals and Energy (DME) was very enthusiastic and announced it as a flagship project for the country (R13). The idea at the national government level was to make polluting industries accountable and fund this project. However, industry regarded this as an 'extra tax' and refused to participate. According to a respondent, the government subsequently withdrew its support and was reluctant to provide any funds (R13).

The support was apparently withdrawn not because of a lack of money, but due to a lack of common goals (R13). It was claimed that there was no willingness from the polluting industries in the first place to engage with communities in highly polluted areas. A respondent further highlighted that government did not have any interest in applying pressure on industry to invest in innovative solutions to improve air quality. As a result, industry had no interest nor compulsion to help implement projects like BM (R13).

Furthermore, respondents stated that the BM method had already earned a bad name in the community. They claimed that the BM method was initially piloted by another NGO, which applied a mass media communication channel approach (R13,18). This NGO apparently did not have any experience in project implementation, such as monitoring and reporting procedures (R18). As a result, the respondent claimed that the BM method was applied incorrectly and got a reputation of being ineffective (R13). This caused negative tensions and disagreements in the NGO sector. Subsequently, all market players in the industry and the government lost confidence in the method (R13).

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[47] Carbon contract is understood as a crediting period of a project which can be either 10 or 7 years with an option to renew twice for a total amount of 21 years. Crediting period is defined as a period during which GHG emissions are verified and issued by the carbon offset projects

Respondents also believed that there was no common understanding in the country that industries and communities are mutually dependent and carry responsibilities for their own actions in relation to environmental damage (R13,18). For example, a respondent highlighted that employee who worked for polluting industries and lived in the polluted areas, did not feel responsible for improving his live nor the lives of others in the community (R13). Furthermore, the respondents claimed that there was a feeling of ignorance and indifference towards the situation, which contributed to low support for the project (R13-18).

9.3.2 Project implementation approaches

During the interviews, it became apparent that respondents used various approaches to distribute their technologies to households in project areas. In the case of the WB project, one respondent reported that they distributed the WB using governmental workshops, educational and skills development programmes and direct sales platforms (R1,2).

Using such a diverse range of channels, the respondent believed that they maximised their potential to reach their target market – which was primarily women, who were largely unskilled, unemployed and often lived in remote areas with little to no access to resources (such as finance or transportation) (R2). The results show that respondents created very close connections with communities through organising 'Wonder Feasts'. One respondent reported that during these events potential users were educated about the technology and had an opportunity to learn how to prepare meals in the WB (R2).

In relation to the BM project, project actors reported that they created close relationships with communities in Wesselton Township. They directly involved residents in the testing and fine-tuning of the BM method (see Photo 14). A respondent explained:

> *'so one other way or technique that we use is to involve people to make the fire themselves to see that it can work… you have to do it with households and with networks that is part of our mission' (R15).*

The respondent believed that this approach created trust within civic structures of the community, such as street and zonal committees (R13). Apparently, the project created 'symbolic capital' that could be utilised to address the needs of the community (van Niekerk, 2017).

Photo 10: Basa Magogo demonstration. Source: Nova Institute, South Africa, 2010

However, respondents also reported that there was some resistance to the BM method within communities that was experienced during the implementation process. The respondents highlighted that some community members created a negative perception around the technique due to the aforementioned ill-fated previous rollout carried out in the project area by another NGO. As a result, respondents felt that it was a challenging task to persuade people to change their sceptical mindset towards the new method (R13,14,18).

Furthermore, a respondent reported that some residents in the township were simply reluctant to engage in live demonstrations (R18). They seemed to be rather irritated to be taught by outsiders on how to make fires (R17). Another respondent added that it was a sensitive topic for some as they were taught how to make fire from early childhood, and therefore were unwilling to adjust (R15).

Moreover, one respondent explained that residents blamed industry for polluting the air and felt that the fieldworkers should rather approach them to reduce their GHG emissions instead (R17). The respondent stated:

> '*Let's say for instance we are working in the community, which has some industry in-between. So it is [a] blame game. The community is blaming the industries that they are the ones who are polluting. So we should rather go and help the industry to offset – I mean not to offset really, but to reduce the air pollution and then also play their role.' (R17)*

With regards to the Wood Stove (WS) project, the results showed that respondents managed to build and foster a positive relationship with all community members. For example, 'indunas' (headmen of a village) pointed out that the NGO educated all community members about the stove and the building process during community meetings (R22,23).

However, the results also revealed that there was a mismatch of expectations between the NGO and residents in the project area. Apparently, the NGO romanticised the idea that communities would immediately buy into the project and follow instructions proposed by the organisation

(R19). In contrast, it seemed that some residents did not take the project intervention seriously (P19,20) nor did they want to make bricks, as they did not believe in the technology (R20,24).

'Indunas' claimed that some residents were simply too lazy to play their part in the project. Alternatively, they felt confused as to why they needed to prepare the bricks if people were employed to build the wood stoves in their areas (R22,23). A stove builder also reported that some households were resentful and rejected the wood stove purely out of jealousy towards the person who was building the stoves, while they remained unemployed during this period (R20). He explained:

> *'…usually black people they are like this: when you have a business, usually people from around closer to you, they do not want to support you. But people who support you who are far. The reason is that people realise that when I am doing stoves, I am getting paid. They have jealousy upon me. So they do not want the stoves at all. They have the attitude towards the stove...' (R20)*

In contrast, respondents in the SWH project apparently had no control over the decision-making process related to the distribution of the technology. A respondent reported that the municipality was the only organisation which decided, without any consultation, on household eligibility to receive the geysers. The responsibility of installers was purely to execute orders by putting SWH systems on the roof (R6,7).

The installer pointed out that this approach created deep resentment and mistrust towards the local government (R8). He explained that residents, who did not receive geysers, questioned the criteria used to qualify for one, created arguments with neighbours and demanded fair treatment (R8). The installer quoted:

> *'It becomes to the point where the neighbours, they are starting to fight because they will ask "how did you get it? How did you qualify for this? Why I did not qualify for this?" And then as we work in the community, they started coming to us, wanting to know "Why I am not getting the geyser. Why is that one gets the geyser but I got the house first and he got the house after me and all that stuff. And we are like: 'We do not know'. The only thing that we know is that we were given the house numbers and we go and install.' (R8)*

The results show that projects actors that involved users in the implementation process created more positive effects on the users than projects using a top-down approach (SWH project). They created better awareness of technologies when compared with projects using a top-down approach (SWH project). However, the results also show that communities can resist technologies – BM method and wood stove – due to cultural and personal reasons

9.3.3. Employment and skills development

The results showed that all carbon offset projects created some employment opportunities in the project areas. Due to high unemployment in the country, these projects apparently attracted several people, who were desperately in need of a job. Respondents explained that they often hired workers with no or limited skills and trained them on the job (R2,7, 15,19). Table 17 shows that some projects created more jobs than others. For example, in the WB project, it was reported that more than 10,000 independent so-called Wonderpreneurs[48] (R1) joined the project across the country and beyond to promote and sell the technology within their own network.

Table 35: Summary of respondents' comments on the number of jobs created in carbon offset projects

Employment			
Projects	Respondents' comments	Number of responses	Number of project actors
Wonderbag	• 24 permanent factory workers • 10,000 'Wonderpreneurs'	4	3
WS	• 68 people in installation and monitoring	2	2
SWH	• 1,000 SWH installers temporarily	5	2
BM	• 385 temporary fieldworkers	4	4

Source: Author's compilation

The researcher's factory visit indicated that 24 people were permanently employed by the WB project, most of whom were women. The floor manager claimed that there was low turnover of staff (R4) and the workers pointed out that the business offered more favourable working conditions than others in the area. The work in the factory was perceived to be easy and enjoyable (R5) (see Photo 11).

Photo 11: Wonderbag factory, Tongaat. Source: Fieldwork, 2017

[48] The concept of Wonderpreneurs was based on the Avon and Tupperware model, which created a direct selling distribution network comprising independent sales representatives who sold goods door-to-door or at parties within their own network and beyond (Klepacki, 2005).

The results of the SWH project showed that the project created approximately 1,000 temporary jobs during the installation of 500 units in Cosmo City (R7) (see Table 35). However, installers reported that they did not have any control over the recruitment process (R7).

To provide some context, a respondent explained that project developers cannot simply enter the township and distribute a technology to residents. Instead, they had to follow a protocol (meet the councillor, community leaders, elders, etc.) to obtain permission before they could interact with residents (R6).

One installer highlighted that the recruitment process turned out to be biased (R7). There was a so-called 'patronage network', whereby the recruitment selection process was placed in hands of the elected community representative (the councillor) which often led to close relatives and friends being favoured often to the detriment of project outcomes (R7). This led to tensions and misunderstandings within the community. The installer explained:

> *'They give you what's called a CFO, "Client Face Officer". He or she now has to source local people for you. So obviously the first thing, who do they give? Their friends, all right. And the first thing you get with respect "a big fat lady". She cannot get on the roof. So who do you use?' (R7)*

A respondent also pointed out that the project was too small to employ workers to do maintenance after the installation was completed. As a result, the project could only create short-term employment for approximately 2-3 months in the project area (R7). However, a worker noticed that during SWH installations his co-workers did not have any interest in learning about the SWH technology nor did they want to do the work as it was perceived to be too laborious (R8).

With regards to the BM project, a respondent reported that 385 fieldworkers were temporarily employed during the implementation and monitoring phases between 2008 and 2018 (R16). However, project actors reported some problems with their fieldworkers. A respondent explained that some of them neither took the project seriously nor complied with the rules prescribed by the project developer during the monitoring process. A respondent quoted:

> *'At one time fieldworkers got caught filling the questionnaire themselves instead of reaching out to the BM users'* (R17).

In the WS project, the results revealed that jobs were primarily given to the 'poorest of the poor' and young people, who were unemployed for some time in rural areas (R21,22,23). In total, the WS project employed 68 people during the installation and monitoring process between 2015 and 2017 (R19). A fieldworker provided the following insights:

'As for me, my CV was poor – one, my CV was not typed because I did not have money for typing, I did not have anything. I am sure they just looked at it, that maybe I qualify because I was the poorest one' (R21).

One of the Indunas expressed his view as follows:

'They were looking first the family backgrounds so that they can help them, they asked the indunas to show the families which are poor so they could be the first people to employ' (R23).

However, the NGO also unexpectedly lost 22 out of 68 employees over the course of a year. A project manager reported that, since the project involved contractual work, it seemed that many people quickly lost interest or found more promising permanent opportunities. As a result, the project constantly suffered from employee turnover (R19). Furthermore, the respondent mentioned some inconsistencies during the building process. Some builders did not take the project seriously and were only driven by financial incentives, hence compromised on the quality of stoves (R19).

On the skills development side, all projects created skills in project areas. These included, for example, technical SWH installation skills (R6,7), building and quality control skills (R19,21) and entrepreneurial (R2) and management skills (area leaders and field managers) (R17) (see Table 36).

Table 36: Summary of respondents' comments on the skills created by carbon offset projects

Skills development			
Projects	Respondents' comments	Number of responses	Number of actors
Wonderbag	• Cutting and measuring skills • Entrepreneurial skills	11	2
WS	• Trained to be a brick master • Training on how to use building tools	2	2
SWH	• Technical SWH installation skills	2	2
BM	• Management skills • Trained to be area leaders and field managers	4	4

Source: Author's compilation

A respondent believed that the most sustainable business model was to teach people how to make the bags and endorse them to sell them within their own community to make some money (R2).

To conclude the section, the results showed that all projects create employment and help local communities develop specific skills. However, the employment was temporary. Project actors experienced problems with their fieldworkers. There was low sentiment among workers and an unwillingness to get involved in the projects due to hard work. However, this finding requires further research as to why people lost interest to be employed by the projects. During the interviews, project actors expressed some barriers that created challenges in implementing their projects. These are presented and analysed in the next section.

9.4 Perceived barriers by project actors

This section examines barriers reported by project actors during the implementation process. The following themes emerged during the interviews: (1) understanding and awareness of technology (2) project costs and (3) external shocks.

To evaluate the responses, the researcher applied the following logic using a three-point Likert-Type scale (1-3):

1 – Low: project actors reported issues that had a small or negligible impact on the project

2 – Medium: project actors reported issues that had a negative impact on the project, but could manage them during the project implementation process

3 – High: project actors reported issues that negatively impacted the project and were beyond the project actors' control

Detailed methodology on how statements of individual respondents were analysed and categorised is described in Chapter 5. Each response from a project actor was assigned a score by the researcher based on the scale above. For each project, all scores within a particular theme are averaged to produce a single aggregate Likert score for each theme. These Likert scores and their standard deviation are summarised in Table 37. Barriers identified varied across projects. Not all project actors reported or faced the same barriers with their projects. In the situation where no barriers were reported, the researcher denoted it as 'Not specified'.

Table 37 and Figure 27 show that among all projects analysed, the wood stove project had the fewest barriers. The standard deviation across projects is relatively low meaning responses are closely clustered around their mean and that similar responses were provided by project actors (i.e., a high degree of consistency in the project actors' experiences).

Table 37: Overview of Likert-type scores of identified barriers by each carbon offset project

Project	Understanding and awareness of a technology				Project costs				External Shocks			
	Mean	StDev	N=	N= actors	Mean	StDev	N=	N= actors	Mean	StDev	N=	N= actors
SWH	2.52	0.47	15	3	3.00	0.00	3	2	3.00	0.00	15	5
Basa Magogo	not specified				3.00	0.00	2	2	3.00	0.00	2	2
WB	2.00	0.00	3	2	3.00	0.00	2	3	2.08	0.14	7	3
Wood Stove	not specified				3.00	0.00	2	2	not specified			

Source: Author's compilation

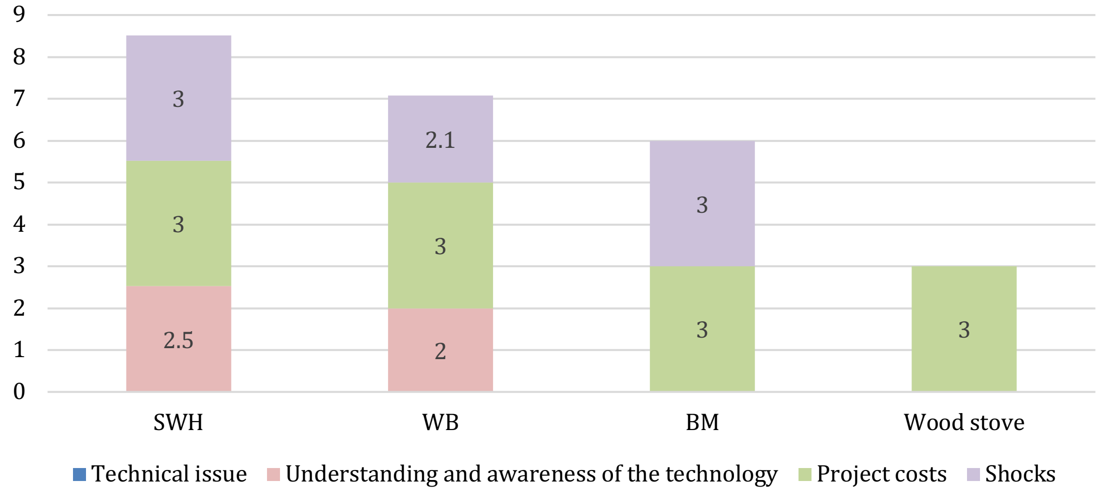

Figure 27: Stacked Likert scores related to barriers of each carbon offset project. Source: Author's compilation

The results show that the SWH project on average faced the highest barriers in comparison to other projects in this study (see Figure 27). Table 38 summarises the key aspects discussed by project actors during interviews and shows that this was mainly due to insufficient understanding of the technology at the user level, high costs and external shocks (subsidy withdrawal and collapse of the carbon price).

Furthermore, Figure 27 and Table 38 show that all projects faced the same barrier of high project costs. Three out of four projects suffered from external shocks (low carbon price, losses from exchange rate, decline in coal use, migration) (see Table 38). While project actors in the BM and WB projects managed to continue with their operations, the SWH project did not recover and collapsed.

Table 38: Overview of barriers of low-carbon technologies cited by project actors during projects' implementation processes and summaries of points made

Project	Understanding and awareness of a technology	External Shocks	Costs
SWH	**2.52 (High/n =3)**	**3.00 (High/n =5)**	**3.00 (High/n=2)**
	• No understanding of the technology functionality • Do not value the technology as it is provided for free • Limited knowledge of technology within installers • No interest within younger people to learn about the SWHs.	• Subsidy withdrawal and low carbon price leads to a collapse of the project	• High costs
Basa Magogo	**Not specified**	**3.00 (High/n=2)**	**3.00 (High/n=2)**
		• Losses due to volatility of the foreign exchange rate • Decline in coal use and migration leads to phase out of the project	• High costs
WB	**2.00 (Medium/n=2)**	**2.08 (Medium/n=3)**	**3.00 (High/n=3)**
	• No awareness of the technology • Expectations to receive the technology for free on the infinite basis	• Low carbon price leads to losses and restructuring of the project	• High costs
Wood stove	**Not specified**	**Not specified**	**3.00 (High/n=2)**
			• High costs

Source: Author's compilation

9.4.1 Understanding and awareness of technology value

Project actors provided evidence that there was limited understanding and a lack of awareness of the SWHs at the user level which created challenges during installation (R7,8). The main issue installers reported was that it was hard for households to grasp the concept of the SWH technology. A respondent explained:

> *'And then again with respect a lot of the guys cannot even read. So what you do is, you have your guy when you put the system up you explain to them what is going on. Or once you put them all up, we normally then have a community meeting and we explain it to them' (R7).*

However, the worker, who installed the geysers in the households, pointed out that no matter how many times he explained the functionality of the SWHs, people would simply forget and then complain when they did not have any hot water on cloudy days or during cold winter periods. He described the situation as follows:

> *'It is like you are explaining the same thing for a month. Every time you explain, they say they understand, but when they see you again, they do not understand. Those are the challenges we faced...We were explaining to them, tomorrow they are coming in groups.*

They do not understand. So we came up with the pamphlets. And then I said, "it is a good idea". We gave people pamphlets. They didn't understand even when they got the pamphlets. Everything is written and it's got pictures, but they couldn't understand' (R8).

Furthermore, the worker noticed that there were differences in understanding and awareness of the technology between younger and older people. It seems that the younger people between 25 and 35 years old were less interested in finding out how the solar system works or how to most effectively use it in comparison to the older generation. The worker quoted:

'The young people from 25 to 35 are not in as much as you expect them to be into the solar things. They are expecting the geysers to work like an electric geyser. They do not want to understand the whole situation of the time limit of the solar system. That is where the interest is too low for the solar system' (R8).

The worker also reported that even installers had difficulty explaining the functionality of the SWHs to households because the technology was relatively new and they too had limited knowledge. However, as time passed, there were more people in the community, who educated themselves and became aware of the benefits the geysers provided (R8).

Furthermore, the SWH installer noted that households apparently did not value the technology as they received it for free (R7). A similar observation was provided by a respondent in the Wonderbag project. Apparently, the partnership with Unilever helped initially to create awareness and launch the techology, it created some distortions in the consumer market and devalued the technology as it was provided free of charge (R3). The respondent noticed that many residents in the township had no awareness of the value of the WB and expected to receive the technology for free indefinitely (R3). The respondent sated:

'…the person who shops at Shopright knows that the Wonderbag is kind of free because they remember the previous promotion. We are still getting enquiries now from people assuming that there is promotion going on where they get it for free. Unilever promotion did create a bit of the distortion in the market where the WB was slightly devalued. It has taking us a while to get people understand that the product is worth a price that they pay' (R3).

While there was limited understanding of SWHs within households, a respondent in the SWH project alluded to the fact that the distribution of SWHs created asymmetric information. The respondent explained that the carbon credits quantified by the project belonged to the homeowners. Since households did not understand the process, they simply ceded the rights in exchange of the geysers (R6). A respondent explained as follows:

'Remember the carbon actually belong to the homeowner and the homeowner had to cede it over to the project. They did not understand it. They said: 'What the hell, we do not care. We are getting hot water' (R6).

The same phenomenon is observed in another project. The information on carbon credits was withheld by the project actors and not explained to the households. A respondent stated:

'Right now with carbon credits, we don't even know. I don't really explain that part, like the whole market is tumultuous whatever. I just tell them we are going to use the money to build more stoves, if we can' (R19).

This is an important finding, which raises a question about the carbon credit ownership. As per Karhunmaa (2016) a common practice is to transfer the ownership of the emissions from the user of the technology to the project developer through signing a waiver. However, the finding of this study revealed that information was obscured to local people on the value of the carbon credits being generated, and the value of the future carbon rights. During the interviews, respondents mentioned a number of external events that negatively affected their project operations. These events are presented and analysed in the next section.

9.4.2 External shocks

Project actors in the WB and SWH projects highlighted that shortly after they registered their projects with the carbon standard in 2012, the carbon price and the demand for carbon credits collapsed (R1,6). This was mainly driven by the economic slowdown at the time which contributed to the decline in emissions in Europe and an oversupply of carbon credits in the EU ETS (see Chapter 7).

Since these projects mainly depended on the carbon revenue, respondents explained that their business models fell apart and they incurred financial losses (R1-3, 6,9,10,12). A respondent described the situation as follows:

'When the carbon market collapsed, I lost a lot of money. I had to re-launch the business and start again in 2013 as a retail business. It has been a huge challenge for me. Our credits were worth nothing. If you can't sell your carbon for a reasonable price, then these projects are not self-sustaining and they're not sustainable. That's the biggest challenge' (R1).

Another respondent observed a lot of fear and uncertainty in the CDM market. A respondent in the SWH confirmed:

"There was a lot of hesitancy, a lot of fear about where carbon was going and I think people just thought the bottom will fall out of the carbon market and without it the roll-out of solar across South Africa is going to be unsustainable because somebody is going to have to pick up the tab' (R12).

Following this, the respondents reported that Eskom's rebate programme was terminated, and no subsidies for the SWHs could be paid out due to corrupt activities in the market (poor installation of SWHs, inadequate reporting systems, manipulated and unverified locations of installed systems, etc.) (R6,7,9). Subsequently, the SWH project collapsed and the partnership dissolved (R12).

Although the SWH carbon offset project never recovered from this shock, a respondent reported that the SWH industry became self-regulated and is now in a good space. The quality of geysers significantly improved and are now required to be locally manufactured (R6).

In relation to the BM project, this project was not affected by the collapse of the carbon price because it was registered in the voluntary carbon offset market. However, project actors experienced other unexpected challenges. A respondent reported losses arising from the foreign exchange rate as soon as funding for the project was received. For example, the project received approximately 1.4 million Rand (€74,000) less than expected, which delayed the rollout of stoves in the project area (R13).

Another respondent reported a 17% annual decline of coal usage in the project area as a result of mass electrification in the country (R13,15). It was apparent to a respondent that 'the low-hanging fruit' was exhausted and there was substantially less coal used, which created some challenges to sustaining the project in the long run (R15).

Migration was another factor that created some issues for the BM project. The respondents noticed that, over the years, many residents migrated to other areas (reasons unknown) and only a few BM users remained in the project area (R13,15). Due to limited project funding, it was too expensive to continue with the project and to constantly remind people to use the BM technique (R13). As a result, the project was phased out as soon as it reached its 10-year access to carbon finance (R15).

9.4.3 Project costs

All project actors interviewed in the study felt that the process of registering carbon offset projects was extremely costly, and hence created a barrier. To protect the identity of projects, total costs are reported within a range; are indicative and subject to change. For example, project actors indicated that they spent approximately R1.5–R9 million (€80,000–€490,000) to implement the projects (R3,16,19) (see Table 39). They budgeted an additional amount of €30,000 to €50,000 to pay for the carbon component registration. This included consultant fees to prepare Project Design Documents, auditor costs to validate the projects and monitoring costs to subsequently issue carbon credits. These costs are defined as 'transaction costs' of a project.

Table 39: Overview of costs reported by project actors and emission reduction (estimated) achieved by technologies

Type of costs	Amount	Number of responses
Budgeted transaction costs	€30,000 - €50,000 [R568,000 – R950,000]	3
Total implementation costs incl. transaction costs	€80,000 - €490,000 [R1.5 million – R9 million]	3
Total cost per technology per tonne of CO_2-e	€1-€2 [R19-R39]	Estimated[49]
Annual emission reduction per technology per tonne of CO_2-e	0.11-0.77 CO_2-e	Estimated[50]

Source: Fieldwork, 2017, 2018

In addition to these costs, a respondent in the WB project pointed out that it was challenging to find the right people to assist with the carbon offset project registration and set up the appropriate infrastructure to verify the emission reductions of the project (R1).

Respondents in the BM project highlighted that carbon standards had no understanding of the practical challenges and complex realities of project rollouts in South Africa. They often doubted every aspect of the fieldwork-related process (R14,18) and required a record of every detail of the fieldwork-related operation, such as fieldworker safety and employment. The respondent highlighted that it was not always possible to fulfil these requirements as some processes, such as meetings in townships and rural areas, were often conducted on an informal basis. The respondent concluded that in the end it became cumbersome, extremely expensive and a time-consuming activity (R16).

During the interviews, it was evident that in reality some project actors incurred much higher costs than stated in Table 39. For example, a respondent in the WB project reported that carbon consultants initially did not understand the rules of the carbon development process and the

[49] The SWH carbon offset project did not issue any carbon credits, hence was excluded from the calculations. The methodology on how total costs per technology per tonne of CO_2-e were estimated is presented in Chapter 5.

[50] The methodology on how annual emission reductions per technology per tonne of CO_2-e were estimated, is presented see Chapter 5.

nature of the project. As a result, the total costs of the project mounted to the point where it became difficult to sustain the project (R1).

The estimated total cost per tonne of CO_2e saved by the carbon offset projects ranged between 19 Rand (€1) and 39 Rand (€2). Furthermore, the annual emission reductions ranged between 0.11 and 0.77 tCO_2e (depending on the technology). However, a project actor highlighted that the mitigation impacts of these projects were not guaranteed and depended on the regular use of technology by individual households (R14).

It was claimed that the technology alone did not provide any lasting effects on carbon emission reduction. Regular monitoring and education around the new technology was needed to ensure that it was able to reduce domestic emissions on an on-going basis (R14). The respondent described the situation as follows:

> *'It does not give the lasting effect you want. You have to keep at it - I mean typically if you want to maintain emission reductions you have to work it house by house, year by year' (R14).*

The amount of carbon revenue received from the carbon offset projects was not disclosed by project actors as it was deemed to be confidential information. However, respondents indicated that carbon revenue helped to establish a system of good governance, e.g., make internal administrative processes more transparent (R1,3). For example, as soon as carbon revenue was received, one respondent reported that it was immediately ring-fenced and used to cover costs (R3), buy necessary materials for the project or simply keep the business in operation (R2). Other respondents explained that carbon revenue was used to invest in sophisticated software systems to improve and make the data collection more effective during the monitoring period of the project (R13).

9.5 Chapter summary

This chapter presented the results from semi-structured interviews conducted with project actors in the Wonderbag, Solar water heater, Basa Magogo and Wood stove carbon offset projects. This chapter examined effectiveness of the projects' implementation process in the project areas. They included partnerships, project implementation approaches, employment, and skill development. Carbon finance was perceived to be as a suitable finance tool to build partnerships. While some project actors managed to create strong partnerships, others struggled to convince the government and the industries to make investments in their projects.

The results showed that projects that involved communities in decision making process were more effective than projects implemented from the top-down. However, the chapter also indicated that community members could still oppose project interventions due to personal reasons, different expectations, and the blame associated with polluting industries.

The chapter revealed that projects managed to create employment. However, these jobs were temporary and residents had low sentiment to get involved in these projects. This was partly due to hard work. The chapter identified various barriers with which project actors had to contend - namely understanding and awareness of technology, project costs and external shocks.

The chapter found that limited understanding of technologies (SWH) at the installer and user level can create confusion and compromise on the quality and use of the technology. It was evident that some carbon offset projects created asymmetric information where households remained uninformed about the current and potential market value of carbon credits. Projects were exposed to various external shocks (collapse of the carbon price, withdrawal of subsidies, volatility in exchange rates, migration) that were difficult to predict and jeopardised the operation of some projects.

The chapter showed that implementing carbon offset projects was expensive. In comparison to costs, emission reductions of these projects were small or negligible. The chapter argued that emission reductions were not guaranteed and heavily depended on regular household use. This is an important insight that opens the opportunity for the next enquiry. The next chapter (Chapter 10) presents the results on the adoption of technologies from the project actors' and end-user's perspectives.

Chapter 10: Adoption of low-carbon technologies in South Africa

This chapter presents the third (of four) sets of findings. It addresses the sub-research question as to how low-carbon technologies are adopted within households in South Africa. These findings are instructive as to how these technologies fit in with people's livelihoods and help identify which factors influence their adoption. Analysis of technology adoption is important. Consistent long-term use impacts the overall emission reductions achieved by carbon offset projects which then determines the amount of carbon credits claimed and traded in the carbon market. This in turn partially corrects the market failure and facilitates an incremental socio-technical transition (see Chapter 4)

The findings are based on project actors' perspectives and end-user experiences. The chapter is structured as follows: firstly, it explains how responses on technology adoption were analysed, then presents the findings from the project actor perspective. Lasty, it examines and summarises household responses on low-carbon technology use. It also analyses difficulties experienced with integrating these technologies into daily routines.

10.1 Comparative assessment of low-carbon technology adoption

As stated in Chapter 2, technology 'adoption' is defined in this study as a persistent use, which involves domestication and integration of a technology into household daily practice (Renaud and Biljon, 2008). In contrast, 'acceptance' is understood as users' interest or willingness to use a technology. It deals with users' attitudes and perceptions before use (Renaud and Biljon, 2008).

The findings in this chapter are based on semi-structured interviews obtained from project actors and household surveys across the four carbon offset projects. The responses were analysed using a thematic analysis described in Chapter 5. The researcher analysed project actors' perspectives on technology adoption and subsequently compared them with households' responses. The analysis includes the frequency of households' technology use and factors that influence adoption, such as technical issues, seasonal changes, gender dynamics, maintenance and personal preferences.

10.2 Project actors' perspectives on low-carbon technology adoption

During interviews, only project actors involved in three of the projects (Basa Magogo, SWH and Wood stove) offered their perspectives in relation to adoption of the technologies. No issues were mentioned by the project actors in the WB project. The key points are captured and discussed in more detail below.

10.2.1 Perspectives on the Basa Magogo method adoption

The project actors 'provided mixed responses on users' adoption of the Basa Magogo technique. While this technique was relatively simple to use, project actors admitted it could also easily fail (R14,18) (see Table 40). A respondent observed that as soon as households adopted the technique and started using it, they often failed to ignite the fire and reverted to their traditional method (R18).

Table 40: Summary of project actors' comments on the adoption of the BM method within households

Project	Project actors' comment	Frequency of responses[51]	Number of actors
Basa Magogo	'Relatively simple to use, but can easily fail'	2	2
	'Depends on type of coal'	1	1
	'The BM method knowledge was not passed on effectively'	5	2
	'No interest to integrate the BM method into daily routine'	2	2

Source: Interviews with project actors, 2017

The respondents stated as follows:

> *'But top-down ignition is finicky. It is sometimes can fail. You have to do it right. You have to focus a bit'' (BMR14).*

> *'...even though this is a relatively simple method, it's easy to fail. And I think when people fail once or twice and you now need to put your head into that stove...'. 'So you do that once or twice and a significant proportion of people that fail will just stop' (R18).*

However, another respondent added that adoption of a new technique not only depended on the skills and attention, but also on the type of coal households used (see Table 40). A respondent claimed that households often used low-grade coal supplied by local coal merchants in the area, which often resulted in ignition failure when using the BM method (R15).

At the same time project actors observed that the new ignition technique had not become part of household practice (R13,18) (see Table 40). At the beginning of the project, the NGO was under the impression that residents would spontaneously teach the method to other people in the target areas (R13,18). However, the method never became a trend nor was passed on to others, such as neighbours or even close and extended family members (R13,18). While the reasons remained unclear, this phenomenon created negative implications for the viability of a project. The

[51] Respondents provided more than one response

implementing NGO regretfully concluded that this was a 'project failure' and due to high costs, it was not possible to maintain the project in the long-run (P13).

Respondents were under the impression that there was no interest amongst community members to incorporate the new technique in their daily routines (R13,18). A project actor confirmed:

> *'...people just didn't draw on it spontaneously and that is something that up to today, we are still investigating- why and how can we actually get people to spread the beneficial solutions themselves, ...why doesn't he demonstrate it to his neighbour immediately?' (R18).*

> *'The intention of Basa was also not near to what we expected or hoped for. We thought that once you have converted households with minimum encouragement, afterwards maybe I think the fieldworker comes passed there once a year and just encourage people to continue to use Basa, they will continue to do so. But we have lost users that far exceeded what we had' (R18).*

Reflecting on the above, it is surprising that the NGO initially had genuinely hoped that this project could be sustained in the long-term. In hindsight, it was unrealistic to assume that the technique would spontaneously spread across households especially because a respondent admitted that making fire was rather personal in the sense that it is learnt from the childhood and forms a core part of the household's daily routine (R18). Outside interference is therefore not welcomed (R14) and technologies may not be adopted despite benefits and value proposition they may offer.

10.2.2. Perspectives on the Solar Water Heater adoption

According to the project actors, adoption of SWH technology was obstructed by technical issues, such as leaks. The project actors' comments on adoption are summarised in Table 41.

Table 41: Summary of project actors' comments on the adoption of SWHs within households

Project	Project actors' comments	Frequency of responses	Number of actors
SWH	'Can use SWHs, but experience leaks'	2	2
	'SWHs are incompatible with RDP infrastructure'	2	2
	'Households have poor quality geysers'	2	2
	'Households do not have funds to maintain the geysers'	2	2

Source: Interviews with project actors, 2018

The respondents confirmed that the rollout of low-pressure SWHs was poorly planned. The technology was initially imported from China and households ended up with poor-quality geysers (R7,11). A respondent explained:

'The way the roll out was done was a bit shoddy and so the quality of some of the stuff that went in, you know, the user experience was poor. (R11).

According to the respondents, the SWHs were incompatible with existing plumbing conditions of RDP houses (R7,8). The worker explained that the geyser could only be connected to one pipe in the bathroom. Due to a difference in pressure between hot and cold water, the cold water pushed hot water out of the tank causing leaks. This issue caused inconvenience and long waiting times to receive hot water (R8) (see Photo 12).

Photo 12: Plumbing problems in the RDP house, Cosmo City township. Source: Fieldwork, 2017

Furthermore, SWH installers confirmed that as soon as the technology was installed, many households complained and started reporting leaks (R7,8) (see Photo 13). A respondent quoted:

'There were some problems because you installed the geyser and then some parts inside there were supposed to stop the water when the geyser is full. The problem was it was not stopping the water and then the water would run out of the system – run down onto the roof and down. Those are the most problems that we encountered when we were installing the geysers. And even after we installed them' (R8).

Photo 13: Leakage from the SWHs, Cosmo City township. Source: Fieldwork, 2017

Although the technology provided hot water, the researcher's observations showed that the enthusiasm for SWHs quickly wore off in the project area (Observations, 2018). There was a general feeling of concern among households who were quick to point out the problems to the researcher. Moreover, the SWH installer acknowledged that households could not afford to maintain the geysers (R7). The SWH installer elaborated:

> *'Now the guy there has not even got the money to buy bread. Where is he going to now have money to put a new tube in and get it going again?' (R7).*

A worker reported that the cost to fix the geyser was between 20 Rand (€1) (to fix the valve) and 200 Rand (€10) (to change the tank) (R8). Since households in the township were constantly confronted with their everyday struggles, such as unemployment and poverty, geyser maintenance was a low priority (R7,8).

10.2.3 Perspectives on the Wood stove adoption

Project actors provided mixed perspectives on the users' wood stove adoption. One project actor reported that the technology was generally well accepted and understood by households in project areas (R19) (see Table 42).

Table 42: Summary of project actors' comments on the adoption of wood stoves within households

Project	Project actors' comments	Frequency of responses	Number of actors
Wood Stove	'Wood stove was well accepted and understood by households'	1	1
	Being part of the project is more important than actually using of the technology	1	1
	Households rejected the technology because they did not believe in it	1	1

Source: Interviews with project actors, 2018

However, a year after installation, to the respondent's surprise, some households had not yet even used the stove once (R19). The project manager was under the impression that some households had no intention of using the technology at all and only wanted to receive it because it was provided for free. It seemed as if it purely gave them a feeling of being part of the project and a sense of community belonging. A respondent explained:

> *'It might be because she just wanted the stove for free and now, she was part of this whole project – because she has one. Yeah, but it doesn't mean she is going to use it (R19).*

Furthermore, the project manager added:

> *'you can only take the horse to the water... you can't force it to drink' (R19).*

It is interesting to note the contrast between a project actor comparing the wood stove to 'water' (i.e., as an essential good to have), whereas the builder (R20) reports that some households simply rejected the stoves as they did not believe in them – perhaps revealing an out-of-touch opinion held by the project actor and insufficient understanding of the community and their needs.

10.2.4 Summary

Based on project actors' responses, Low-carbon technologies were not entirely popular. While some low-carbon technologies did not fit well within the daily user's routines, other technologies came with some technical issues (leaks, fire ignition difficulty) and needed costly maintenance which further hampered users' adoption. As a result, initial acceptance did not necessarily translate to adoption in the long term. Although project actors provided useful insights, the next section will investigate and compare them with households' perspectives in relation to technology adoption

10.3. Low-carbon project technology use within households

To understand how low-carbon technologies were adopted within households, the researcher asked the respondents during the survey how often and for what activities they used these technologies. This information helped to understand the context and the frequency of technology use.

Since the technologies were rolled out at different timelines – Wonderbag in 2013, fire technique in 2010, solar water heater in 2012 and the wood stove in 2018 (Burgersdorp) and 2016 (Bonn), the researcher also asked the respondents to indicate the last time they had used these technologies. This helps to understand consistent use of low-carbon technologies and factors that may limit users' adoption.

10.3.1 Wonderbag project

Starting with the WB technology, 84% of respondents in the sample (n=16) said that they typically cooked warm and hearty meals with the WB, whereas 16% of respondents (n=3) only used the technology to keep food warm (see Table A10.1). The most common dish cooked by respondents[52] in the WB was 'samp', a traditional Xhosa meal made of corn kernels and beans (see Figure 28). Since this meal takes time to cook, respondents explained that they did not cook this meal every day, but only 2-3 times a week (42%) or once a week (16%) (see Figure 29).

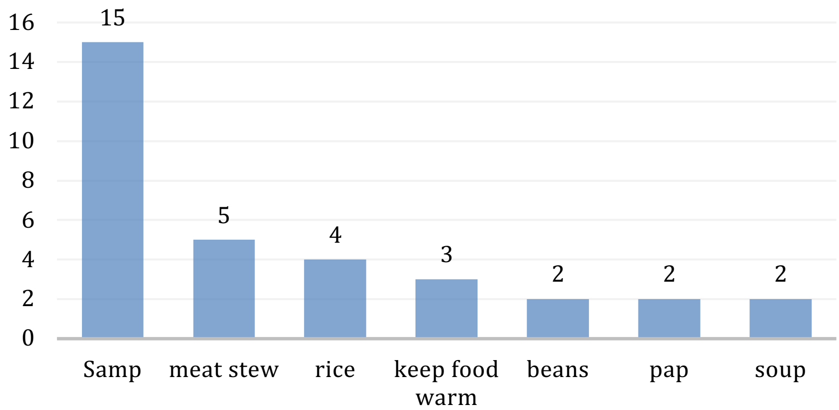

Figure 28: Most common use and dishes cooked with the WB reported by respondents. Source: Field Survey 2017, Langa

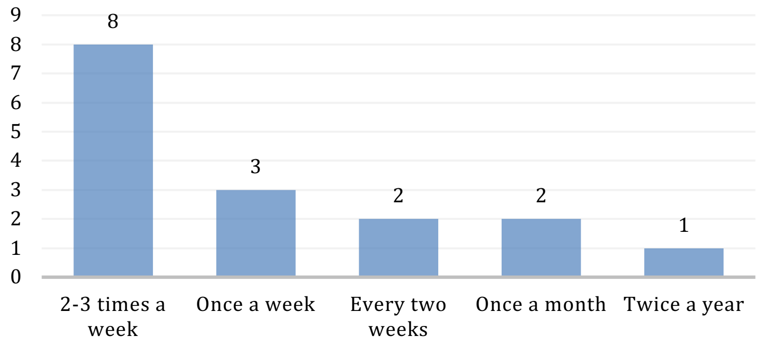

Figure 29: Frequency of the WB use reported by respondents. Source: Field Survey 2017, Langa

Findings showed that seasonal changes significantly affected households' use of the technology. For example, 17 out of 19 respondents in the sample (84%) used the WB more in winter than in summer[53] (see Figure 30).

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[52] Respondents provided more than one response during the survey

[53] Respondents in all carbon offset projects referred to winter or summer months to capture the seasonal extremes of their technology use. Winter period in South Africa typically runs from June to August, whereas summer period is from December to February. Due to time constraint, it was not possible to investigate technology use in other seasons, e.g., spring and autumn.

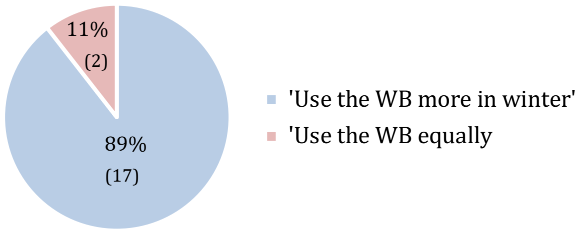

Figure 30: Use of the WB during seasons reported by respondents. Source: Field Survey, 2017, Langa

Due to hot summers in Cape Town, the respondents pointed out that they did not cook any heavy meals like samp or stews, instead they ate cold food (WBR 1,5,8,9)[54]. However, in the winter period some respondents used the WB not only to cook warm meals, but also to keep baby bottles warm (WBR1) and store warm water for bathing in the morning (WBR9). The respondents explained:

> *'I do not use is so much in the summer. We eat cold food. Especially in winter everybody wants to eat meat stew. We need something hot, you know' (WBR5).*

> *'...in summer, we eat light food so we do not use it' (WBR8).*

The data shows that the use of the WB has been sustained throughout the years. For example, 63% of respondents in the sample (n=12) confirmed that the last time they used the cooking technology was between "yesterday" and "last month" (See Table A10.2). Only 37% of respondents in the sample (n=7) used the WB between 2 months and 2 years ago. The respondents provided various reasons for their infrequent usage. For example, one respondent pointed out that the WB was at the end of its life and not strong anymore (WBR14). Furthermore, the researcher observed that respondents kept the technology in bedroom cupboards due to limited living space (Observations, 2017). Following this, three respondents confirmed that they simply forgot about the technology as it was not visible to them (WBR10,12,15). A respondent stated:

> *'Unfortunately, because I keep it where I do not see it. I was wondering the other day when I was seeing it that I got this wonderful product and I am not using it, because it really saves electricity and time (WBR15).*

Another respondent explained that she did not use the technology anymore as she did not cook in the house due to other commitments, e.g. schooling (WBR11). A respondent confirmed:

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[54] WBR stands for Wonderbag Respondent. All respondents are abbreviated as Project name, Respondent (R) and Respondent Number that was assigned during coding

'It's been a while since I last used the bag, because I have been attending school. My husband was the one doing the cooking in my absence. I do not even know where it is right now, but I think it is in the suitcase under my bed' (WBR11).

In summary, the Wonderbag technology was in general well adopted by households in the long run. The majority of households continued to use the technology on a regular basis.

10.3.2 Basa Magogo project

Residents in Wesselton township typically experience cold winters with up to 80mm per day of rain and sharp frosts (Msukaligwa Local Municipality,2020). As a result, 64% of respondents in the sample (n=16) used the BM coal fire technique 'twice a day' or even 'three times a day' (20%) to cook food and keep warm during cold winters (see Figure 31). In the summer, respondents seemed to use the BM method more or less the same (once or twice a day) for cooking meals (see Figure 31).

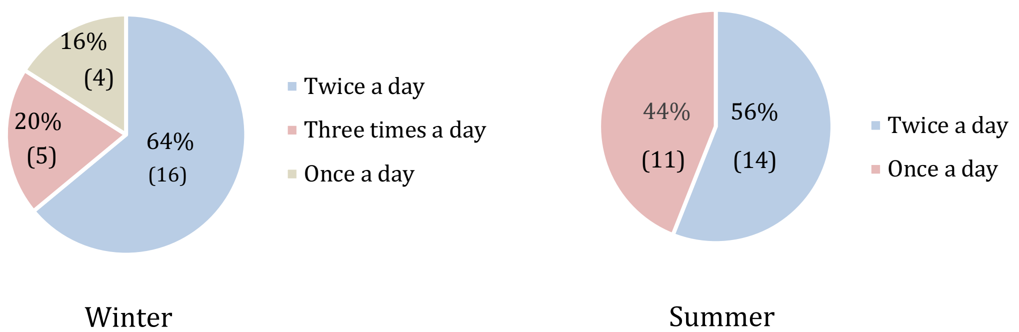

Figure 31: Frequency of coal fire used reported by respondents in winter and summer. Source: Field Survey, 2017, Wesselton Township

Furthermore, the results showed that 22 out of 25 respondents in the sample (88%) stopped making coal fire using a traditional method and completely converted to the BM method (see Table A10.3). Only three out of 25 respondents in the sample (12%) reported that they occasionally used the traditional coal fire technique in situations when they were in a rush and quickly needed to make fire (BMR4,15,19).

Respondents elaborated:

'Sometimes I do not use it, because I have to make things faster. Then like I need to make food for everyone' (BMR4).

'If I am rushing– going somewhere then I am using the open fire. Like today, I am only doing the washing; as soon as I am done with everything, I use the Basa Magogo technique' (BMR19).

While it is evident that the majority (88%) of households in the survey successfully adopted the BM technique into their daily routine, nine respondents in the sample (36%) revealed that they struggled to start the fire. For example, two respondents forgot how to apply the BM method correctly (BMR13,18) or struggled and went through a process of trial and error generating a lot of smoke before they could adjust to and successfully apply the new fire technique (BMR2,6,8,9,20,21,24). This finding is in line with project actors' perspectives, who admitted that the BM method requires a user to pay careful attention as the fire technique can easily fail.

It was evident that 14 out of 25 respondents in the sample (56%) passed on their BM method knowledge to their family members. Of those 14, half of them (n=7) successfully converted their family members to the BM technique, while the other half (n=7) were unsuccessful (see Table A10.4). A respondent pointed out as follows:

> '*My children use the old technique. I taught them, but they are lazy to use the BM method' (BMR15).*

Two respondents in the sample claimed that they even experienced tensions with their husbands, who refused to use the BM technique as they did not want to be taught by a woman on how to make a fire (BMR3,5). A respondent specified as follows:

> '*The Zulu man is stubborn and would not listen, and they do not want to listen. He would not use it because he does not want to do the same what is done by me. He wants to do it in its own way; follow the culture without changing anything. He would not compromise. If he follows magogo [me, grandmother], he compromises his dignity. He refuses to change.' (BMR5).*

It seems that when it came to making lifestyle changes, such as learning a new fire technique, people did not take the BM method seriously (BMR11), simply did not like it (BMR16), or found it difficult to change (BMR15). Furthermore, 44% of respondents in the sample (n=11) never spoke about the BM method at home and ended up using both techniques (BMR12,24), thus continuing to inhale smoke and suffer from indoor air pollution (Observations, 2017) (See Photo 14). A respondent elaborated on the situation as follows:

> *'Others are saying it is a difficult way. They have been with the old method for years and years and now they have to change to something else. It is difficult to change. They do not like to change' (BMR15).*

> *'It is very difficult to convince people because they like to look at the negativities than the advantages. Especially when a foreigner comes in and starts teaching them how to make fire' (BMR15).*

Photo 14: Indoor air pollution in Wesselton township. Source: Fieldwork, 2017

These findings are in line with project actors' aforementioned perspectives and provides further evidence that the BM method was not spontaneously spread across households in the project area. However, since it remains unclear as to why some respondents did not pass their knowledge, more research is needed to investigate this matter.

10.3.3 Solar Water Heater project

In relation to the SWH technology, findings showed that respondents in the sample mainly used hot water from the SWH for bathing (n=28) and washing dishes (n=23). The geyser water was also used for cooking (n=11), washing clothes (n=4), cleaning (n=3) and even drinking (n=1) (see Figure 32).

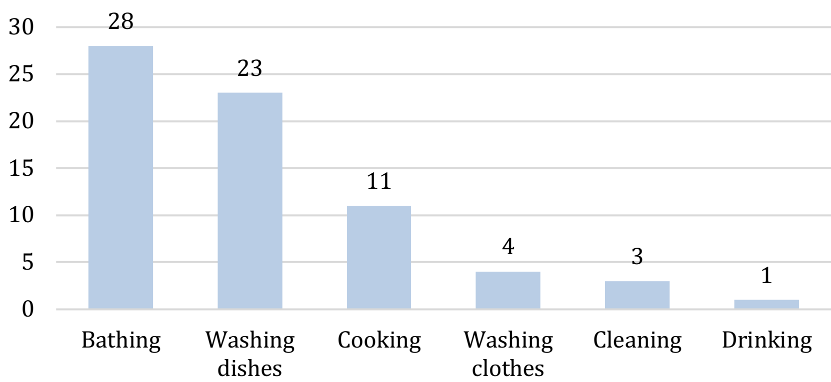

Figure 32: Reported activities carried out by respondents[55] using hot water from the SWH. Source: Field Survey, 2018, Cosmo City

[55] Respondents provided more than one response

The data showed that majority of respondents in the sample used the geyser on a regular basis: twice (71%) or once a day (21%) (see Figure 33).

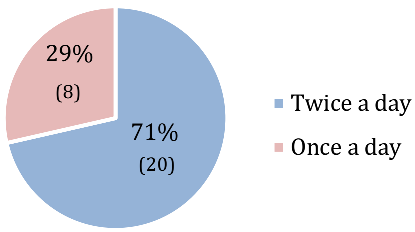

Figure 33: Frequency of hot water use from the SWH reported by respondents. Source: Field Survey, 2018, Cosmo City

At the same time, 71% of respondents in the sample (n=20) reported that they used the SWHs more in summer than in winter (see Table A10.4). Respondents claimed that during summer they could simply open the tap and receive hot water immediately (SWR20,22). However, in the winter period, eight respondents in the sample explained that the water remained lukewarm or cold and they had to revert to electricity to boil water for their bathing activities (SWHR10,11,12,13,16,23,24,26). During the conversations, the respondents appeared to be vulnerable and complained that hot water was not available when they needed it the most. A respondent stated:

> *'When it gets cold, the water is cold and the geyser is useless. You boil water there with electricity, then we bath. We boil water using electricity and we wait for each other with the kettle and pour water.' (SWHR13).*

Another respondent added:

> *'In winter the water is cold and children are scared to bath. But in summer, that is where we see the water is used a lot because each and everyone knows that the water is hot' (SWHR10).*

The results also revealed that 86% of respondents in the sample (n=24) experienced technical faults, such as leaks, when using the SWH technology (see Table A10.5). Respondents complained that continuous leaks caused permanent damage to the roof, e.g., cracks (SWHR11,13), whereas others expressed their concerns that asbestos was getting wet and may not be strong enough to hold the heavy geyser (SWHR14,16,18,23,25,27). Respondents also reported that they could not find appropriate technical support to maintain and fix their geysers (SWHR 1,2,4,15,18), hence had no choice but to live with this issue. Two respondents in the sample were unhappy with the geysers to the extent that they wanted to have them removed (SWHR1,4). A respondent explained:

> *'They just installed it and left. We do not know, where they are. That's why the geysers are not being cleaned. People remove it. I will also remove it and throw it there outside because other people are removing it since it causes damage. It damages a lot' (SWHR4).*

It seemed that residents did not receive any training on how to use the SWHs. It seems that education was necessary because the majority of people living in Cosmo City came from the informal settlement and did not have any experience or familiarity with the geysers. (SWHR28).

10.3.4. Wood Stove project

In the wood stove project, the results showed that all respondents[56] mainly used the wood stove for cooking and boiling water for bathing (see Figure 34). In addition to these activities, some respondents used the technology as a heater, while others boiled water for drinking and washing dishes.

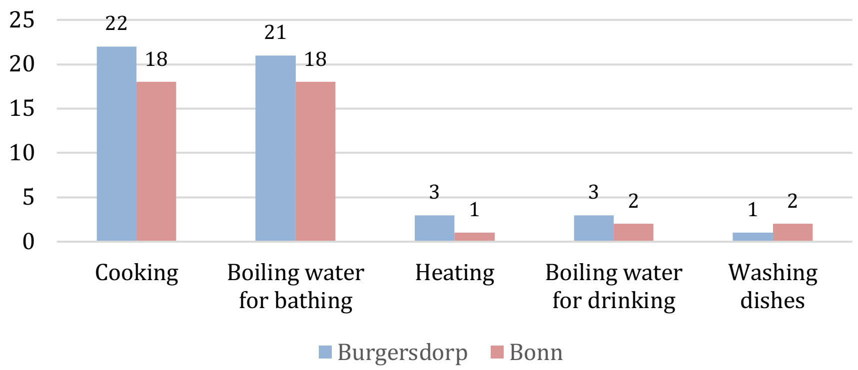

Figure 34: Reported activities undertaken by respondents using the wood stove. Source: Field Survey, 2018, Burgersdorp and Bonn

Since respondents mainly cooked with the wood stove, they used it every day – once (95%) or twice a day (5%) (see Figure 35).

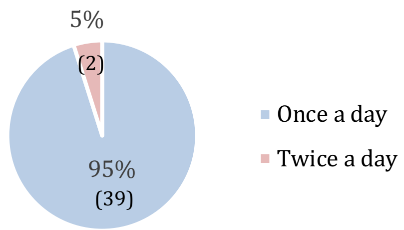

Figure 35: Frequency of the wood stove use reported by respondents. Source: Field Survey, 2018, Burgersdorp and Bonn

Similar to other technologies, findings showed that 51% of respondents in the sample (n=21) used the wood stove more in winter than in summer periods (see Table A10.6). Due to cold winters, respondents explained that they usually added more firewood after cooking and sat around the wood stove to keep warm (WSR5, 40). A respondent stated:

---

[56] Respondents provided more than one response during the survey

'In winter we use it more than in summer because in winter it is usually cold. So when we put it on and we cook, we are likely to sit around it and get warm (WSR5).

Another respondent confirmed:

'In winter the wood stove works a lot even if we don't cook, we just put it on and get warm, but in summer we only put it on when we want to cook' (WSR33).

During the summer some respondents did not use the wood stove at all. The reason reported was that the kitchen becomes unbearably hot (WSR5,25,28, 36). A respondent explained:

'I am scared of the heat because inside the house its hot and I have high blood pressure' (WSR25).

There was a stark difference between the two project areas in relation to the last time respondents used the woods stove. In Burgersdorp, where WS was introduced in 2018, results showed that 87% of respondents (n=16) used the stove within the last month, e.g., yesterday (22%), today (13%) and two days ago (9%) etc. (see Table 43).

Table 43: Respondents' comments on the last time they used the wood stove in Burgersdorp village

Burgersdorp			
Respondents' comments	Frequency of responses	Percentage (%)	Aggregated frequency of use (%)
Yesterday	5	22	87
Today	3	13	
2 days ago	2	9	
A few days ago	2	9	
Last week	3	13	
2 weeks ago	1	4	
Last month	4	17	
3 months ago	2	9	13
6 months ago	1	4	
Total	**23**	**100**	**100**

Source: Field Survey, 2018, Burgersdorp

In contrast, the last time 65% of residents (n=12) in Bonn village used the stove (which was introduced in 2016) was a year (38%) or two years ago (27%) (see Table 44). It seems that the wood stove was abandoned by the majority (82%) of the respondents in the sample. They provided several reasons.

Table 44: Respondents' comments on the last time they used the wood stove in Bonn village

Bonn			
Respondents' comments	Frequency of responses	Percentage (%)	Aggregated frequency of use (%)
Today	1	6	18
Last week	1	6	
Last month	1	6	
2 months ago	2	11	82
4 months ago	1	6	
1 year ago	7	38	
2 years ago	5	27	
Total	18	100	100

Source: Field Survey, 2018, Bonn

For example, two respondents explained that they had to remove the outside kitchen together with the wood stove due to space limits (WSR26,36). Others reported that their wood stove was destroyed by a storm (WSR29,41) or had been damaged and rendered unusable (WSR31). Some wood stoves in the area were apparently incorrectly built and this created frustration among users, leading to the complete abandonment of the technology (WSR34).

Three respondents in the sample stopped using the wood stove for practical reasons. They claimed that they needed to use big traditional pots that did not fit the wood stove. As a result, they reverted to using open fire (WSR25,27,33). A respondent stated:

> *'Back then we were only two. So I was using the pot, which was only fit for two of us. But now we are many. Now we have to use a bigger pot so that is why I cannot use the wood stove anymore. We are eight' (WSR25).*
>
> *'The reason, which made me stop using the wood stove, is because now the schools are closed and kids are around, so I am using a bigger pot with legs and it does not fit there on the wood stove' (WSR33).*

Other respondents acknowledged that they simply did not enjoy using the wood stove and preferred open fire as they grew up with it (WSR26,34,36,38). Some did not have time to collect wood nor money to buy it, and hence stopped using the stove altogether (WSR39). The findings showed that there was initial excitement in Bonn village at the time of introduction, but that quickly wore off after approximately six-month (WSR26,39). A respondent confirms as follows:

> *'The problem is that it was only exciting to us at the time we received it. But then we had our own stoves [electric] so we were just excited for a short period of time. We were happy because it was something special and it was prestige to have the wood stove, when we are talking to other people, who also had it' (WSR26).*

Furthermore, some respondents complained that they could not maintain the stoves (WSR26,29,34) Since respondents were involved in other household chores, e.g., laundry and cleaning, they felt that maintenance of the wood stove was wasting their time, hence they completely abandoned the stoves (WSR29,31). A respondent explained:

> *'The difficulty is that I have to go and look for cow dung. Then I mix it with soil then I start fixing it on the holes where the cracks are. I had to fix it until it is looking good. I felt like it is too much work for me because at the same time I have to do laundry and clean the house. It wastes my time, so I stopped doing it' (WSR29).*

A respondent reported that she would maintain the wood stove mainly to please the NGO who inspected the stoves in the area. The respondent stated:

> *'I maintained it a lot of times because when we hear they are coming [NGO] to check the stoves, we would fix it. I would fix it to make sure it is looking nice. Remember if you cook pap with it, it will look dirty so you had to clean it' (WSR26).*

In fact, 32% of respondents in the sample (n=13) still continued using an open fire (See Table A10.7). Two respondents claimed that they rotated their cooking practices between the wood stove and the open fire (WSR 9,34), while others used the open fire every day to boil water (WSR22,33). To make cooking processes faster during parties, spiritual ceremonies, weddings or funerals, five respondents in the sample reported that they used open fire and the wood stove together at the same time (WSR6,24,33,37,40).

However, findings also revealed that respondents struggled with the wood stove, despite receiving instructions on how to use it. For example, women could not get used to the technology (WSR8) and it took time for them to light up the fire (WSR35,38). The respondents emphasised that the wood stove required dry wood, which they often did not have. As a result, they needed to revert to the open fire, as wet wood did not burn or produced a lot of smoke (WSR11,12,13). A respondent explained:

> *'The wood stove requires dry wood and I ran out. Now what I have is the wet ones. The wet wood does not burn well when you use it on the wood stove. I have been using open fire because I haven't got dry wood. I love the wood stove. Just that now I ran out of dry wood' (WSR12).*

A majority (61%) of respondents in the sample did not educate any family members on how to use the wood stove as they were mainly responsible for cooking in the house. Only 39% of respondents in a sample (n=16) passed on the knowledge on the wood stove to family (see Table A10.8). However, only nine out of 16 respondents managed to successfully convert their family members to the new technology. The rest continued cooking using electric stoves or open fires.

Five respondents in the sample noticed that especially younger people (daughters) between 25 and 35 years old preferred to use electricity (WSR10,12,40) or open fire (WSR37,41). For example, a respondent stated:

> *'You know when you are not around, kids (daughters) will not use it because they don't like this kind of thing. They use open fire' (WSR37).*

It seems that the adoption of the wood stove varied across locations. While the wood stove was successfully adopted in Burgersdorp village, use of the technology gradually declined in Bonn village. The study therefore concludes that the use of this technology is not sustainable in a long-run due to various reasons, such as on-going maintenance requirements, changing habits, larger family size and personal preferences. Similar to the BM method, the skill on how to use the technology tended not to be passed on among family members.

10.4 Chapter Summary

The chapter revealed that households regularly used low-carbon technologies received. However, the integration varied across households and depended on factors, such as seasonal changes, functionality, maintenance requirements and willingness to change habits. The Wonderbag seems to be the only technology in this study which was relatively well integrated within households. Other technologies were set back by technical issues, such as leaks in the SWH project or users' inability to ignite the fire in the BM and the Wood stove projects.

The chapter showed that adoptive technology was constrained due to lack of time and funds to maintain the technologies. In some instances, there was an absence of technical support in the project area that was another contributing factor. Access to resources (good quality coal/dry wood), changing habits, personal preferences and growing family size were factors that limited the use of the technologies.

The results showed that young people seemed less inclined to adopt the wood stove than the older generation. However, given that this evidence is based on only a few respondents, further research is needed to investigate this apparent trend in more detail.

To conclude, the chapter showed that low-carbon technologies did not fully displace the use of unsustainable fossil fuels within households during their cooking and heating activities. Households rotated their cooking activities around new technologies, instead of giving up their traditional cooking practices or household habits altogether. Although this chapter generated new knowledge, it is still unclear how livelihoods of households change as a result of low-carbon technology adoption. This phenomenon will be further investigated in the next chapter (Chapter 10).

Chapter 11: The livelihood outcomes of carbon offset projects

This chapter presents four sets of findings addressing the sub-research question as to how livelihoods of households change as a result of carbon offset project interventions. The chapter shows that low-carbon technologies helped households in two ways – namely, by reducing energy costs and saving time. Additional benefits were often derived but varied depending on the household technology use– they either were associated with improved social relations, health and wellbeing, or quality of life. The chapter also presents the negative effects experienced by households, such as technical issues and the impacts of an unequal distribution of a technology.

The chapter explores these aspects in detail and demonstrates that these patterns are complex and location-specific. This chapter firstly explains how changes in livelihoods have been measured in the study. Then, it describes the demographic and socio-economic characteristics of participant households. Lastly, it presents the results from the data collection and discusses various livelihood changes of the four carbon offset projects.

11.1 Household survey categorisation impact

This section presents data obtained from the household survey. The researcher analysed it using indicators developed from the Sustainable Livelihood Approach (see Chapter 5) (Scoones, 1998). The impacts were then assessed using the Multi-Criteria Assessment (MCA) described in Chapter 5. To make sense of different incommensurable qualitative and quantitative impacts to livelihoods, the researcher clustered them together using criteria based on household responses from the household survey (see Table 45 and 46).

This approach helped to provide an aggregate assessment of the different impacts and technologies used in different households. The key insight from this research provided evidence that livelihood changes facilitated by technologies had both pros and cons and were evaluated subjectively by different households. The study therefore tries to make sense of households' perspectives and applies categorisations to simplify the matter. However, the researcher still acknowledges that it is a complex phenomenon and some responses may provide ambiguous results.

11.1.1 Quantitative indicators

For quantitative indicators significant impacts were evaluated by applying either a 'Positive' or 'Negative' criterion. If no impact was detected, a criterion of 'No impact' was assigned (see. Table 45).

Table 45: Assessment of livelihood impacts using quantitative

Quantitative indicators	Description	Criteria of Livelihood Level Impact
• Energy use • Energy cost • Cooking time • Water consumption • Time required to collect firewood	Significant improvement in energy/ water/time saving (kg/ Rand/time/litres/days) when compared to the baseline	Positive
	No impact on energy/water/ time saving (kg/ Rand/time/litres/days) when compared to the baseline	No impact
	Significant negative energy/water/time/ saving (kg/ Rand/time/litres/days) when compared to the baseline	Negative

Source: Author's compilation

11.1.2 Qualitative indicators

For qualitative indicators, the researcher used the diverse set of responses from the household survey to build up a composite picture to infer what the overall livelihood impact has been. To provide a framework upon which comparisons could be made, the received details are incommensurate, but the following criteria was applied to the responses: 'Positive', 'Ambiguous' or 'Negative'.

In the situations where either positive or negative responses for a particular livelihood impact outweigh the other, an overall 'Positive' or 'Negative' criterion was respectively assigned. In situations where there was not a preponderance of either positive or negative responses, an 'Ambiguous' grade was assigned (see Table 46).

Table 46: Assessment of livelihood impacts using qualitative indicators

Qualitative indicators	Description	Criteria of Livelihood Level Impact
• Perceived value of a technology • Health and wellbeing • Hygiene and sanitation • Perceived technology safety • Convenience • Social relations	Positive responses significantly outweigh negative responses when compared to baseline.	Positive
	Responses provide mixed feedback (+/-5%) in relation to a particular livelihood impact when compared to baseline.	Ambiguous
	Negative responses significantly outweigh positive responses when compared to baseline.	Negative

Source: Author's compilation

The respondents who did not have any opinion in relation to the topic – these are classified as a 'no opinion'. It is important to mention that the livelihood impact assessment is indicative and only provides an impression of respondents' behaviour at the time of the study. Impacts that were not related to some carbon offset projects were denoted as 'Not Applicable' (NA).

11.2 Socio-economic characteristics and energy use of households

This section presents the socio-economic and demographic characteristics, and energy use of households surveyed in this study. This data allows us to better understand the community profile in the project areas, their background and resources. The sample shows that a majority of respondents are women over 50 years old, who take responsibility for the adoption of the technologies (see Figure 36). The survey indicated that women typically carry out household functions, such as cooking, cleaning, bathing children etc.

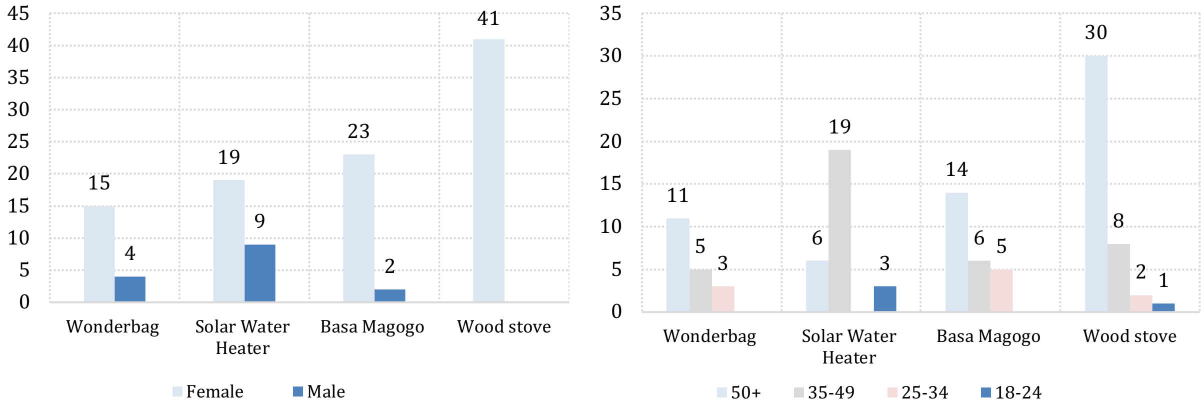

Figure 36: Gender and Age breakdown of respondent household user. Source: Authors' compilation

Figure 36 shows that the most frequent category size of South African households in the project areas consisted of five or more individuals. The most frequently cited level of attained education was the secondary school tier (grades 8-12). However, a sizeable minority of wood stove users (14 of 41 respondents – region: Limpopo) and Basa Magogo users (13 of 25 respondents – region: Mpumalanga) only had primary education or no schooling at all. In metropolitan cities, such as Johannesburg (22 of 28 respondents) and Cape Town (15 of 19 respondents), the majority tended to have completed their secondary schooling.

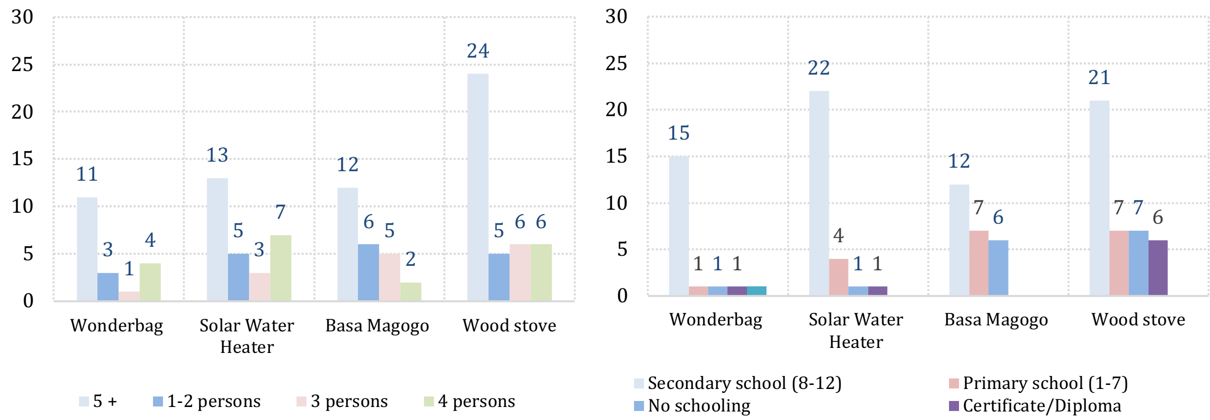

Figure 37: Household size and Education breakdown of respondent household user. Source: Author's compilation

The data on the employment status breakdown across the sample provides mixed results (see Figure 38). In general, the majority of women were either unemployed, self-employed or in temporary employment. The average monthly income reported by respondents was approximately R2,500 (€132) (see Figure 39). This indicates that women were likely to be financially vulnerable and may have limited resources to complete their daily tasks.

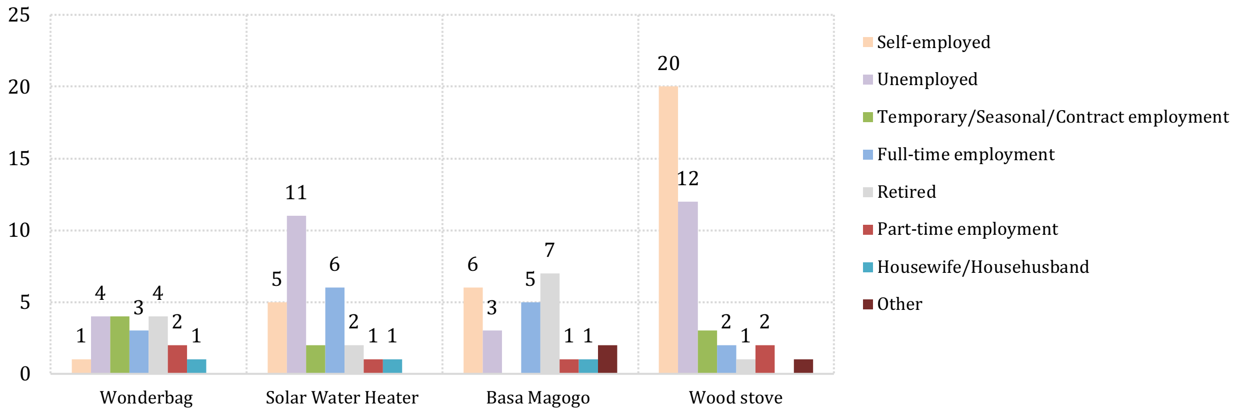

Figure 38: Employment status breakdown of respondent household user. Source: Authors' compilation

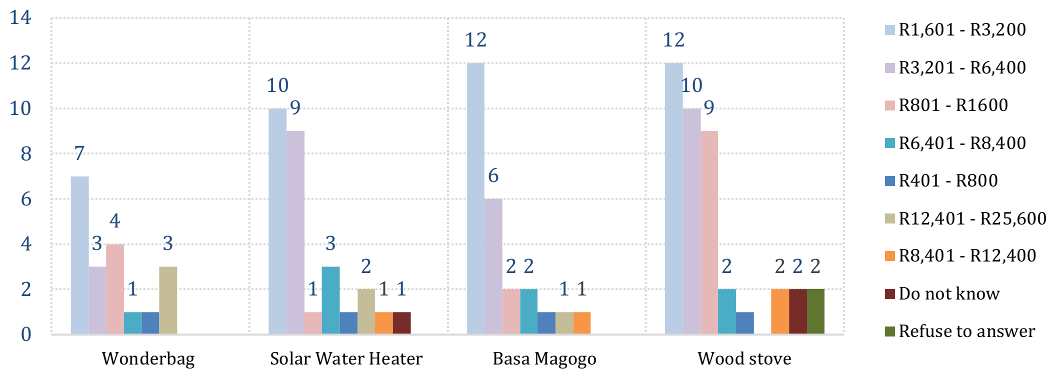

Figure 39: Monthly Household Income breakdown of respondent household user. Source: Author's compilation

The main source of energy used by households on a daily basis depended on the location. Women in the sample reported that they typically used multiple energy sources. For example, in urban areas, such as Cape Town and Johannesburg (where the Wonderbag and the SWHs were rolled out), they mainly used electricity for cooking and bathing (see Figure 40). Since electricity was expensive and not a reliable energy source due to regular electricity blackouts, households often combined different fuel sources. Women reported that they used electricity for cooking smaller dishes, making tea or cooking vegetables. In contrast, they used paraffin or gas for heavy meals, such as meat, stews and beans, that take more energy and time to cook.

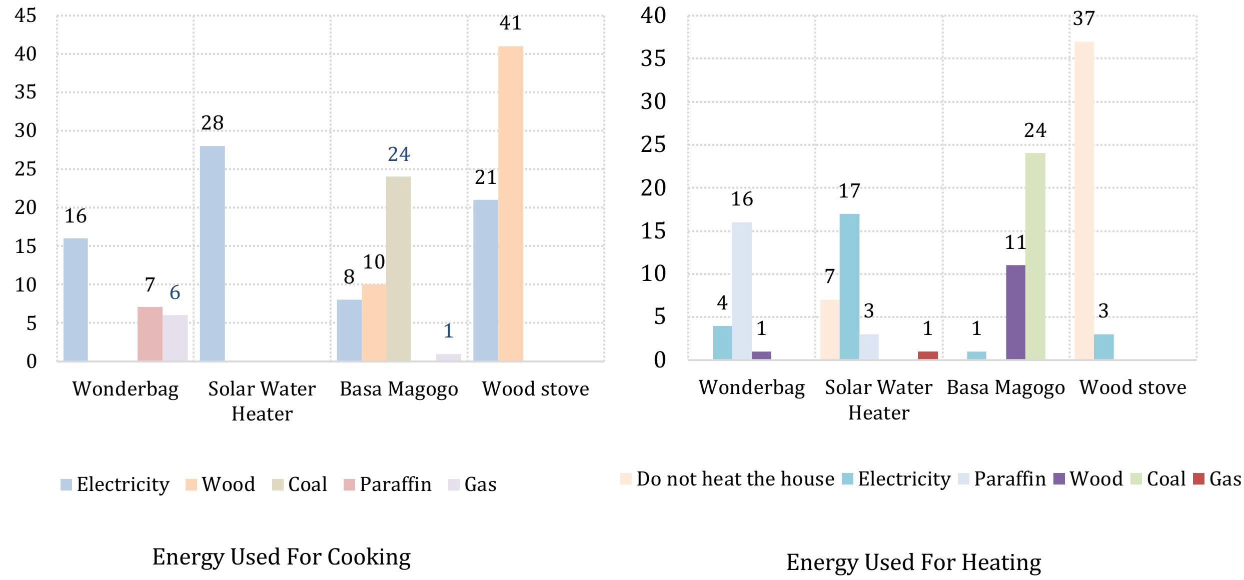

Figure 40: Energy use of respondent households in carbon offset projects. Source: Author's compilation

In Ermelo, in the Mpumalanga province, where large coal deposits are located, (see Chapter 6), 24 out of 25 respondents in the sample in the BM project mainly use coal as a cheap energy source for cooking and heating purposes (see Figure 40). In the rural area of Limpopo, where the wood stove was rolled out, all respondents in the sample use wood for cooking. Depending on the type of food, e.g., light or heavy meal, respondents also complement their wood use with electricity in their daily cooking practice (see Figure 40).

After this brief introduction, the next section provides a detailed assessment of how these households and their livelihoods are affected by new low-carbon innovations.

11.3. Assessment of households' livelihood impacts

This section analyses the results of livelihood impacts on technology users in Langa (Cape Town), Cosmo City (Johannesburg), Wesselton Township (Ermelo) and Burgersdorp and Bonn villages (Greater Tzaneen). It examines impacts, such as the perceived value of the new low-carbon technologies (physical capital), energy use and costs (household budget), gender labour allocation (cooking time, time required for firewood collection, convenience), human capital (health and wellbeing, perceived technology safety) and social capital (community cohesion).

11.3.1 Households' perception on the value of new technologies

The results revealed that for some of the technologies (Wonderbag, Solar Water Heater and Wood stove), households gained a physical artifact. However, in the Basa Magogo project, households received only an education about the new fire technique. Overall, the respondents in all projects agreed that they preferred to have these technologies rather than not.

Wonderbag project (WB):

In the WB project, all respondents reported that they liked the technology. For example, six respondents found the cooking technology 'helpful' (WBR2,3,10,11,15,16) and four respondents pointed out that it was an important cooking device (WS1,6,18,19). Others called the WB a 'magic thing' (WBR10,12), 'precious baby' (WBR3,7), 'handy' (WBR5,13), the 'best' (WBR2) or the 'number one' (WBR17) cooking technology they have ever had (see Table A10.9).

Furthermore, the respondents pointed out that the WB 'saves electricity' (50%), 'keeps food warm' (17%), 'saves time' (8%) and 'water' (4%) (see Table A10.10). 58% of respondents (n=11) in the sample did not know how they would cope without the WB if it were to break (see Figure 41). They worried about the fact that they did not know where to obtain the technology since it was not available in any local shops in Langa (WBR11,14,15,19). One respondent explained that the technology could only be received through workshops or a programme organised by an NGO or the government (WBR15).

The researcher's observation shows that most people in Langa were not computer literate, hence had no ability to buy this technology online (Observations, 2017). A respondent in a sample pointed out that it was difficult to get hold of the WB and residents could not buy it in their local area. A respondent confirmed:

'I do not think it has much exposure in my surrounding area…I have never seen a shop selling the Wonderboxes (sic). You find Wonderboxes (sic) in projects or NGOs' (WSR,19).

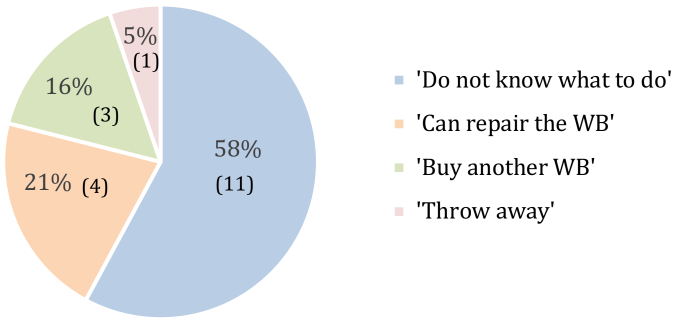

Figure 41: Respondents' comments on the situation when the 'Wonderbag' breaks. Source: Field Survey, 2017, Langa

This is an important finding, which indicates that a 'Positive' impact created by the WB project was not permanent and could end as soon as the WB breaks. The findings showed that households did not have any access to the technology (e.g. unable to buy or replace it in their residential area).

Solar Water Heater project (SWH):

Similarly, in the SWH project, respondents perceived the geysers as a valuable technology to have. Many provided more than one answer during the survey (captured in Table 4). For example, for 46% of respondents (n=16) in the sample agree that the SWH 'saves electricity' and helps complete household chores. 11% of respondents (n=4) in the sample simply appreciated having hot water available in the house (see Table A10.11). A respondent confirmed:

'It's not the same when you do not have it because I do not have money to buy the geyser from the shop. I am thankful for what I have. At least I am able to have a geyser and hot water' (SWHR8).

It seems that SWHs were especially useful during electricity power cuts in Cosmo City (see Table A10.11). Due to high electricity prices and an increase in illegal connections, households reported that they often experienced electricity cuts. Since the transformers were constantly overloaded and eventually exploded, the electricity outages typically lasted between three and four days in some areas of Cosmo City. In this situation, households could make use of their SWHs and felt much more self-sufficient (SWHR3,9,28). A respondent quoted:

'Like now the electricity is cut off, but the water from the geyser will be hot. We are able to bath and wash dishes with it. There is a difference' (SWHR3).

However, some respondents in the sample provided mixed responses regarding the SWH technology. They were not entirely happy with the technology as it could 'only help in summer, but not in winter' (see Table A10.11). A respondent explained:

> *'At the moment I do not like it because the water is too cold. It does not help, it only helps in summer. In summer the water is hot' (SWHR25).*

However, there were also respondents (n=2), who used SWHs on a daily basis, but still did not think the geysers were of any value as they were provided by the government for free. The respondents pointed out:

> *'this one does not have the value, because it is government's thing' (SWHR4).*
>
> *'I got the geyser for free, I would not really put so much value on it' (SWHR14).*

Another respondent in the sample complained that hot water in the tank was not enough for the seven people (4 children and 3 adults) in the household. In the situation when a person took a bath, the rest of the family had to wait until the water was hot or boil water using electricity (SWHR1). Despite this criticism, 68% of respondents (n=19) in the sample provided positive comments about the SWH technology (see Table 47). The impact on the physical capital was therefore classified as 'Positive'

Table 47: Evaluation of the total number of respondents' providing comments on the value of the SWHs

Evaluation of responses	Number of respondents[57]	Percentage of respondents (%)
Positive comments	19	68
Mixed comments (helps in summer, but not winter)	6	21
Negative comments	3	11
Total	**28**	**100**

Source: Field Survey, 2018, Cosmo City

Basa Magogo (BM) project:

In relation to the BM project, Table A10.12 shows that all respondents liked the BM method. The respondents pointed out that the method saved coal (26%), produced less smoke (26%) and was easy to use (12%).

It seems that the BM method proved to be particularly useful in cold and rainy winter months in Wesselton township. Respondents stated that the BM method provided heat (BMR7,21,24), which

[57] Ibid.

lasted for a long time (BMR 5,24). Others could cook more food with the same fire (BMR7,21) (see Table A10.12). A respondent explained:

'I am getting the heat plus I make food and it's a double effect' (BMR21).

One respondent in the sample claimed that the BM method helped avoid Tuberculosis (TB) in her family because it produced less smoke (BMR14). However, another respondent pointed out that the heat generated by the BM method was too slow and delayed him in getting to work (BMR3). While reasons as to why the BM method was slow were unknown, researcher's observations indicated that this could be due to the respondent using bad quality coal (dirty unwashed coal), which was sold in the area. As a result, it took more time to ignite the fire and generate heat (Observations, 2017). This observation was also confirmed by another respondent, who explained as follows:

> *'It depends on the type of the coal. If they are ok, they are clean, it just heats up suddenly. If the coal is dirty, it can take an hour for the stove to heat up (BMR2).*

Having said that, overall, the BM method created a Positive effect on the physical capital within all households sampled in the study.

Wood Stove project:

In the wood stove project, the majority of respondents perceived the wood stove as the most valuable technology introduced in the village. Women, who were the main users of the technology, spoke highly of the wood stove during the survey. The respondents liked the wood stove because it consumed less wood (34%), provided comfortable cooking (20%) as no kneeling down was required (WSR5,19,30,39,41) and produced less smoke (15%) (See Table A10.13).

The respondents used specific words during the conversation that emphasised the importance of the technology. For example, some respondents 'loved' the wood stove (34%) and cooking was perceived to be 'fast' when they used the technology (29%).

Table 48: Key words provided by respondents on the value of the wood stove

Key words	**Frequency of responses[58]**	**Percentage of responses (%)**
'love the stove'	20	34
'fast'	17	29
'nice stove'	4	7
perfect	2	3
'good'	2	3
'convenient'	1	2
'cheap to use'	1	2
'good, but do not love it'	1	2
'flexible'	1	2
'happy with the stove'	1	2
'helps a lot'	1	2
'new development'	1	2
'something special'	1	2
'thankful'	1	2
'strong'	1	2
'very important'	1	2
'very helpful'	1	2
'disappointing'	1	2
Total	**58**	**100**
Total respondents	**39**	**95**
Not specified	**2**	**5**
Total sample size	**41**	**100**

Source: Field Survey, 2018, Burgersdorp and Bonn

A respondent expressed her gratitude:

> *'I just like to thank people of Nova for bringing that wood stove because if they did not bring it to us our lives would be at stake. Many times, we are sitting around open fire getting warm with kids. You find that someone might get burned, but with the wood stove, it is safe because when we are done cooking, we just cook inside the kitchen and get warm, while we are sitting far away from it because it makes the whole house hot' (WSR38).*

Another respondent described her situation as follow:

> *'I love it because it reduces the level of poverty, when you don't have money to buy electricity or even if you have a few woods, you are able to cook. Even that wood there, I are able to finish a month if I can take a saw and cut it into pieces, I can cook with it' (WSR20).*

However, one respondent in the sample acknowledged that it was a 'good' stove, but she did not love it (see Table 48). She only used it to impress her in-laws. She elaborated:

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[58] Ibid.

'It was good but I just did not love it. It is a lot of work to use it. You need to go to the bush and collect the wood, then come back and wait for the wood to dry, only then you can use and I don't get along with working hard. Old people used to say that food, which is cooked by electricity is not nice compared to pap which is cooked using wood. That is why I had to use the wood stove to make sure that I impress them [in-laws], the way they want it (WSR36).

Table 48 also shows that one respondent in the sample found the wood stove 'disappointing' as it produced a lot of ashes and made her kitchen dirty. A respondent explained:

'I have used it a lot when I just received it when it was new. But when time goes on, it was disappointing me because of the ashes. Then I started disliking it because it makes the house dirty' (WSR26).

Overall, the results showed that 93% of the respondents (n=38) in the sample were pleased about the wood stove (see Table 48). The impact on physical capital is therefore classified as 'Positive'.

Summary

All technologies analysed in this study created a positive physical contribution to the households. While these technologies created different impacts, they all helped reduce energy consumption and costs within households. The extent to which these factors were reduced, is analysed in the next section.

11.3.2 Effects on energy use and household budget

Wonderbag project:

In the WB carbon offset project, Table A10.14 shows that all respondents felt that they saved a portion of their electricity when they used the WB. However, due to multiple activities carried out in the household, it was difficult for respondents to indicate how much electricity they saved. At the same time, some respondents lived with extended family members and could not determine their electricity consumption. For example, one of the respondents pointed out as follows:

'Yes, there is a difference when I use the Wonderbag. I spend less on electricity but not sure exactly how much electricity I save' (WBR,11).

There were three respondents in the sample (16%), who indicated the difference in their electricity expenses before and after the WB intervention (see Table 49). They reported that during winter they saved on average approximately R80 per month when using the WB (see Table 49). The respondents could use this additional income to buy vegetables, bread or a cold drink for a visitor (WBR6), or groceries needed for the household (WBR10).

Table 49: Monthly electricity expenses and savings reported by respondents in the winter period before and after the 'Wonderbag' use

Respondents	Before WB (month/Rand)	With WB (month/Rand)	Saving (month/Rand)	Saving (%)
Respondent 5	200	150	50	25
Respondent 6	150	110	40	27
Respondent 10	300	150	150	50
Total average	**217**	**137**	**80**	**34**

Source: Field Survey, 2018, Langa

Although this finding is only based on three respondents, it provides an indication that households in the sample could potentially save more than 30% on electricity when using the WB.

Solar Water Heater project:

In the SWH project, 75% of respondents in the sample (n=21) reported that they felt that they saved electricity when they used the SWHs. However, similar to the WB project, the respondents did not know how much exactly electricity they saved (see Figure 42)

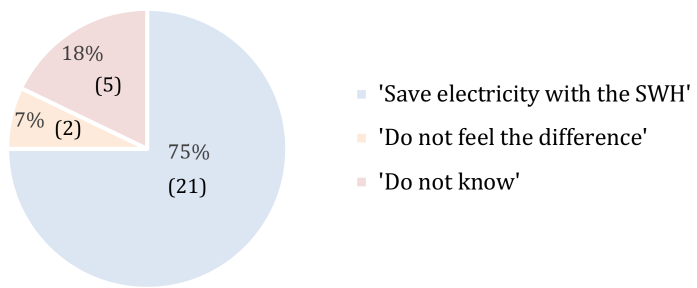

Figure 42: Respondents' comments on electricity savings using the SWH. Source: Field Survey, 2017, Cosmo City

This was because all respondents in the sample received a Free Basic Electricity (FBE) allowance of 50 KWh a month to meet their basic needs for lighting, media access and some water heating. As a result, it was difficult for them to determine how much electricity they used for their household activities on a monthly basis. While these results provide a broad indicative understanding of the impact on household electricity costs, further research would be needed to accurately estimate this. Unfortunately, this is beyond the scope of this study.

Basa Magogo project:

The respondents in the BM and the wood stove projects provided more accurate information on their coal and wood use. However, these results should still be treated with caution as they are approximations only and depend on individual use. It appears though that households in the BM project could significantly reduce their consumption of coal and improve their monthly budget in both winter and summer periods.

Table 50 indicates that 13 out of the 25 respondents in the sample (52%) experienced an average monthly decline in coal usage of approximately 40% (38% in winter and 43% in summer). However, there were also 12 respondents in the sample, who could not determine their coal consumption. They either did not know their consumption, bought coal in bulk or simply did not notice how much coal they used with the traditional coal fire technique. As a result, the comparison before and after the BM method intervention for these households could not be performed. Detailed data on monthly coal consumption (in kg) reported by each household before and after the BM method intervention is available in Appendix A11.

Table 50: Average household's monthly coal consumption (estimated) before and after the BM carbon offset project intervention in the winter and summer periods

Average coal consumption in winter[59]				
Frequency of responses (n=25)	Before BM method (kg/month)	After BM method (kg/month)	Saving (kg/month)	Saving (%)
13	248	153	95	38
5	Do not know	Do not know	Do not know	NA
7	Do not know	190	NA	NA
Average coal consumption in summer				
Frequency of responses (n=25)	Before BM method (kg/month)	After BM method (kg/month)	Saving (kg/month)	Saving (%)
13	138	79	59	43
6	Do not know	Do not know	Do not know	NA
6	Do not know	165	NA	NA

Source: Field Survey, 2017, Weselton Township

All respondents in the sample reported that they typically bought coal in their area. In relation to the household budget, Tables 51 shows that 13 respondents spent on average R467(€24) per month on coal in winter when using the traditional coal fire technique and R240 (€15) per month in summer.

However, upon introduction of the BM method, the respondents reported an average monthly saving of 38% (R287) on coal in winter (see Table 51) and 41% (141) in summer (see Table 51). Since 12 respondents in the sample could not provide a full picture of their coal consumption, they were omitted from this analysis. Detailed data on monthly coal expenditure (in Rand) reported by each household before and after the BM method intervention is included in the Appendix A12.

[59] Winter period in South Africa typically runs from June to August, whereas summer period is from December to February.

Table 51: Average household's monthly coal expenditure (estimated) before and after the BM carbon offset project intervention in the winter and summer periods

Coal expenditure in winter				
Frequency of responses (n=25)	Before BM method (Rand/month)	After BM method (Rand/month)	Saving (Rand/month)	Saving (%)
13	467	287	180	38
5	Do not know	Do not know	Do not know	NA
7	Do not know	283	NA	NA
Coal expenditure in summer				
Frequency of responses (n=25)	Before BM method (Rand/month)	After BM method (Rand/month)	Saving (Rand/month)	Saving (%)
13	240	141	100	41
6	Do not know	Do not know	Do not know	NA
6	Do not know	134	NA	NA

Source: Field Survey, 2017, Weselton Township

Some respondents explained that they used saved money to buy more food (BMR6,11,15,18,24,23,9), electricity (BMR24), firewood (BMR1,3) Others could take their children to the hospital, pay for transport (BMR11,15) or buy building materials (BMR17). Furthermore, two respondents gave saved money to children, who did not have parents (BMR4,8). A respondent explained:

> *'There is a difference. I do not buy more coal. I save money for the children. They do not have parents' (BMR8).*

Another respondent confirmed:

> *'I realised I have seen a big difference. We've got children. We are buying food for them. We take them to the clinic or to the hospital (BMR11).*

Wood Stove project:

In the WS project, respondents reported that they used more firewood in winter than in summer (see Chapter 10). However, because respondents could only broadly describe their firewood consumption, quantifying this difference was not possible. The results indicated that 19 out of 41 respondents in the sample (46%) used on average 228 kg of firewood per month when using an open fire and 127 kg per month with the wood stove. This represents an average reduction of 44% per month per household. Stated differently, this equates to an average of 8 kg of firewood used per day per household, when using an open fire, and only 4 kg of firewood per day, when using the wood stove.

Table 52 shows that there were 22 respondents in the sample who could not determine their firewood consumption as they either did not know, could not tell how much firewood they used with an open fire or provided unclear information ('undefined'). As a result, the comparison before and after the wood stove intervention for these respondents could not be conducted.

Detailed data of each household monthly firewood consumption (in kg) using open fire and the wood stove are presented in Appendix A13.

Table 52: Average household's monthly firewood consumption (estimated) before and after the Wood stove carbon offset project intervention

Wood consumption				
Frequency of responses (n=41)	Before Wood stove (kg/month)	After Wood stove (kg/month)	Saving (kg/month)	Saving (%)
19	228	127	101	44
16	Do not know	Do not know	Do not know	NA
3	Do not know	164	NA	NA
3	Undefined	Undefined	NA	NA

Source: Field Survey, 2018, Burgersdorp and Bonn villages

With regards to the cost of firewood, Table 53 indicates that 15 out of 41 respondents in the sample (39%) spent on average R269 (€14) per month when using the open fire. Upon introduction of the WS, indicated expenditure decreased on average by 42% to R156(€8) per month - achieving an average monthly saving of R113 (€6).

Similarly, 39% of respondents (n=16) in the sample 'did not know' their firewood expenses, whereas ten respondents in the sample collected firewood free of charge with a wheelbarrow or using their head (see Table 53). As a result, these respondents were excluded from the cost analysis. Detailed data on firewood expenditure (in Rand) of each household using open fire and the wood stove is available in Appendix A14.

Table 53: Average household's monthly firewood expenditure (estimated) before and after the Wood stove offset project intervention

Wood expenditure				
Frequency of responses (n=41)	Before Wood stove (Rand/month)	After Wood stove (Rand/month)	Average monthly saving (Rand)	Average monthly saving (%)
15	269	156	113	42
8	Do not know	197	NA	NA
8	Do not know	Do not know	Do not know	NA
9	Collect with wheelbarrow	Collect with wheelbarrow	NA	NA
1	Collect with head	Collect with head	NA	NA

Source: Field Survey, 2018, Burgersdorp and Bonn villages

Women reported that they typically used the saved money to pay for transport (WSR6), electricity (WSR32) or gave it to children as pocket money (WSR24). Furthermore, one respondent in the sample could reduce her anxiety and stress levels that money may run out in the middle of the month due to high electricity costs (WSR20). The respondent explained

'Since I started using the stove, I found that it helps me with my budget, which used to trouble me in the middle of the month; just like when I had to buy electricity worth of R250 for cooking, lighting and ironing and all that. Now I can see that I am not suffering anymore and the stove has now reduced my stress load. If I buy wood and use it, it brings me back within my budget. I am able to do something else with that money, which I would have spent on electricity for cooking. When I buy a load of wood, I am cooking with it for a long time. The wood stove has helped me to budget my money' (WSR20).

Summary

All four project technologies that were implemented, created a 'Positive' impact by reducing households' energy consumption and improving the household budget. The next section will examine if technologies have any effect on gender labour allocation within South African households in urban and rural project areas.

11.3.3 Effects on gender labour allocation

As presented in Figure 36, the majority of respondents interviewed in this study were women. They were typically responsible for all care and domestic chores, such as cooking, making fire, collecting firewood and bathing children. It is therefore important to analyse how low-carbon technologies affected their daily lives, and if women were able free up their time for other household activities. This section includes the data collected on cooking time, convenience and time required for firewood collection.

Cooking time

Wonderbag project:

The majority of respondents indicated that they mainly used the WB for cooking samp (the traditional Xhosa meal made of corn kernels and beans - see Chapter 9). Table A10.15 shows that 84% of respondents in the sample (n=16) noticed a difference in cooking time before and after the WB intervention. Fifteen respondents indicated that, when they used the conventional electric stove, they approximately spent three hours cooking samp (see Table 54).

In contrast, when they cooked this meal in the WB, they only needed on average an hour cooking time on the electric stove, before putting it in the WB to complete the cooking process. As a result, they could reduce their cooking time on average by approximately two hours (see Table 54). Detailed data on cooking time reported by each household is available in Table A15.1 in Appendix A15.

Table 54: Average cooking time for a single meal (samp) reported by respondents before and after the Wonderbag carbon offset project intervention

Average cooking time of a single meal (samp)				
Frequency of responses (n=16)	Before WB (hours/samp)	After WB (hours/samp)	Saving (hours)	Saving (%)
15	3	1	2	67
1	NA	NA	NA	NA

Source: Field Survey, 2017, Langa

Wood Stove project:

In contrast, results related to households' cooking time in the wood stove project were mixed. Whilst a variety of meals were prepared on the wood stove, the most frequently cited were pap[60] and *sishebo* (see Figure 43). *Sishebo*, translated from isiZulu, is a side dish, which is spinach, meat, fish and beans.

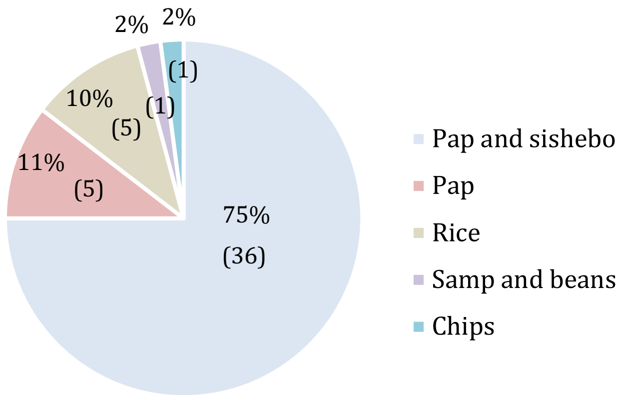

Figure 43: Respondents' comments on the most common dishes cooked with the wood stove. Source: Field Survey, 2018, Burgersdorp and Bonn

Table A10.16 indicates that 46% of respondents in the sample (n=19) noticed that cooking activity on the wood stove was much faster than on the open fire. In contrast, other respondents did not see any difference (37%) or did not know (7%) for how long they cooked samp.

Women, who noticed a positive impact on their cooking activities, explained that cooking pap outside on the open fire required them to constantly monitor the fire. The fire was often deflected, which prolonged the cooking process as it wasted energy (WSR5,13,17,19,21,28,40). However, with the wood stove, the fire was directed to the pot (WSR21,33,5) and the whole process was

[60] Pap is a traditional staple food in South Africa made out of maize. The frequency of cooking pap varies. Depending on the household size, women often prepare pap every 2 or 3 days a week (Field Survey, 2018, Burgersdorp and Bonn)

faster and more efficient. One respondent reported that she would even forget that she was cooking (WSR5).

Nineteen respondents could on average reduce their cooking time by 50%, from two hours to one hour, when cooking pap (see Table 55). The respondents explained that they could use the spare time to sit and relax (WSR6,28), watch TV (WSR6) or engage in other daily chores, such as cleaning (WSR6,19,24,33) and doing laundry (WSR33).

Table 55: Average cooking time of a single meal (pap) with and without the wood stove reported by respondents

Cooking time of a single meal (pap)				
Frequency of responses (n=19)	Before wood stove (hours/pap)	After wood stove (hours/pap)	Saving (hours)	Saving (%)
19	2	1	1	50

Source: Field Survey, 2018, Burgersdorp and Bonn

Overall, the results revealed that the impact of the wood stove project on cooking time was 'Positive'. However, it is worth mentioning that estimated cooking times in the Wonderbag and the wood stove projects are indicative only as they are only based on one meal cooked by one person. To provide a comparative analysis, further research is needed to investigate cooking time of other dishes when using these technologies

Convenience

Wonderbag project:

The benefits of reduced cooking time created a dividend for households in terms of extra time available, also including other factors, such as convenience. Respondents in the Wonderbag project reported that they did not need to monitor samp for hours on the electric stove and could now divert their attention to other activities, such as relaxing, sleeping, reading or watching TV (see Table A10.17).

Six respondents were in the position to put a meal in the WB and go to work. Some women typically continued with their household chores, such as laundry, cleaning, shopping for the house (WBR10,12) or simply spent more time with their children (WBR18) or visited friends (WR7,8) (see Table 29).

Wood Stove project:

Figure A10.18 shows that 37% of respondents in the sample (n=15) liked the fact that the heat with the wood stove lasted longer than with an open fire. A respondent explained:

> *'When I use the wood stove to warm water, I put it today in the evening, tomorrow morning, the water will be still warm and the kids will bath and then go to school' (WSR3).*

Furthermore, 24% of respondents in the sample (n=10) were more comfortable as they no longer needed to kneel down to monitor the fire (see Figure A10.18). They could stand or comfortably sit on a chair next to the wood stove when feeling tired. A respondent elaborated:

> *'I love it because it is fast and when I am cooking it allows me to cook while standing. I am able to move around and pick what I want, so when I am tired I just sit down' (WSR36).*

Other respondents in the sample pointed out that the wood stove allowed them to sit in the kitchen and get warm (17%) or simply enjoy the warmth (2%) (see Table 30).

Basa Magogo project:

Similar to the wood stove project, it looks like the BM method also created some feeling of comfort for the respondents. For example, 68% of respondents (n=17) indicated that the fire lasted much longer (up to 5-6 hours during the day). While some respondents could simply enjoy the warmth in the house (BMR3,7,4,24), others were able to cook food twice with the same coal fire (BMR11,21) (See Figure A10.19).

Solar Water Heater:

In the SWH project, 29% of women (n=8) were able to carry out their household activities, such as cooking and cleaning much faster with the SWH than without. The availability of hot water allowed 21% of respondents (n=6) to sleep an hour longer in the morning (see Table 56). Women did not need to worry about boiling water for bathing with an electrical kettle for themselves and their children (SWHR5,16,19,22). A respondent explained:

> *'It is easier for my children. I wake up at 6 a.m. because my children have to go to school at 7.30 a.m. If I did not have a geyser, we would wake up at 5 a.m. At least now the children have an hour to rest. Now I wake them up at 6 a.m.' (SWHR5).*

Table 56: *Respondents' comments on the convenience factors of the SWHs*

Respondents' comments	Frequency of responses	Percentage of responses (%)
'Household chores are done faster'	8	29
'Can sleep one hour longer'	6	21
'Helps with water cuts'	5	18
No opinion	9	32
Total	**28**	**100**

Source: Field Survey, 2017, Cosmo City

Furthermore, Table 56 shows that SWHs helped households reduce their vulnerability to water cuts. Due to water pipe leaks in Cosmo City, residents reported that they often experienced an interrupted water supply, which typically lasted a few hours or even up to three days (SWHR10,11). During this period, some respondents used the geyser water even for drinking

(SWHR18,13). Other respondents felt reassured that they had enough water during this time, which allowed them to carry out their cooking and household chores (SWHR9-11).

Summary

To conclude the section, all technologies seem to have improved the quality of life of the majority of respondents in the sample. The users felt a sense of comfort and convenience as soon as these technologies were introduced. However, respondents in the wood stove also reported changes in the time required to collect the firewood. This impact is analysed and presented in the next section accordingly.

Time required for firewood collection

Wood Stove project:

The results revealed that 63% of respondents in the sample (n=26) collected firewood in Bonn and Burgersdorp villages on a regular basis (see Figure A10.20).

The respondents either took local transport to a nearby private farm, cut the firewood for a load and hired a bakkie to collect it, or they walked to a nearby forest to gather firewood with a wheelbarrow (see Table 57).

Table 57: Method of collecting firewood reported by respondents in Burgersdorp and Bonn

	Bonn	Burgersdorp	Burgersdrop and Bonn	
Respondents' comments	Frequency of responses	Frequency of responses	Total	Percentage (%)
Bakkie load	7	8	15	58
Wheelbarrow	8	2	10	38
Head	1	0	1	4
Total	**16**	**10**	**26**	**100**

Source: Field Survey, 2018, Burgersdorp and Bonn

However, it appears that firewood was no longer available around Bonn village. During an interview, the *Induna* (headman of a village) stated that, due to a decline in the forest, logging was illegal and residents could get arrested. Selling firewood was apparently also not allowed. Regardless of the situation, residents in Bonn village still continued collecting the firewood as it was their main energy source for cooking (see statistics on energy use – Figure A10.19). Some respondents explained that they typically walked between 1.5 to 2 hours to reach the destination (WSR,28, 29,33). A respondent, who lived in Burgersdorp village, explained:

> *'We get wood from very far, we suffer. We walk and walk like you going to Julesburg [12 km from Burgersdorp]. We leave around 4 a.m., when it strikes 8 a.m. we get there and get wood' (WSR3).*

The respondents stated that they were often scared to walk alone to collect firewood due to high risk of being mugged by criminals sitting in the bushes. They, therefore, tend to walk in large groups (WSR11,12,27,30). When the wood stove was introduced, respondents reported that they did not need to collect firewood as often as they did when using the open fire. Eight out of 26 respondents in the sample could now travel on average 3 times a year instead of 6 times a year to cut and collect firewood for a bakkie load (see Table 58).

Table 58: Average number of trips made to collect firewood reported by respondents before and after the Wood stove project intervention

Average number of trips to collect the wood per year				
Unit	Frequency of responses	Open fire	Wood stove	Number of trips saved per year
Bakkie load	8	6	3	3
Wheelbarrow	3	52	26	26
Do not know/Cannot tell	15	NA	NA	NA
Total respondents	**26**			

Source: Field Survey, 2018, Burgersdorp and Bonn

Seven respondents in the sample indicated that they spent on average two days cutting firewood for a bakkie load during a trip (see Table 59). This means that they could now save on average six days per year as the result of wood stove intervention.

Table 59: Average time required to cut firewood for a bakkie-load by respondents

Respondents	Time (day)
Respondent 5	2
Respondent 7	3
Respondent 11	2
Respondent 16	2
Respondent 22	2
Respondent 34	3
Respondent 35	3
Mean	**2.4**

Source: Field Survey, 2018, Burgersdorp and Bonn

It seems that only three respondents in the sample used a wheelbarrow to collect firewood. They reported that they did not need to collect firewood every week (in the case when using an open fire), but could now go to the forest every 2 weeks when using the wood stove. This translates to half of the number of trips needed to collect firewood per year. Some respondents explained that they now had more time for other activities, such as cleaning, (WSR12,29,37) fetching water (WSR12), doing laundry (WR37) or simply sitting and relaxing (WR28).

It seems that the wood stove created a 'Positive' impact on the time required to collect firewood for households in Burgersdorp and Bonn villages. The frequency of collecting firewood was reduced and some respondents said they were able to divert their time to other important tasks in the household (e.g., cleaning, fetching water, relax). A positive impact was also noticed in time required by respondents to cut the firewood on an annual basis.

Summary

Overall, it is apparent that all project technologies created a 'Positive' effect on gender labour allocation in project areas. They reduced cooking time, created comfort and convenience and saved time collecting firewood. Furthermore, respondents mentioned several other impacts related to their health and wellbeing as a result of project interventions. These impacts are analysed and presented in the next section.

11.3.4. Health and wellbeing

The results in this section are based on three of the four carbon offset projects: the Basa Magogo, wood stove and SWH projects. Impacts on health and wellbeing of the WB project were not reported - 84% of respondents in the WB project (n=16) pre-dominantly used electricity to cook their meals in Langa Township (see Figure 40), therefore they did not report any problems with indoor air pollution.

Indoor particulate air pollution is considered to be a major cause of pre-mature deaths and is responsible for approximately 9 million deaths per year worldwide (Fuller et al., 2022). The most significant indoor air quality issue is the exposure to particulate matter ($PM_{2.5}$) concentration released during combustion of solid fuels used for cooking and heating (Shezi and Wright, 2018).

Studies carried out by Masondo et al., (2016), Shezi et al., (2017) and Wernecke et al., (2015) report that the concentration of this pollutant remains very high in low-income South African households due to burning of solid fuels as the primary energy source. The authors point out that the concentration of the $PM_{2.5}$ exceeds national air quality limits and the guidelines set out by the WHO for indoor air quality within households.

Basa Magogo project:

Households in the BM and the wood stove projects confirm that they consistently suffered from indoor particulate air pollution when cooking their meals using coal or firewood. For example, 88% of respondents in the sample (n=22) in the BM project complained that the traditional coal fire technique generated a lot of smoke causing serious health issues (see Figure 44). Some respondents claimed to have developed chest pains and coughs (BMR2,3,7,11,12,19,25), asthma (BMR24), sinus infection (BMR18) and tuberculosis (TB)(BMR14,16,21).

The respondents expressed their concerns as follows:

'I have pains. The smoke causes me chest pains. It would be hard to inhale' (BMR12).

'We had one child that was taking to the doctor and then the doctor said the child must get tested of TB. We found out that the child had TB' (BMR16).

Another respondent pointed out that several people in the project area had cancer and believed that it was caused by long-term inhalation of harmful smoke (BMR1). However, as soon as the BM project was introduced, 80% of respondents in the sample (n=20) confirmed no smoke and 20% of respondents (n=5) noticed less smoke when using the new technique (Figure 44). Some respondents explained that the colour of the smoke was lighter, white and almost invisible (BMR11,19). Three respondents reported that their symptoms seemed to have improved (e.g., less cough, reduced sinus issues) (BMR7,14,16). Others could safely stay in the room and breathe, while the coal fire was burning (BMR18,19,25).

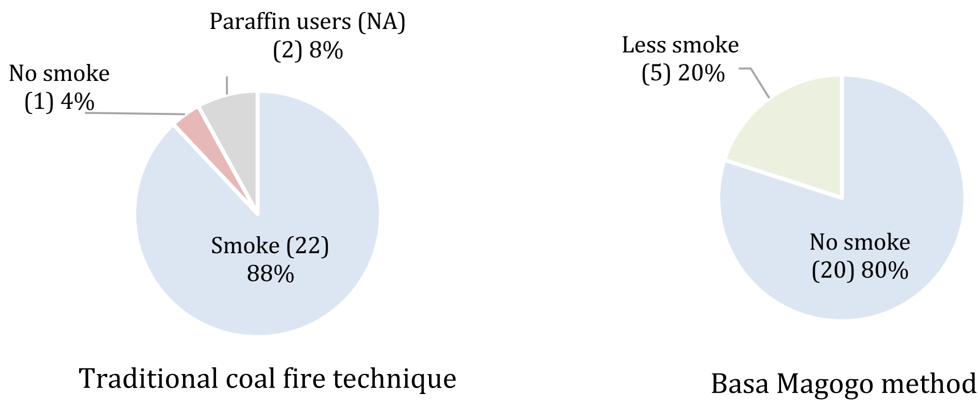

Figure 44 Respondents' comments on smoke when using traditional coal fire technique and the BM method. Source: Field Survey, 2017, Wesselton Township

However, some respondents also reported that smoke was not only influenced by the method they used to ignite the fire, but also by the cleanliness of the stove (BMR4,8,17,19, 22). 64% of respondents in the sample (n=16) reported that they burned coal using self-fabricated welded stoves, while 36% of respondents (n=9) carried out their cooking activities using traditional cast iron stoves (see Figure 45; see Photo 20 and 21).

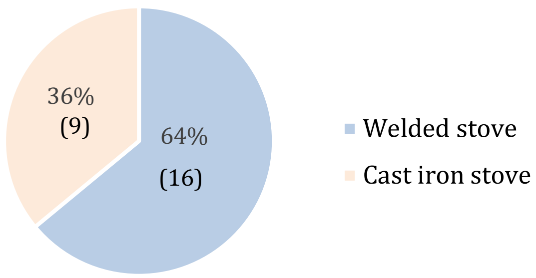

Figure 45: Stove types used by respondents in Wesselton Township. Source: Field Survey, 2017. Wesselton Township

Photo 15: Self-fabricated welded stove. Source: Fieldwork, 2017, Wesselton township

Photo 16: Traditional iron stove. Source: Fieldwork, 2017, Wesselton township

The researcher noticed that such type of stoves were badly ventilated and often had broken chimneys, causing indoor air pollution with or without the BM method (Observations, 2017). This observation was confirmed by the study carried out by Lloyd (2018), who explains that cast-iron stoves were originally designed to burn biomass, hence produce a lot of smoke when used by the households. However, further research is still needed to investigate to what extent these stoves contributed to the indoor air pollution and the effects on the BM method.

Wood Stove project:

In the WS project, the researcher's observation showed that the majority of women carried out their cooking activities in outside kitchens that were dark and badly ventilated with little or no windows (see Photos 17and 18). During the survey, 95% of respondents (n=39) confirmed that the open fire produced a lot of smoke (see Figure 46), which was detrimental to their health. Only two respondents (5%) indicated that there was no smoke when using open fire as it got dispersed quickly in the open space (WSR26,35) (see Figure 46).

Photo 17: Outside kitchen. Source: Fieldwork, 2018, Burgersdorp village

Photo 18: Traditional cooking practice. Source: Fieldwork, 2018, Burgersdorp village

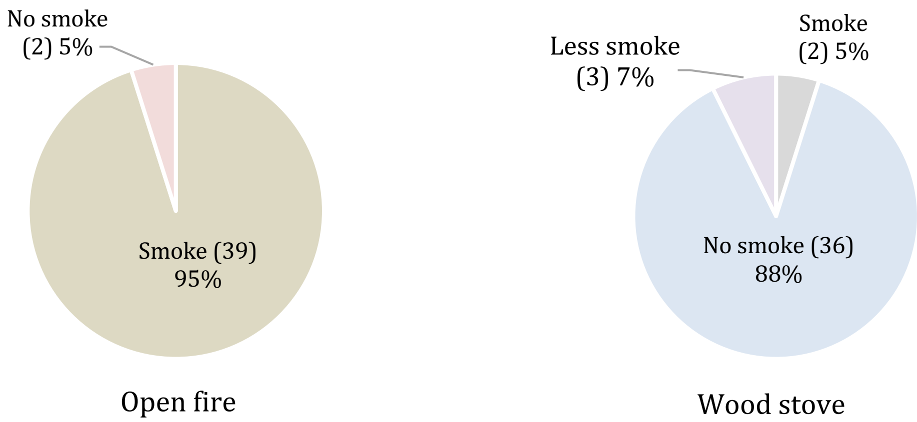

Figure 46: Respondents' comments on smoke when using open fire and the wood stove. Source: Field Survey, 2018, Burgersdorp and Bonn

Furthermore, 41% of respondents in the sample (n=17) complained that they had problems with their eyes, such as itchiness, pain and tears when using open fires. Other respondents reported that they developed coughs, chest pains, sinus infections and headaches (see Table 60).

Table 60: Respondent's comments on health impacts when using open fire

Respondents' comments	Frequency of responses	Percentage of responses (%)
'Smoke affects my eyes'	17	41
'Smoke does not affect me'	11	27
'I cough'	5	12
'Have chest pain'	3	7
'Have sinuses problems'	2	5
'Headache'	1	2
'Smoke effects lungs'	1	2
'Triggers asthma'	1	2
Total	**41**	**100**

Source: Field Survey, 2018, Burgersdorp and Bonn

Some respondents described their situation as follows:

> '*It affects me in a chest. I encounter breathing problems. I feel like choking in my chest and it becomes difficult to breath' (WSR38).*

> *'Sometimes I could not see what I am cooking clearly inside the pot, because of the smoke. When you remove the lid I had to look inside the pot and because of the smoke food would even burn while you don't know, if it's ready or not' (WSR5).*

One respondent in the sample explained that she was aware of her eye problems, but got used to it as she has been using the open fire for a long time. Another respondent added that she did not understand the health implications of the open fire and continued to cough as a result. A respondent elaborated:

> *'It used to affect our health although we are Africans. We did not understand, but it used to affect us. From the open fire I used to cough' (WSR18).*

As soon as respondents started using the wood stove, 88% of respondents (n=36) reported that they experienced no smoke and 7% of respondents (n=3) less smoke (See Figure 46). Although respondents did not provide information whether or not their symptoms improved, 44% of respondents (n=18) broadly indicated that their health was no longer negatively affected when using the wood stove (see Table A10.21). Some respondents reported no longer having issues with coughing (WS18,14), sneezing (WS24) or tearing eyes (WSR15).

However, during the survey one respondent (WSR19) pointed out that the effects of smoke did not only depend on the wood stove, but also on the type of firewood (wet or dry wood. If the wood was wet, it would apparently create smoke. Figure 47 shows that 90% of respondents (n=37) in the sample used plastic on a regular basis to ignite the fire in the wood stove (split 78% (n=32) using a mixture of plastic and paper, and 12% (n=5) using plastic exclusively). Respondents stated that they used plastic bags, including plastic covers from bread and sugar (WSR7,28) or from snacks and sweets (WSR18).

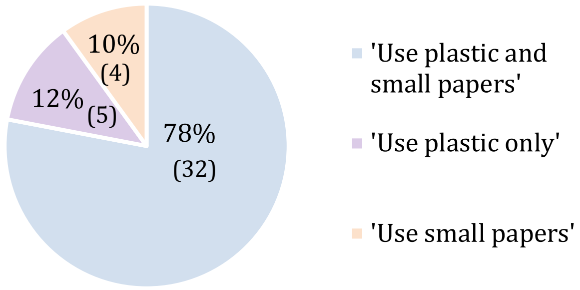

Figure 47: Respondent's comments on the materials used to ignite the fire in the wood stove. Source: Field Survey, 2018, Burgersdorp and Bonn

This is a matter of concern as burning plastic bags releases toxic chemicals into the air, such as dioxins, furans, Polychlorinated Biphenyls and can cause serious lung damage and other long-term health problems (Verma et al., 2016). As a result, burning plastic may be a counteractive activity to the goal of reducing indoor air quality of the wood stove. However, the extent to which plastic affects respondents' health and wellbeing, needs to be further investigated and is out of scope of this study.

Solar Water Heater project:

In the SWH project, the respondents were asked to indicate if the availability of regular hot water from the geyser made any difference to their health and wellbeing.

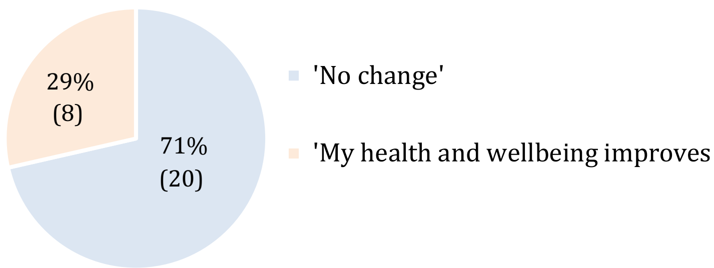

Figure 48: Respondents' comments on health and wellbeing when having hot water from the SWH Source: Field Survey, 2018, Cosmo City

Figure 48 shows that 71% of respondents (n=20) in the sample stated that they did not see any changes. Their health and wellbeing remained the same as before when they boiled water with other heating devices e.g., kettle, electric bucket or a pot, on the electric stove.

In contrast, 29% of respondents in the sample (n=8) confirmed that they felt much better when using hot water from the geyser. For example, respondents reported that they felt much more 'alive' (SWHR10), 'refreshed' (SWHR18,28) and 'happier' (SWHR21) when using hot water from the geyser. Some respondents indicated they were not getting sick as easily nor as frequently, since they could open the tap and get warm water immediately (SWH1, 20,22). Respondents were also asked to indicate how much water they typically used for one bath before and with the SWH. Given the fact that these households came from informal settlements and never had free flowing hot water in their dwellings, this comparison provided additional evidence in respect to the amount of hot water used for personal hygiene and sanitation.

Table 61 shows that respondents, who used a bathtub for bathing (43% of respondent; n=12), used on average 17 litres for one bath per day without the SWH. As soon as they received the technology, the average consumption per person more than doubled to 37 litres per bath per day. However, the average water consumption of respondents using a dish/basin increased only slightly from 9 litres (before the SWH) to 10 litres (with the SWH) per person per bathing activity. Detailed data on water consumption per bath per person is presented in Appendix A16.

Table 61: Average water consumption for a person for one bathing activity reported by respondents before and after the SWH carbon offset project intervention

Water consumption					
Bathing facilities	Frequency of responses (n=28)	Before SWH (litres/bath)	With SWH (litres/bath)	Difference (litres/bath)	% increase
Bathtub	12	17	37	20	117
	2	Do not know	Do not know	NA	
Dish/basin	12	9	10	1	11
	2	Do not know	Do not know	NA	
Total	**28**				

Source: Field Survey, 2018, Cosmo City

This is a significant finding, which indicates that not only does the SWH technology offer convenience to households by way of the ability to fill a bathtub immediately, but it also increases their water consumption, which indicates improved sanitation and hygiene. However, some households seemed to have paid less attention to the amount of water they used with the SWH with perhaps an increased risk of being wasteful. The respondents confirmed:

> *'I cannot enjoy to bath if I am using a kettle, but with geyser I am enjoying because I put a lot of water' (R26).*
>
> *'Children normally like to use a lot of water when they are bathing. They would open the water tap and go outside and call their friends and forget that they actually open the tap, and then when they come back, the bathtub is full' (R2).*

The quote above indicates that a more efficient systems like the SWHs follow the Jevons paradox[61], where the convenience and efficiency offered, generates increased demand on the limited natural

[61] Jevons paradox is defined in the situation when efficiency causes the natural resource use to rise (York and McGee, 2015)

resource, such as water). Since Johannesburg is historically known for its water challenges due to its location which is at a high altitude of 1,800 m, away from the largest body of water sources (Murwirapachena, 2021) the aggregate increase of water consumption caused by SWs may add to water stress.

As a result, regulation of use may be required in order to safeguard and ensure equitable distribution of the limited resource. However, these results only provide a snapshot of one individual for one bathing activity, hence cannot be generalised to the whole household. Further research is needed to investigate broader impacts at the aggregate household level. However, this is beyond the scope of this study, which only aims to provide an understanding of individual behaviour change.

Although the SWH technology created positive impacts on households (primarily through convenience and time saving), the results on health and wellbeing are classified as 'Ambiguous'. The majority of respondents (71%) indicated no change to health and wellbeing.

Summary

Although project technologies created positive effects on households, impacts were also contingent on external factors. Such external factors included the types of stoves used, quality of coal, or household practices (such as use of plastics in fire ignition for example). These external factors may work counter or blunt the impact of these new technologies. While SWHs offer a convenience factor and improved the quality of life, including hygiene and sanitation, they also increased demand for water and may have created pressure on natural resources (water).

11.3.5 Perceived Technology safety

This section presents and analyses respondents' perceived safety of the technologies received from three of the projects: the Wonderbag, wood stove and the SWH. This is not applicable to the BM project as it does not provide any physical artifact.

Wonderbag project:

Within the sample, 47% of respondents (n=9) perceived the WB as a safe cooking device. The respondents pointed out that it could be left unattended and did not burn the food (see Figure A10.22). Considering that many households in Langa Township lived in informal housing, such as hostels and single-room shacks, the technology was ideal for such types of accommodations as food could be kept warm for a long period of time whilst being conveniently and safely stored in kitchen cupboards, wardrobes or simply under the bed (Observations, 2017).

Wood Stove project:

In the case of the Wood stove project, half of the respondents (n=20) in the sample reported that they regularly experienced accidents and burns when using an open fire (see Figure A10.23). Respondents elaborated:

> *'Usually when you are using the open fire – when you are cooking – the pap might spill in your arms. And you might step on the wood. So… you burn' (WSR12).*
>
> *'I burned several times. You find that in times when I am busy walking around and when you go back there, you forgot that you do not wear shoes, you step on top of wood' (WSR14).*

In contrast, it seemed that all respondents felt relatively safe cooking with the wood stove as they did not get burned and perceived it as a lower risk for accidents (see Figure A10.23). Some respondents concluded that cooking on the wood stove was much safer for families with children. For example, the respondents described a number of incidents where small children often played with wood and got burned by wood particles (WSR27), boiling water (WSR21), cooking oil (WSR19) and burning plastic (WSR25). Some accidently fell into the fire (R38). Respondents explained:

> *'They the grandchild burned once. They were sitting around the fire on the cold day and then there was water boiling there. And you know how kids play – by mistake kicking the wood and water spilled on the body' (WSR21).*
>
> *'I put a pot and I wanted to cook then the boys were chasing each other. The younger brother was running toward me to get coverage, but just before I could catch him, he fell in the fire and burned his hand' (WSR38).*

Solar Water Heater project:

Due to continuous leaks experienced by households with the SWHs, 50% of respondents in the sample (n=14) claimed that they felt unsafe having SWHs on their roof (see Figure A10.24). After hearing about an incident in Cosmo City where the SWH fell through the roof and injured the community members (SWHR6,11,13,16,25,28), respondents appeared to be alerted, anxious and scared (Observations, 2017).

A respondent explained:

> *'It is giving me problems because our roofs are like this [pointing out at the cracked roof]. Sometimes I become scared that the leak will damage the roof and the solar water heater will fall inside the house. I would not say that I am safe' (SWHR13).*

In contrast, 43% of the respondents in the sample (n=12) felt safe with the geyser despite the problems with leaking (see Figure 46). While some respondents restored the asbestos (SWHR4), others managed to fix the leak themselves (SWHR3,11,28), permanently close the geyser (SWHR20) or manually control the water entering the tank (SWHR4). However, there was still a level of concern and anxiety among two respondents (SWHR10,20).

Despite the positive impacts created by the SWH technology (convenience, time saving, prolonged sleep, possible improved hygiene), the results revealed that the technology caused a lot of grievances within households and, in some instances, damaged the infrastructure of the house. 50% of respondents did not feel safe with the geysers, and even if respondents confirmed feeling 'relatively' safe, 7% still experienced some anxiety. Taking this into account, the overall impact on perceived technology safety is classified as 'Negative'.

Summary

Overall carbon offset projects created a safe environment for the users to utilise the technologies. However, the results also included unresolved technical issues, e.g., leaks (SWH project) that had damaging effects on the physical infrastructure and created mental health issues for the users. The findings up to this point focused on the impact on individual households. To understand how communities as a whole were affected by the projects, the next section analyses households' perspectives on social relations created in project areas.

11.3.6. Social relations

To understand the social interactions between people in the community, the respondents during semi-structured interviews were asked to indicate if they engaged and shared their experiences with other people in relation to the low-carbon technologies.

Basa Magogo project:

In the BM project, 16 out of 25 respondents in the sample (64%) explained that most people in Wesselton township were aware of the BM method (see Figure A10.25). Apparently, the majority of residents participated in the BM demonstration when the project was introduced (BMR7,10,23,24). However, researcher observations showed the opposite. There was little awareness of the BM method at the time of collecting the data (Observations, 2017). The observations showed that many people migrated to other areas or simply forgot how to use the method.

52% of respondents in the sample (n=12) did not talk to anyone about their experience relating to the fire technique (see Table 62). Respondents explained that people simply 'would not listen' (BMR3) or regarded this conversation as a 'waste of their time' (BMR15). Another respondent highlighted (without providing any further information) that particularly the younger people were not interested in this method (BMR5). A respondent stated:

> *'They do not want it ["the BM method"] especially the youth– the younger ones, they do not want it. I, the Magogo [grandmother] use it, but not the others in the family (BMR5).*

48% of respondents (n=12) engaged with residents in the project area sharing their experiences about the BM method - specifically to neighbours (16%), friends (4%) and customers (4%) (see Table 62).

Table 62: Social interactions reported by respondents in relation to the BM method

Social interactions		
Respondents' comments	Frequency of responses	Percentage of responses (%)
'Do not talk to anyone about the BM method'	13	52
'Talk about my BM experience to people'	6	24
'Talk to my neighbour about the BM method'	4	16
'Talk to my friends about the BM method'	1	4
'Talk to customers about the BM method'	1	4
Total	**25**	**100**

Source: Field Survey, 2017, Wesselton Township

Furthermore, the researcher observed that there was no coordinated community-wide adoption of the BM method. Three respondents confirmed that not everyone uses the BM method in the area as heavy smoke levels can still be observed (BMR19,21,25). A respondent claimed that the whole location could turn dark from domestic cooking and heating activities (BMR25; see Photo 19). A respondent indicated:

> *'I cough a lot from the smoke, from the other method not with Basa Magogo. A lot of people use the old technique here in Ermelo [Wesselton Township]. There is so much smoke that somebody who does not know, would say that the town is on fire. The smoke affects me as I cough a lot (BMR25)*

Photo 19: Prevailing smoke levels from domestic household activities, Wesselton township. Source: Fieldwork, 2017

Another respondent remained highly frustrated and continued experiencing chest pains in the mornings as a result of the smoke coming from her neighbour (BMR21). She explained as follows:

> *'The neighbour is not using the Basa Magogo technique because with Basa you usually have whitish smoke and it's not strong. Every morning I am getting up at 6 a.m. the smoke is here in my chest. The neighbour is burning rubber when they make fire. The smoke affects me. I developed chest pains until today. I have treatments; they say I have TB [tuberculosis] from the smoke' (BMR21).*

The impact of the BM fire technique on social relations is classified as 'Ambiguous'. Although 64% of respondents in the sample confirmed that people in the township were aware of the BM method, there was no widespread adoption of the technique as heavy smoke continued to prevail. The findings also suggested that adoption by younger people is lagging. However, further research into this topic is needed to investigate preferences in energy use by age and how the BM method influences users in different age categories.

Wonderbag project:

In the WB project, 63% of respondents (n=12) happily engaged and shared their cooking experience with their close friends, family members and neighbours (see Table A10.26). For example, some respondents explained that they often shared their WBs with extended families, who lived in the rural areas of Eastern Cape with limited electricity supply (WBR12,6).while others often lent their WBs to their neighbours and friends, who needed to cook samp (WBR5,8).

However, 37% of respondents in the sample (n=7) refused to talk about their experiences or share the technology in their circles. Some respondents explained that they feared that the WB will be damaged and become dirty (WBR3,7). For example, a respondent stated:

> *'I did not want anyone to use it. I felt like they will damage my Wonderbag and make it dirty. I only share my Wonderbag experience with those people who had it; who understand the value of having this bag in their lives. Other people won't understand how it works'(WBR7).*

Overall, it seems that the WB project created a 'Positive' impact on social relations among technology users. However, researcher observations also showed that many people in Langa had no awareness about this technology and did not know where to obtain it (Observations, 2017).

Wood Stove project:

Similarly, a positive effect was created on social relations in the wood stove project. 93% of respondents in the sample (n=38) closely interacted with each other, shared their experiences and created a strong sense of awareness and understanding about the wood stove in project areas (see Figure A10.27). For example, residents helped each other obtain local materials, such as cow dung and soil, borrowed the brick frame from the project developer and shared it with everyone in the community who wanted to make bricks (WSR3,16,24). The researcher observed that there was a strong sense of community belonging as a result of a project intervention (Observations, 2018).

However, another respondent claimed that enthusiasm about the wood stove could only be felt among women. Men did not apparently pay much attention and were indifferent to the rollout of the wood stove. A respondent explained:

> *'It is only us women, who want the stove…. you can see the man does not care about the wood stove' (WSR3).*

Some respondents reported that residents did not believe in nor understood the new technology. As a result, they made a lot of judgement and were unwilling to participate in the project (WSR10,18,19). A respondent indicated:

> *'…[there is] a tendency to judge things before residents can even see it with their own eyes. After they realised that it is a good thing, that's when they wanted to have it, but then it was already too late.' (WSR19)*

Overall, the respondents agreed that as soon as the wood stoves were built in the areas, every household realised their value and started to admire the technology (WSR1,18,23,32,33).

Solar Water Heater project:

The impact of the SWHs on social relations seems to be 'Ambiguous'. Table 63 shows that 36% of respondents (n=10) did not engage with anyone on matters concerning the SWHs. However, 21% of respondents (n=6) reported that SWHs specifically helped during electricity blackouts. Respondents shared water with their tenants, neighbours and kids, who often came with buckets or kettles to fetch water for cooking, drinking and bathing purposes (WSR2,4,6, 21) (see Table 63).

Table 63: Social interactions reported by respondents in the SWH carbon offset project

Social interactions		
Respondents' comments	Frequency of responses	Percentage of responses (%)
'Do not engage with anyone'	10	36
'Share geyser water with tenants, neighbours'	6	21
'Hear complaints about the leak problem'	5	18
'Hear complaints about not being able to find spare parts'	1	4
'Hear people wanting geysers'	6	21
Total	**28**	**100**

Source: Field Survey, 2018, Cosmo City

However, social interactions were also influenced by negative experiences caused by technical faults with the SWHs, e.g., leaks. For example, 18% of respondents in the sample (n=5) highlighted that they constantly heard people complaining about the geysers (see Table 63). A respondent explained that leaks wasted water, created mud and caused conflicts between neighbours (SWHR8, 27). Residents apparently complained about not being able to find appropriate technical support to maintain the geysers (SWHR16).

The results also showed that SWHs were unequally distributed in Cosmo City. 75% of respondents in the sample (n=21) confirmed that many people did not receive the SWHs (see Table A10.28). As a result, 21% of respondents (n=6) heard people complaining that they also wanted to receive the geysers (SWHR1,2,4,5,18) (see Table A10.28).

Since residents did not know the household selection criteria for receiving SWHs, two respondents were convinced that the rollout of the SWHs was carried out favouring a certain group of people over another (SWHR9,26). The respondents explained:

> *'I think they chose particular people because not everyone have them [geysers]' (SWH26).*
>
> *'They do not have the geysers. Seems like they [government] were choosing the people. They are crying that they do not have the geysers' (SWH9).*

Summary

It seems that all carbon offset projects created some positive effects on social interactions between community members in project areas. Households, especially in the WB and the Wood stove projects, managed to create strong social relations by sharing their experiences with each other. While the results in the BM project remained 'Ambiguous', social interactions in the SWH project, were overshadowed by complaints and the unequal distribution of the technology, hence the impact on social relations was classified as 'Negative'.

11.3.7 Synthesis of results

The results revealed that impacts created by technologies were mostly positive. Technologies were perceived to have added significant value as physical capital within households (see Table 64). Of particular importance, technologies substantially reduced households' energy consumption and costs. By improving gender labour allocation – that is, reducing cooking time, decreasing trips needed to collect firewood and creating comfort - women were able to manage their time more effectively (see Table 64).

The results also indicated that some impacts of technologies remain ambiguous. The SWH technology created no difference to health and wellbeing of households. However, the technology encouraged higher use of hot water, which suggests better hygiene and sanitation and improved quality of life within low-income households (see Table 64).

The BM project created ambiguous results on social relations (see Table 64). The method was not widely accepted and adopted across households. The SWH project caused negative impacts on communities. This related to technical issues that triggered complaints and created a feeling of being unsafe at the user level. All findings of the comparative assessment of household level impacts are summarised and presented in Table 64.

Table 64: Summary of comparative assessment of household livelihood level impacts of carbon offset projects

Livelihood level impact	Wonderbag (n=19)	SWH (n=28)	Basa Magogo (n=25)	Brickstar Wood stove (n=41)
Physical capital				
Perceived value of a technology	**Positive**	**Positive**	**Positive**	**Positive**
	• 74% of respondents (n=14): technology as a valuable asset; • 26% of respondents (n=5): no opinion	• 68% of respondents (n=19): technology as a valuable asset; • 21% of respondents (n=6): mixed views; • 11% of respondents (n=3): negative views	• 100% of respondents (n=25): method is valuable contribution to the daily life	• 98% of respondents (n=40) provided positive comments; • 2% of respondents (n=1): wood stove as disappointing
Nature capital				
Energy use	**Positive**	**Positive**	**Positive**	**Positive**
	• 100% of respondents (n=19): a portion of electricity saved	• 75% of respondents (n=21): a portion of electricity saved • 7% of respondents (n=2):no difference; • 18% of respondents (n=5):do not know	• 52% of respondents (n=13): reduction in average coal use by 38% per month in winter and 43% per month in summer; • 48% of respondents (n=12): do not know	• 46% of respondents (n=19): reduction in average firewood use by 44% per month • 46% of respondents (n=19): do not know • 7% of respondents (n=3): undefined
Household budget				
Energy costs	**Positive**	**Positive**	**Positive**	**Positive**
	• 100% of respondents (n=19): a portion on electricity costs saved	• 75% of respondents (n=21): a portion of electricity saved • 7% of respondents (n=2): do not feel the difference; • 18% of respondents (n=5): do not know	• 52% of respondents (n=13): reduction in average A12 by 38% per month h in winter and 41% per month in summer; • 48% of respondents (n=12): do not know	• 37% of respondents (n=15): reduction in average firewood costs by 42% per month • 39% of respondents (n=16): do not know; • 24% of respondents (n=10): collect firewood for free
Gender labour allocation				
	Positive	**NA**	**NA**	**Positive**
Cooking time	• 79% of respondents (n=15): reduced cooking time by 67% from 3 hours to 1 hour per meal • 5% of respondent (n=1): did not cook samp with the WB; • 16% of respondents (n=3): did not cook with the WB at all (kept food warm)			• 46% of respondents (n=19): reduced cooking time by 50% from 2 hours to 1 hour per meal • 37% of respondents (n=15): no difference; • 7% of respondents (n=3): wood stove slower than open fire; • 10% of respondents (n=4): do not know
	Positive	**Positive**	**Positive**	**Positive**
Convenience	• 93% of respondents (n=14): cooking was convenient with the WB; • 5% of respondents (n=1):no opinion • 5% of respondents (n=1): do not cook samp • 16% of respondents (n=3): do not cook with the WB	• 68% of respondents (n=19): more comfortable with SWHs; • 32% of respondents (n=9): no opinion	• 92% of respondents (n=23): comfortable with the BM method; • 8% of respondents (n=2):no opinion	• 80% of respondents (n=33): comfortable with the wood stove; • 20% of respondents (n=8): no opinion
	NA	**NA**	**NA**	**Positive**

Livelihood level impact	Wonderbag (n=19)	SWH (n=28)	Basa Magogo (n=25)	Brickstar Wood stove (n=41)
Time required for wood collection				• 20% of respondents (n=8): trip reduction from 6 times to 3 times a year to collect firewood for a bakkie load • 7% of respondents (n=3): trip reduction from 1 week to 2 weeks to collect firewood with a wheelbarrow • 36% of respondents (n=15): do no not know • 37% of respondents (n=15): buy firewood
Human capital				
Health and wellbeing	**NA**	**Ambiguous**	**Positive**	**Positive**
		• 71% of respondents (n=20):no change • 29% of respondents (n=8): health improved • 43% of respondents (n=12): water consumption increased from 17 to 37 litres/ bath/ day/person –better hygiene and sanitation	• 12% of respondents (n=3): less cough, no sinuses • 12% of respondents (n=3): could breathe safely during coal fire • 76% of respondents (n=19): no opinion	• 44% of respondents (n=18): health no longer negatively affected • 27% of respondents (n=11): no difference • 10% of respondents (n=4): no longer cough, sneeze or tear • 2% of respondent (n=1): felt safe for health • 17% of respondents (n=7): no opinion
Technology safety	**Positive**	**Negative**	**NA**	**Positive**
	• 47% of respondents (n=9): WB was safe and food did not burn • 53% of respondents (n=10): no opinion	• 50% of respondents (n=14): felt unsafe • 43% of respondents (n=12): felt safe • 75 of respondents (n=2): felt safe but show a feeling of anxiety		• 100% of respondents (n=41): felt safe with the wood stove; no accidents/burns
Social capital				
Community cohesion	**Positive**	**Negative**	**Ambiguous**	**Positive**
	• 68% of respondents (n=13): engaged and shared experiences of the WB • 32% of respondents (n=6): no engagement nor experiences sharing of the WB	• 36% of respondents (n=10): no engagement • 21% of respondents (n=6): shared water from the SWH • 43% of respondents (n=12): heard complaints regarding SWHs	• 52% of respondents (n=13): engaged and shared experiences • 48% of respondents (n=12): no engagement nor sharing of experiences • No widespread adoption of the BM method in the project area	• 93% of respondents (n=38): close interaction and strong sense of community belonging • 7% of respondents (n=3): no opinion

Source: Author's compilation

11.4 Chapter Summary

The chapter presented and discussed the findings of livelihood changes generated by four low-carbon innovations: the Wonderbag, Basa Magogo method, Brickstar Wood stove and the Solar Water Heater. The chapter was centred around the daily lives and routines of households (demographics, socio-economic characteristics, energy use) and household experiences with technologies.

Overall, changes in livelihoods created by the projects were positive. Technologies became valuable assets for households. They were able to reduce household energy consumption and improve their household budget. The chapter showed that technologies that related to food preparation reduced cooking time and allowed women to divert their time to other important tasks. The technologies were perceived to make life easier and more convenient, helping women to perform their daily routines with greater ease.

The findings also revealed that technologies, such as the WB and the Wood stove, fostered social relations and brought the community together, with sharing of resources (e.g., water) frequently taking place. The chapter also indicated that technologies (e.g., SWH) caused frustration among residents due to technical faults, lack of technical expertise and an unequal distribution of the technology. These factors created negative impacts on social relations in the project area.

Although some technologies (BM and the wood stove) improved indoor air pollution and had positive effects on health and wellbeing, these benefits were also influenced by external factors, such as badly ventilated coal stoves, wet wood or use of plastic as a fire-ignition. The study suggested that these factors generated smoke. However, further research is needed to investigate their contribution to the indoor air pollution and the effects on the low-carbon technologies.

The chapter showed that livelihood impacts were influenced by households' personal judgements – relating to not believing in or understanding new technologies. Furthermore, communities did not have a common goal to use technologies collectively to reduce air pollution in the area. The chapter found some impacts (social relations) were mainly gender focused and could only be felt by women in the project areas. To conclude, these findings provide valuable insights that will be discussed in the next chapter (Chapter 12).

Chapter 12: South Africa's struggle for socio-technical transition

This chapter explores the key insights from the research presented in the four results chapters (Chapters 8, 9, 10 and 11). It specifically reflects on the Multi-Level-Perspective-Sustainable Livelihood Approach framework I developed and tested. It reflects on the findings and addresses the gaps discussed in Chapter 3.

12.1 Reflection on the theoretical conceptualisation of a socio-technical transition

The study builds on the perspectives developed by Geels (2018) and Sovacool (2016). Both argue that it would be insufficient to consider a low-carbon transition facilitated by a single technology only. As a result, the study considered four different consumer energy innovations to show how they can contribute to an incremental socio-technical transition. I integrated the Multi-Level Perspective with the Sustainable Livelihood Approach to provide a robust articulation of a new comprehensive model that enables us to gain insight into users' behaviour and household adoption.

As observed by Kuzemko et al., (2017), consumer energy innovations can be the most promising, fastest, cheapest and safest means to help facilitate a low-carbon transition. However, I have learnt through this study that the implementation of these innovations was challenging, expensive and time consuming. The results also revealed that the reduction of GHG emissions of the four low-carbon technologies studied here were not guaranteed. They were contingent on users' technology adoption.

Users' technology adoption was critical for the success of the carbon offset projects. The contingency on users' technology adoption was observed on three levels, that is, the 'landscape' (external environment), 'technological niches' (project level) and households. As shown in Chapter 9, the overwhelming nature of the 'landscape', such as the withdrawal of subsidies, policy changes, carbon price volatility or exchange rate fluctuations can negatively influence implementation of low carbon technologies and undermine technology adoption.

The study showed that it was difficult to change peoples' behaviour to adjust to new low-carbon technologies due to social practices (habits, culture). There was some resistance to accepting and adopting new low-carbon technologies due to personal judgement (not believing in the technology) or cultural context. I argue that it is difficult to motivate and create incentives for households, particularly the poor, to change their behaviour and reduce GHG emissions. This argument is consistent with Anderson et al., (2013), who confirm that low-income households are more concerned with meeting their basic needs than the environment.

I argue that the pathway to an incremental socio-technical transition in South Africa remains inherently uncertain and difficult to achieve. The enabling institutional arrangements seem to be inconsistent with policy reforms in South Africa. Although the 'landscape' created pressure on the energy regime to reduce GHG emissions, the mitigation activities remained rhetorical. While the carbon offset market 'sub-regime' was created to encourage investments in low-carbon technologies, no restrictions were put in place on the coal-based energy regime. Instead, the South African energy regime maintained its 'business-as-usual' coal mining operations. The energy regime was 'locked-in' to long-term carbon intensive infrastructure with an intention to make long-term profits on its investments.

This study showed that the Multi-Level Perspective could be successfully applied beyond European studies. It made a valuable contribution to analysing less functional energy markets, like the South African energy system. A socio-technical transition in this type of energy market is complex. The residential sector is dominated by social practices and households' use of multiple fossil fuel sources, so-called 'fuel stacking', that collectively create barriers to a low-carbon transition. In light of this study, I argue that it is important to expand this work to other countries with less efficient energy markets to seek comparison between different energy regimes and compare how household practices contribute to socio-technical transitions.

As mentioned above, the assessment of the MLP-SLA is complex and time consuming. It may not capture every component of a socio-technical transition. Due to time constraints, I excluded the analysis of research and development, testing and design processes of the technological niches and their related networks. As a result, further research is needed to provide more details into these components. To expand the scope of the MLP-SLA, the framework could be used to assess radical innovations to understand how end-users participate in socio-technical transitions. The MLP-SLA could be applied to technical climate change experimentations in urban infrastructure systems – such as small-scale water supply systems, energy and water conservation measures, retrofitting energy and water-efficient technologies etc. (Broto and Bulkeley, 2013). This model can provide an innovative approach to urban planning and can help assess how benefits of a transition at the city level filter down to its citizens.

Scholars also argue that top-down perspectives and state-driven innovations may slow down the pace of a transition (Seyfang and Smith, 2007; Seyfang and Haxeltine, 2012; Hargreaves et al., 2013). As a result, they urge for greater focus on grassroot innovations or community-led initiatives that reinforce and engage with behaviour change. This is where the MLP-SLA provides a good fit. The model can assess the effectiveness of a network of small-scale projects and provide a foundation for scaling up these innovations.

12.2 Socio-technical transition in South Africa

12.2.1 National Level Landscape

The study shows that the South African government introduced policies with the stated intention to improve energy efficiency and gradually decarbonise power generation as early as 1998. However, it is apparent that the pace of the transition has been very slow. It seems that the South African government adopted a 'two-faced' governance approach as there is a disconnect between narratives for international and national policy arenas. For example, the South African government has shown international leadership in climate change. However, at the national level, it adopts a 'business as usual' approach and endorses building new coal power plants (DMRE, 2019). This shows that it does not ultimately intend to mitigate GHG emissions, but rather wants to be seen internationally as being proactive in combatting climate change.

Despite adopting a range of climate change policies, their implementation remained limited. Similar sentiment is shared by other scholars, who point out that the South African government is good at formulating policies, but not following them through as outlined (Trollip and Boulle, 2017). As a result, they remain rhetorical.

As revealed in Chapter 7, the government was also able to raise finance for climate change mitigation activities. For example, it helped to secure a $100 billion Green Climate Fund for developing countries to reduce emissions (Nelson, 2016). However, domestically the topic of climate change has not become widely supported. The government has shown insufficient support for mitigation projects, such as carbon offset projects, due to ideological views of some government officials, who were previously environmental activists. They were critical of carbon offsetting and did not recognise it as a legitimate policy tool in the country.

Furthermore, South African society has been suffering from race-based deprivation, poverty and unemployment, and severe weather events. As shown in Chapter 7, 55% of people live in poverty, of whom 25% are in extreme poverty, with an unemployment rate that reached 32.6% in 2021. To reduce their vulnerability, it is therefore important to find ways to transition to a low-carbon economy. Widespread poverty means many households and communities are vulnerable to climate-induced events and are unable to effectively respond and recover from such setbacks. This makes the need to transition to a low-carbon economy more pressing. However, these issues also create challenges to facilitating a transition. Low-income households can become more vulnerable as they are unable to afford to pay more for energy (Mdluli et al., 2010; Sovacool et al., 2019). As a result, policies for a more 'just' low-carbon transition are needed, so that workers and communities are not negatively impacted by the decline and shuttering of the fossil fuel industry (Pollin, 2019; Strambo et al., 2019).

12.2.2 Decarbonising the energy regime

This section critically discusses the role of the South African energy regime in the socio-technical transition. The coal mining and power generation sectors remain an important source of employment, investment and wealth generation for the country (Winkler and Marquard, 2007; Strambo et al., 2019; Huxham et al., 2019). The energy regime consists of vested interests that are reluctant to change to a low-carbon economy. As mentioned earlier, it is 'locked-in' to long-term investments in fossil fuel-based infrastructure. Since the South African government itself is deeply entangled with coal interests through state-owned utilities like Eskom and (formerly state-owned) Sasol (Hanto et al., 2022), it does not have the power to overrule profit seeking corporate elites, including multi-national corporations. There is thus little or no room for lobbying pressure to change the current status quo.

Furthermore, the South African industry, abundant in natural resources (coal, gold, diamonds etc.), suffers from a 'resource curse' scenario (Elbra, 2013). The resource curse is defined as 'the paradox by which mineral-rich states fail to keep pace, economically, with their non-mineral-rich peers' (Sachs and Warner, 1995). While the country experiences relatively slow Gross Domestic Product (GDP) growth, inequality and entrenched unemployment, the large portion of South African citizens have not benefited from resource extraction. Corruption, a lack of social services and the increased likelihood of mine-related violence remain prevalent issues in the country (Elbra, 2013). As a result, this phenomenon creates challenges and limits the socio-technical transition.

12.2.3 Functioning of the South African carbon offset market

This section reflects on the key findings and the missing gap identified in the literature in the South African carbon offset market. Through this study I have learned that the carbon market was poorly developed at the time of the fieldwork in 2017. There is insufficient demand for and supply of carbon offset projects in South Africa. This was mainly due to the collapse of the global carbon price in 2012 in the compliance carbon market driven by the economic slowdown contributing to the decline in emissions in Europe and oversupply of carbon credits in the EU ETS (Kossoy, 2012).

Although the study provides fresh knowledge on the functioning of the carbon market, it is apparent that actors suffered similar issues as mentioned by Steenberg (2018), Little et al., (2007), Wilson (2007) and Nkusi et al., (2014). These are complexity, bureaucracy and high costs that may obstruct a transition away from the carbon intensive regime.

However, this study provides deeper insight into the actors' behaviour. I have learned that the carbon market in South Africa was less transparent and dominated by a few players, who maintained intellectual control. Carbon consultants behaved like 'hybrid actors', having exploited their role through their technical 'know-how' by driving down the purchase price and pushing up the retail price, thus making significant margins. This is also consistent with studies carried out by Lohmann (2008) and Watt (2016). However, this behaviour is not illegal and not even considered unethical.

The study has shown that there were unequal power relations among actors in the carbon market. Although Eskom is the biggest polluter in the country, it also engages in carbon offset activities. It maintained close political ties to the state and received consistent support from the Designated National Authority to set up carbon offset projects at the expense of other actors, who remained 'at the back of the queue' and experienced delays in project approvals.

Furthermore, I have learned that buyers could not differentiate between a 'good' or bad' project, despite carbon offset projects being verified. It is therefore almost impossible to create an independent opinion on the quality of carbon offset projects in relation to social impacts and environmental integrity by using only project documents or verified auditors' reports.

The literature confirms that the verification process may create conflicts of interests because auditors are paid by companies to verify the GHG emissions of their projects. Established relationships between auditors and project developers can result in misrepresentation of information (Lohman, 2006; Watt, 2016). To improve transparency in the South African carbon market, verified carbon offset projects need to be legally safeguarded by an independent association that serves the public interest to ensure that these projects maintain environmental integrity and are socially sound.

The development of the carbon tax and carbon offset regulation seem to have overcome the lethargy of the carbon offset market and created a more dynamic policy environment. It is reported that demand for carbon credits has outstripped supply (Szabo, 2020; Elston, 2021). While demand under the carbon tax is estimated to be around 10 million tonnes per year (Szabo, 2020), the analysis of this study indicates that carbon offset projects only issued approximately 20MtCO_2-e in total between 2008-2021 (equivalent to 1.5MtCO_2-e per year).

The demand for these offset credits mainly comes from Eskom and Sasol (synthetic fuel producer[62]), the biggest polluters in the country, who are locked-in to a long-term coal-based

[62] Synthetic fuels were developed during apartheid for energy security and other reasons. Sasol gasifies coal and converts it to liquid fuels (Burton et al., 2018).

energy system (Burton and Winkler, 2014; Baker, 2022). Since these parastatals have resisted change and the attempts of low-carbon niches to grow (Tyler and Hochstetler, 2021), the results indicate that the rate of the carbon tax (R120/tCO_2e) is perceived by actors to be too low to create a realistic incentive to reduce emissions. At the same time, the South African government has exempted Eskom and Sasol from the carbon tax. This indicates that the South African government is not serious about their commitment to reduce emissions.

Summary

To reflect on the gap on the literature, I have learned that the carbon market is dominated by actors' vested interest and unequal power relations. It provides an incentive to generate profits paying less attention on emissions reductions. The market is not transparent and creates asymmetric information whereby the buyer is not able to differentiate between a 'good' or bad' project, despite carbon offset projects being verified.

However, it seems that the carbon market has become prevalent as a result of the carbon tax introduction. The South African government appears to have changed its position in relation to carbon offset activities in the country. It now endorses carbon offset projects and supports the development of South African offset standards (DMRE, 2022). While additional carbon offset projects are being initiated (Roelf, 2022), the carbon market is yet to prove its effectiveness under the carbon tax regulation.

12.2.3 'Technological niches' - complexity of carbon offset project implementation

This section discusses the project implementation processes of the four carbon offset projects. It provides key insights learned from these findings and reflects on the gap identified in the literature.

Actors' agency

The study has shown that carbon finance created opportunities for project developers to build partnerships between financial institutions, carbon consultants and other companies of the consumer industry to launch nascent low-carbon technologies in the consumer market. Scholars believe that these partnerships are crucial for raising carbon finance (Streck, 2021) and diversifying risks in carbon offset projects (Teichmann, 2011). However, my study shows that these partnerships were highly vulnerable and influenced by actors' vested interests and a mismatch of expectations.

For example, project developers claimed to have philanthropic reasons for setting up their projects, e.g., poverty alleviation, hot water as 'a humanitarian need', carbon consultants and financial institutions, on the other hand, were primarily interested in generating profits. This behaviour confirms the findings obtained from Chapter 8 that carbon offsetting is mainly a 'profit maximising' activity instead of ensuring environmental integrity.

This is not surprising as private agents are known to be motivated by profits (Spash, 2010). It is therefore the government's responsibility to protect the public good and manage actors' expectations to ensure that incentives and disincentives are aligned with the ultimate aim to reduce GHG emissions and achieve a socio-technical transition. In relation to partnerships, I have learned that they can also lead to counterproductive outcomes. For example, when a low-carbon technology was provided free of charge, the partnership obscured the real costs of a technology and caused distortions in the consumer market making it difficult for the project developer to put a price and sell the technology to the customers.

Furthermore, despite the South African government stating its enthusiasm towards carbon offset projects, it shifted the responsibility to polluting industries to fund these projects. But since there was no legal obligation to reduce GHG emissions, the government seems to have allowed the industry not to have the need to invest in low-carbon technological solutions. As a result, there was no support for carbon offset projects in the industry. In comparison, in Kenya, where one can see the opposite effect, technologies, such as improved cookstoves, were mainly funded through governmental subsidies and complemented by carbon offset credits. This created an enabling environment for new low-carbon technologies to flourish and allowed the cookstove industry to develop (Lambe et al., 2015).

However, in South Africa, project actors did not have a chance to utilise carbon finance before the collapse of the compliance carbon price. This was the case for the Solar Water Heater project, which instead incurred financial losses and led to the termination of the partnership. These results seem to confirm the market actors' sentiments provided in Chapter 8, who characterised carbon offsetting as a 'bottomless' and 'unsustainable' activity. Other shocks, such as subsidy withdrawal, jeopardised the operation of the projects (SWH project – Chapter 9). These findings are in line with research carried out by Lambe et al., (2015) and provide another example as to how overreliance on subsidies can lead to project failure if no financial safety-net is available to project actors.

This study revealed that users signed informed consent by simply exchanging their carbon rights for the low-carbon technology without being properly informed by project developers about the market value of carbon credits. This is concerning and may verge on commercial fraud. Karhunmaa (2016) argues that the end-users should receive financial compensation from the sale of carbon credits. However, in reality project developers tend to create asymmetric information. This is not surprising as carbon trading is referred to by scholars as the 'wild west' where activities are non-transparent and remain unregulated (Boyd et al., 2010; Böhm, 2009).

Resistance to carbon offset projects

Chapter 9 shows that project developers experienced some resistance from community members. For example, the Basa Magogo project, which was implemented using a community-based participatory approach, created some sensitivity around households' existing practices. Since community members knew how to make fire from childhood, it was not surprising that households refused to engage or be taught by foreigners on how to make fire. Instead, community members seemed to apportion blame on the coal industry for polluting the air and not taking any responsibilities for their own actions.

This contradicts the findings provided by Koster (2018) and Musall and Kuik (2011), who suggest that community-based participatory approaches have greater community support and are less likely to create local resistance than projects implemented from the top-down without community consultation. The results obtained from the Wood Stove project resonate with the theory provided by Huijts et al., (2012) and illustrate that community members could proclaim or agree with a 'low-carbon technology', but still resist it due to personal reasons, e.g., jealousy towards employed fieldworkers or simply not seeing the claimed value of the technology.

In the Solar Water Heater project, community members developed deep resentment and mistrust towards the local government. Dupas (2014) argues that subsidised technologies can generate an 'entitlement effect' whereby consumers refuse to pay more or at all, once the subsidy is reduced or removed. In this case, residents felt unfairly treated as they were uninformed of the eligibility process for the solar water heaters. As a result, they felt it was their right to demand that solar water heaters be installed for everyone in the project area. This is a sensible reaction as there is an issue of unfair governance that may involve a patronage network at the municipality level.

This study revealed that a patronage network was created during the employment process in the Solar Water Heater project, favouring certain people over others (family members, friends). This behaviour led to tensions, bad faith, misunderstandings among project developers and community members in the project area. This finding resonates with research carried out by Haque et al., (2021) and Staniland (2008), who confirm that councillors play a key role in selecting who gets employment opportunities in townships. However, we argue that this is not a fault of the project, but a political reality. It seems that project actors did not take account of that nor how to deal with it realistically. There are several factors that project actors need to consider if they do not want to fail. Those factors are the nature of community politics, e.g., use and abuse of power, the nature of gate keepers, who can often but not inevitably be self-serving and the probability of corruption.

Uptake of carbon offset projects

The results showed that none of the low-carbon technologies studied have become dominant technologies that could facilitate a socio-technical transition. There was not much uptake of these technologies. Technologies were not well developed and were inaccessible to users. They were costly to implement and influenced by external factors such as migration and policy changes.

In the case of the Solar Water Heater technology, carbon finance and subsidies helped develop the solar water heater industry in South Africa. As explained in Chapter 8, minimum quality standards for solar water heaters were introduced and local geysers were subsequently manufactured. However, the South African government also made a mistake by investing public funds into poor quality Chinese geysers. It seems likely that the South African government did not pay enough attention to developing this 'niche' innovation, hence the geysers seemed to have created a so-called 'dumping ground' for failed technology in the country (Wilson, 2007).

Other low-carbon technologies, such as the Wonderbag, were not easily accessible to low-income households. The technology therefore remained exclusive to a limited number of users in the project area. With regards to the Wood stove, this technology was made out of clay and cow dung. It was too fragile and required regular maintenance to be sustained in the long run. As a result, the uptake of this technology, including the adoption, was limited.

The study has shown that the Basa Magogo method suffered from 'landscape' pressures, such as migration and changes in national policies, which eventually led to project phase out. In relation to migration, it became too expensive for the project developers to search for existing Basa Magogo users, educate and encourage new users to use the fire technique. National programmes, such as the mass electrification programme, eliminated the 'low-hanging fruit' abatement opportunities and naturally reduced the consumption of fossil-fuel sources (coal), thus leading to insufficient commercial viability and a phase out of the project.

Furthermore, the total implementation costs of these low-carbon technologies were between R1.5 million (€80,000) and R9 million (€490,000), which supports the arguments provided by Wilson (2007), Nkusi et al., (2014) and Steenkamp (2018) that the uptake of such projects is expensive. High transaction costs were also created by insufficient technical carbon expertise in the country. Carbon consultants went through a learning curve themselves as to how to register carbon offset projects at the expense of some project actors, who in the end encountered higher costs than stated above.

The estimated total cost per tonne of CO_2-e saved by the carbon offset projects ranged between 19 Rand (€1) and 39 Rand (€2), whereas the annual emission reduction of these projects ranged between 0.11 and 0.77 tCO_2-e (depending on the low-carbon technology). This evidence indicates that the emissions reduction of these projects is relatively small or almost negligible. Furthermore, the mitigation impact of these projects was not guaranteed and depended on the regular household use, which is discussed in the next section.

Summary

The study has shown that (1) Technological niches are fragmented. They include actors' vested interests that primarily served a profit-maximising agenda subject to constraints. (2) Technological niches suffer from landscape pressures, e.g., migration, volatility of foreign exchange, subsidy withdrawal and policies changes. (3) They are associated with high implementation costs and relatively low or almost negligible GHG emission reductions. (4) Communities resist carbon offset projects no matter how they are implemented (bottom-up or top-down) due to personal reasons or judgement. (5) Carbon offset projects are deceptive, leading to potential fraud.

12.2.4 Low-carbon energy technology adoption within households in South Africa

Factors that influence the low-carbon energy technology adoption within households in this study are (1) seasonality, (2) social practices, (3) social interactions, (4) other factors, e.g., maintenance, fuel and stove 'stacking', (5) demographic household characteristics and (6) gender roles. Each factor is discussed in turn.

Seasonal variations

The use of low-carbon energy technologies was influenced by seasonal variations. SWHs were often used more in summer than winter due to insufficient sunlight. Similar findings were reported by Wlokas (2011) and Mukwada et al., (2014). In the summer, respondents seemed to quickly accustom to the convenience of having hot water. However, in winter they appeared to be vulnerable and complained that hot water was not available when they needed it the most. Other technologies, such as the Wonderbag, Basa Magogo and Wood stove, were used more in winter than in summer for cooking and heating purposes. This finding shows that adoption of technologies may be limited and households were forced to revert to their old unsustainable practices, e.g., use of coal-based electricity, open fire etc. Seasonal variations also create uncertainties around the GHG emission reductions. They cannot be exactly estimated and can lead to overestimation of emissions (Gill-Wiehl et al., 2021).

Social practices

For each of the projects (except in Bonn village) over 60% of households regularly used new low-carbon technology. However, the users in almost all projects (except the Wonderbag) encountered some issues. They related to users' inability to ignite the fire (Basa Magogo and Wood stove) or technical faults (leaks) experienced with the solar water heaters. While users could overcome the fire ignition problems, others had to live with faulty geysers.

I have learned that it was difficult to transform users' domestic practices - that is, to change habits and personal preferences to adapt to the new low-carbon technologies. Attitudes towards new technologies were clouded by users' personal judgement, e.g., not believing in the new low-carbon technologies. Southerton (2012) explains that habits often include repetitive behaviour, which becomes a psychological condition that is difficult to change. Maréchal (2010) highlights that habits may involve apparently 'irrational' behaviour, which can be 'counter-intentional'. As a result, people may be 'locked-in' to their daily practices and find it difficult to change their behaviour.

In the context of this study, the users' 'counter-intentional' habits were reflected in the use of plastic to ignite the fire in the wood stove. Despite knowing that plastic generates black smoke and creates adverse health effects, users continued to use it and were 'locked into' unsustainable repetitive routines. This activity seems to counteract the objective of the wood stove to reduce indoor air pollution. It is rather in line with Bruce et al.'s (2006) argument that the use of plastic and other toxic materials (rubber) is primarily a result of poverty, unemployment and poor living conditions of communities. As a result, households have little choice but to use these toxic materials.

Social interaction

The study has shown that users in the rural area, where the Wood stove project was implemented, showed positive attitudes towards the wood stove (as physical capital was improved). However, they were less inclined to use the technology in the long run. This finding supports Southerton's (2012) argument that users may have positive attitudes towards the environment or a low-carbon technology, but their subsequent behaviour may not reflect their initial enthusiasm.

My observation is indeed consistent with Southerton (2012). Households used the technology for around six months and then abandoned it. Some users used the technology mainly to impress family members (in-laws), whereas others were unwilling to maintain the technology, lost confidence or were unable to use it for traditional cooking practices.

Community members in Bonn village (Wood stove project) seemed to have accepted the wood stove because it was a 'prestige' equipment worth having, which allowed women to be part of the project and use the wood stove as a topic of discussion. This shows that technology adoption may not necessarily have to do with personal preferences but is influenced by social interaction (group-based interaction) and collective norms as stated by Southerton et al., (2004).

In terms of the Basa Magogo project, project developers were rather unrealistic to think that the fire technique would spontaneously spread and be adopted by all community members. It seems that project community members' interests diverged in relation to this new technique, which led to weak community cohesion. Since the project failed to achieve collective adoption, smoke continued to billow from the dwellings in the project area. A similar phenomenon was observed in the wood stove project. Although the project achieved strong community cohesion (social capital), the skill on how to use the technology was not transferred to family members by the majority of users. While the reasons were not revealed, further research is needed into this topic.

Other factors

The study has shown that users in the Basa Magogo and the Wood stove projects, were locked into collecting/buying a particular type of wood/coal (wet/clean) to be able to operate the technologies. This is consistent with Shove and Southerton's (2000) argument that technologies can create their own conditions and force users to adjust. These conditions, however, restricted or even forced users to discontinue the use of these technologies when the required fuel sources (wood/coal) were not available or too expensive to buy.

On-going maintenance put an extra strain on the users' time and budgets, as was confirmed also by Pailman et al., (2018) and Wlokas (2011). However, users did not take maintenance of the wood stove seriously, and in some instances followed through only to please the implementing NGO. This behaviour eventually led to technology abandonment in the project area. Design of some low-carbon technologies (e.g., the wood stove) did not allow households to cook with traditional pots/utensils for large families. As a result, larger family size not only limited user's technology adoption, but also led to discontinued technology use.

Furthermore, the findings revealed that low-carbon technologies did not entirely displace the use of unsustainable fossil fuels within households during their cooking and heating activities. The study adds to the current knowledge provided by Pailman et al., (2018), Kasangana and Masekameni (2019) and Kapfudzaruwa et al., (2017) and confirms that South African low-income households typically practice energy and stove 'stacking'. Households rotated their cooking practices between low-carbon technologies, the traditional method (open fire) and 'modern' technologies (electricity). Such cultural preferences make it more difficult to decarbonise the residential sector.

Demographic household characteristics and Gender roles

On average, households in this study are within a similar income bracket (R2,500 per month). As a result, it could not be determined if technology adoption was influenced by income. However, users (n=4) indicated that low-carbon technologies were less popular among younger people between 25 and 35 years old. They were not keen to use and/or showed no willingness to learn about new low-carbon technologies. It seemed that they preferred to use electric stoves during their cooking practices, which was easier, quicker and more comfortable, and/or open fire, which they learnt from childhood. Since these results are based on a few participants, further research is needed to investigate how young people relate to low-carbon energy innovations. Based on the sample, which mainly included older people (50+), it seems that they had a lot of experience in cooking practices and a wide social network that allowed them to be more open to new ideas and adopt low-carbon technologies.

In the Basa Magogo project, admittedly only a sample of two - both respondents indicated that men did not like to learn from women and hence did not adopt the method. This echoes Mncwango's and Luvuno's (2015) finding. I have learned that low-carbon technology is implemented into pre-existing social gender norms which can be tense or involve power relations, therefore compounding, rather than resolving, the pre-existing tensions.

Summary

The study has shown that, although, low-carbon technologies were frequently used (depending on technology), it was still difficult for users to adjust and change their behaviour and habits. Instead, they prioritised their personal needs, preferences and traditional practices over new low-carbon technologies. Due to poor quality (SWHs), tenuous structure and inability to fit within traditional cooking practices (Wood stove), some users lost confidence and subsequently abandoned the technologies. Low-carbon technologies thus did not entirely displace the use of fossil fuel sources but were part of so-called energy and stove ‘stacking’. The technologies were adopted more readily by older than younger people and rejected by male counterparts due to social norms.

12.2.5 Changes in livelihoods within households in South Africa

Small-scale carbon offset projects created multiple co-benefits for households, e.g., reduced domestic energy use and costs, improved health and standard of living etc. It supports desk-based (Olsen and Fenhann, 2008; Wood, 2011; Mori-Clement, 2019) and field studies carried out by Erion (2007) and Wlokas (2011).

Furthermore, in case of the Basa Magogo and the Wood stove projects, users could reduce their coal or firewood consumption and costs by approximately 40% per month per household in winter and summer seasons. This saving helped households diversify their livelihood strategies and reduce their vulnerability to meet their basic needs, such as buying more food, electricity, paying for transportation and supporting their children (Chapter 11). Households were much more aware of their energy consumption and costs than before the project interventions. The technologies allowed them to better manage their budgets and reduce financial anxiety.

In addition to monetary incentives, the study showed that technologies such as the SWHs helped users become self-sufficient during electricity blackouts and water cuts. Despite leaks, solar water heaters still appeared to be helpful and allowed households to deal with an unstable power supply. This finding is most relevant to the current South African electricity crisis (Reuters, 2023). It seems that the demand for solar water heaters in South Africa is on the rise to reduce reliance on the national electricity grid and save energy costs (Writer, 2022; Fourie, 2023). However, Fourie (2023) adds that due to high upfront costs, this technology still remains unaffordable for many.

Impacts of low-carbon technologies were mostly felt by women. Being responsible for all household chores, women were the key users of these technologies They therefore had a strong interest and were more enthusiastic about new innovations than their male counterparts. Compared to the rhetoric of gender empowerment in the project documents, women did not actually allocate their freed-up time to engage in educational or income generating activities. They often allocated their time to other daily chores or could have time to relax or spend more time with their children. Although the time demand was lowered for their chores, this may not necessarily lead to gender empowerment. The reduction on domestic chores on women involved a gradual, but not a dramatic, change.

The reduction in time spent collecting firewood (often in isolated areas/forests) reduced women's vulnerability to crime. Overall, all low-carbon technologies studied created comfort, convenience and ease for women in their daily life, followed by improvements in health and wellbeing (reduced indoor air pollution; better hygiene and sanitation). This finding fits well within the social practice theory (Shove, 2003). In case of the solar water heaters, 'turning on the tap' provided households an opportunity of increased everyday comfort, convenience and cleanliness. Households quickly adjusted their behaviour and comfort became an essential component of their life for example allowing them to sleep longer in the mornings, among other benefits. Women, in the Wonderbag project could socialise or carry out other important tasks while their food was cooking; others could comfortably sit and cook next to the wood stove.

However, more efficient systems like the solar water heaters follow Jevons paradox[63]. 42% of households (n=12) increased their water consumption from 17 litres to 37 litres per day per bath per person. Since Johannesburg is known for its water shortages due to its location, which is

[63] Jevons paradox is defined in the situation when efficiency causes the natural resource use to rise (York and McGee, 2016)

inland at a high altitude of 1,800 metres and at some distance to large bodies of water (Murwirapachena, 2021), making it cheaper to produce more hot water can lead to more aggregated water demand. This creates another challenge for the municipality as to how to either provide enough water for the residents or distribute water equitably so that solar water heaters do not lead to water crisis.

Households were highly adaptable and resourceful in reconfiguring their daily practices, which resonates with the study carried out by Brown et al., (2015). In the situation when hot water was not available from the solar water heaters, especially in winter, low-income households felt vulnerable, but managed to adapt to the situation by reviving their old practices. However, this activity locked them into unsustainable practices which required the use of fossil fuel sources (open fire) or coal-based electricity to heat up water for their basic needs.

Low-carbon technologies caused negative impacts on households. Leaks of solar water heaters, for example, increased households' vulnerability and led to discontent and fear of feeling unsafe. Due to complaints, this problem led to tensions that had a negative effect on social relations in the project area. It seems that the unequal distribution of this technology put an additional strain on social relations and created unnecessary friction among community members. This phenomenon resonates with the argument provided by Haque et al., (2021) and suggests that solar water heaters may have improved households' standard of living, but, as a sub-optimal technology, created a bigger gap in inequality in the local area.

12.3 Chapter Summary

This chapter critically discussed the theoretical and empirical contributions of this study. The empirical results from Chapters 8, 9, 10, and 11 generated a rich set of data and helped create an extensive discussion in this chapter. The chapter made a theoretical contribution by arguing that the combination of the MLP with the SLA provides a deep understanding of the socio-technical transition. The model was able to accommodate and capture actors' perceptions and discourses, including households' technology adoption and changes in livelihoods.

However, the chapter also indicated that there was significant resistance to change within the energy regime despite the several climate change and energy efficiency policies introduced by the South African government. The regime is rather locked-in to fossil fuel technologies to benefit specific corporate elites. The carbon market sub-regime remained relatively small involving only voluntary activities. It was also locked-in to its own inefficient structures, suffering from asymmetrical information and unequal power relations.

'Technological niches' are highly vulnerable in particular to actors' vested interests and external factors, such as withdrawal of subsidies, migration, volatile carbon prices and policies. As a result, they did not manage to become dominant technologies in the consumer market. Their implementation is expensive in comparison to small and almost negligible GHG emission reductions. Project actors created asymmetric information on the value of carbon credits and appropriated future carbon rights from the technology users.

Technology adoption within households was complex, unpredictable and influenced by habits, culture and daily routines. Some households abandoned the technologies due to poor quality of the solar water heaters, the build quality of the wood stove and the inability to use them for traditional cooking (Wood stove). Low-carbon technologies were less popular among younger people, who preferred to maintain their own cooking practices.

Carbon offset projects created multiple co-benefits beyond the GHG emission reduction. They reduced energy use and costs by 40%, made households more self-sufficient and allowed them to experience comfort and convenience in their daily life. However, technologies, such as the solar water heaters, increased households' daily water consumptions. The study argued that they follow Jevons paradox and are likely to lead to water stress in the project area. The study found that solar water heaters created negative effects on households due to leaks that created fear and a feeling of being unsafe among individuals. Unequal distribution of technologies had negative effects on social relations in the project area.

In conclusion, low-carbon technologies do not provide a permanent solution for reducing energy demand and GHG emissions. These technologies did not become dominant in the consumer market and are likely to be phased out in the long term. They do not entirely displace the use of fossil fuel sources as energy, and stove 'stacking' prevails in South African households. As a result, the low-carbon technologies analysed in this study are not suitable to decarbonise the residential sector and represent a false low-carbon energy transition.

Chapter 13: Concluding remarks

The overall aim of this research has been to analyse whether carbon offset projects contribute to the necessary transition towards a low-carbon energy system in South Africa. In particular it has examined: the functioning of the carbon offset market, small-scale carbon offset projects and their implementation (specifically four case study projects), users' project technology adoption, and the effects that these low-carbon technologies have on adopting households.

The study found that carbon offsetting as a policy tool was perceived by the actors involved in the market as a flawed tool for reducing GHG emissions in South Africa. It created an opportunity to generate profits instead of addressing environmental problems. Project implementation of carbon offset projects was expensive and time consuming. In comparison to the costs, emission reductions of these projects were small or negligible. GHG emission reductions were not guaranteed and depended on regular household use. The study showed that low-carbon technologies were regularly used by households. However, users found it difficult to adjust and change their behaviour and habits. Some technologies did not fit well with users' practices and were subsequently abandoned.

We found that low carbon technologies had an overall positive effect on households' livelihoods and became valuable assets. However, there were also some negative effects that will be summarised in this chapter. The chapter concludes with the core findings and contributions made by this study to answer the sub-research questions. The study provides suggestions for further research and some concluding remarks.

13.1 Thesis overview

South Africa is one of the largest GHG emitters on the African continent. In 2019, national emissions totalled 474 MtCO2-e (Enerdata, 2020). The main reason is that coal remains the primary (75%) energy source. The per capita GHG emissions are 8.7 tCO2e/person, compared to Africa's average of 1.1 tCO2-e per capita, but 14.86 tCO2-e in US (Statista, 2021).

The economists frame GHG emissions that drive anthropogenic climate change as an 'negative externality', caused by market failure, in sense that there has been real cost to polluters emitting GHG pollutants into the atmosphere. So called 'market-based solutions', such as the carbon offsetting, have been promoted and adopted as a mitigation option, in order to help 'internalise' part of the costs of GHG emissions, align disincentives and incentives, and thereby help 'correct' the market failure (Chomitz, 2000). Carbon offsetting, is claimed to incentivise investments in innovative low carbon technologies and also facilitate the gradual transition towards a low-carbon economy (Sato et al., 2019).

The research question for this study has been, '*Do carbon offset projects contribute to livelihoods within communities in South Africa, and if so, how?*'

To address climate change and GHG emissions, in 2019 the South African government introduced the carbon tax and carbon offset regulation. Carbon offsetting is claimed by the South African government as a viable pathway to facilitate a transition to a low-carbon economy, thereby creating jobs and incentivising investments in non-fossil fuel-based energy generation (National Treasury, 2014).

But climate change is recognised by the South African government as not only an environmental problem, but also a developmental concern, as it can undermine poverty reduction and affect the most vulnerable. Impacts, such as extreme weather events, like flooding, rainfall, drought and heatwaves, have already caused devastating effects on South African citizens – particularly the poor. South African communities still suffer from race-based deprivation, widespread poverty and unemployment. Hence policies also aspire to provide positive effects on the livelihoods of marginalised groups – so called 'co-benefits'.

Existing studies have shown that South African 'market actors' (that is, agents engaged professionally in carbon markets in various roles) experienced various barriers in the CDM, such as high costs, lack of expertise, excessive bureaucracy, amongst other concerns. This study found that the literature has become outdated by significant and more recent developments in the carbon offset market, including attitudes towards co-benefits provision of carbon offset projects in the country. Further research has therefore been called for in order to deepen the understanding of the evolving local carbon markets and their imbalances created by the discursive behaviour of actors (for example Bumpus, 2011; Ullström, 2017). Hence this research has sought to address this shortcoming.

In terms of implementation, studies have shown that carbon offset projects can be very expensive in terms of both transaction costs and costs per unit of carbon notionally offset. It has also proved difficult to scale up these projects, due to several factors such as insufficient funding, inadequate governmental interest or support and shortage of local skills. These studies also focused on 'best practice' cases, e.g., the Kuyasa CDM project, and paid less attention to the many other projects. Furthermore, few studies examined how carbon finance could help with the uptake of improved domestic energy use, for instance cooking technologies. Hence, this study has examined the implementation processes of carbon offset projects.

Existing studies have shown that household adoption of low-carbon technologies was complex and contingent on some specific factors, which included fit with varying seasonal conditions (usefulness in winter and summer), technology design (user friendliness, reliability, low maintenance), socio-economic and demographic household characteristics (like age, income and educational attainment) and so on. Studies have generally not paid sufficient attention to the fit with actual social practices, e.g., users' daily routines, culture, habits and social norms, that influence technology adoption. This study therefore examined the regular use of low-carbon technologies and the issues with which users have struggled. Not enough field studies were conducted to capture the experiences of local communities with carbon offset projects in South Africa. Therefore, a wider assessment of multiple case studies was needed to bridge the gap between desk-based and field studies (Karhunmaa et al., 2015).

As a result, this study analysed four small-scale carbon offset projects in South Africa. It was understood that carbon offset interventions help facilitate socio-technical transitions gradually by replacing carbon-intensive technologies with new low-carbon energy innovations. The study applied a framework integrating the Multi-Level Perspective with the Sustainable Livelihood Approach. This model has provided a deep understanding of actors including households in the socio-technical transition. It has given insights into users' behaviour and their adoption of low-carbon technologies. The South African carbon market has been characterised in this model as a 'niche' element of a bigger energy system trying to disrupt the fossil fuel regime to facilitate the socio-technical transition. However, it is a complex 'sub-regime', safeguarded by rules to channel investments into nascent technologies.

It is influenced by the 'landscape' – the external environment. The 'technological niches' are comprised of the low-carbon technologies selected for this study. As soon as these technologies have been implemented, they are understood to change the flow of household assets, their activities and outcomes. To answer the research question, I adopted a multiple case study approach. I purposefully selected four small-scale carbon offset projects and five sites across the country. Primary data was collected over the period 2017-2018. I triangulated the data with multiple data sources, such as secondary data analysis, semi-structured interviews, household surveys, observations and site visits. I selected the relevant actors and explained their contributions to the study. The study analysed the 'landscape' related to the energy emission profile of South African industry, the vulnerability of South African citizens to climate change, and the government's response to address climate change impacts. It found that the South African government has introduced several policies and regulations, including large-scale demand-side interventions to help improve energy efficiency at the consumer level. However, these policies remained largely unimplemented due to political uncertainty and turmoil caused by 'state capture' over the past 10 years (Averchenkova et al., 2019).

To understand how the carbon market is governed, I reviewed carbon standards in the compliance and voluntary markets. The study found that the future of the CDM is uncertain given that the second commitment period of the Kyoto Protocol came to an end on 31 December 2020. The nature of the carbon offset market has moved towards voluntary activities, whereby countries now increase their demand for carbon offset credits and are actively involved in the voluntary carbon offset market to achieve their domestic GHG emission targets (Lang et al., 2019; Schneider and Theuer, 2019). I carried out desk-based analysis of carbon offset projects registered under the CDM, Verra and Gold Standard in South Africa. The study found that the uptake of carbon offset projects and innovative technologies was slow and mainly dominated by large-scale renewable energy, landfill gas, industrial energy efficiency, N2O and methane projects. This was due to the collapse of the global carbon prices (CDM and EU ETS) in 2012. When comparing the emission reductions achieved by carbon offset projects with the relevant sectoral emissions of the country, it is evident that these projects hardly made a dent in reducing emissions in these sectors. In the next section, I elaborate on the empirical findings and the main contributions of this research.

13.2 Key findings and contributions

This study sought to provide answers to the overarching research question:

Do carbon offset projects contribute to livelihoods within communities in South Africa, and if so, how?

Through applying the integrated MLP-SLA framework to the context of the South African energy regime, the study made a theoretical contribution by providing deep insights into the process of socio-technical transition in the less efficient South African energy market. It provides an understanding of people's behaviour and how they may influence a low-carbon energy transition. Adoption of consumer energy innovations is the central pillar of the socio-technical transition. The study has shown that South African low-income households are deeply entrenched in social practices (habits, daily routines, preferences etc.) and use multiple fossil fuel sources, so-called 'fuel stacking'. Importantly, these factors create barriers for a low-carbon transition.

The MLP-SLA model shows that there are too many barriers within the process of a socio-technical transition. The transition to a low-carbon economy in South Africa is highly uncertain. Specifically, the South African energy regime is 'locked-in' to long-term investments in fossil fuel-based infrastructure with an intention to continue to generate profits long term, hence there is a strong reluctance or push-back to any change.

From a policy perspective, the MLP-SLA helps uncover that the South African government has created different narratives for international and national policy arenas. The South African government has introduced several climate change and energy efficiency policies since 1998 and has been playing a leading role in international climate change negotiations. However, at the national level it has maintained 'business as usual' behaviour and has been delaying implementation of proposed climate change policies. Since it has long-term interests in the carbon intensive energy regime (state-owned Eskom), it continues to support coal-based activities in the country. As a result, it seems that a transition to a low-carbon economy remains an activity in rhetoric only, without any real measures being imposed or reforms created.

The MLP-SLA framework has shown that the overwhelming nature of the landscape has created disruptions in the carbon market sub-regime and the technological niches. Although the carbon market 'sub-regime' is governed by rules and structures, the study has shown that it is vulnerable to 'landscape' pressure (external environment), such as the carbon price volatility and economic uncertainties. Since it relies on actors' networks and their market activities, the 'sub-regime' can easily collapse because of shocks. The study therefore concludes that a carbon market as a 'sub-regime' it is inappropriate to facilitate a socio-technical transition. The carbon market sub-regime is also 'locked-in' to its inefficient structures (bureaucracy, high costs), thus delaying and undermining environmental issues. The study has shown that 'technological niches' are fragmented by actors' vested interests. They are vulnerable to landscape pressures, such as subsidies, migration, policy changes and foreign exchange. Similar to the carbon market sub-regime, they can collapse if no financial safety net is provided.

While the MLP-SLA model is valuable and can help uncover hidden realities of less functioning energy systems like in South Africa, it has its limitation. It does not take into the account the historical context of inefficient infrastructures created by Apartheid. Actors at different levels (market and project actors, households) are entrenched into systemic inefficiencies that have become the norm (water cuts, electricity blackouts). Inefficiencies across sectors make it difficult to facilitate a socio-technical transition and subsequently lock the industry and consumers into unsustainable practices.

Furthermore, the study shows that there is systemic disempowerment, which was a central tenet of the apartheid regime, which continues to cast a long shadow over marginalised communities. Communities still lack basic service delivery and live with infrastructure that is woefully inadequate. As a result, I argue that basic levels of service delivery and infrastructure first need to be in place before an energy transition can be facilitated. Household adoption of low-carbon innovations will in all likelihood remain sub-par whilst this backdrop prevails.

To conclude, the MLP-SLA framework provides a comprehensive understanding of a socio-technical transition related to consumer energy innovations. This study could be expanded to other countries to compare inefficient energy systems and investigate hidden realities of the energy regimes. This will help policy makers make informed decisions and introduce policies that can effectively address the inefficiencies of the local energy system. The MLP-SLA could be developed further to take into account racial disparities, poverty and inefficiencies faced at the household level.

Sub-question 1: How does the carbon offset market function in South Africa?

In Chapter 8, I analysed actors' storylines on the functioning of the South African carbon offset market. I interviewed 27 market actors in South Africa in 2017. I found that on-balance actors were critical about the legitimacy of the South African carbon market. They agreed that carbon offsetting was a flawed policy tool to reduce GHG emissions in the country. They perceived the carbon market as 'immature', poorly developed and almost 'non-existent'. This was largely due to the prevailing low carbon price in the CDM and economic instability. Actors experienced inefficiencies, e.g., bureaucracy, limited understanding, no local expertise, and various risks, such as climate-related, financial and political, that created challenges to fully embrace carbon finance. I found that the carbon market was fragmented and susceptible to fraudulent transactions and manipulation, such as the overestimation of GHG emissions.

The study found that there was inconsistencies in governance structure and insufficient institutional capacity to approve CDM projects in the country. The South African government showed leadership in the CDM and helped other African countries, like Kenya, Zambia and Namibia to set up offices to govern CDM projects. However, it remained silent at the national level and did not engage nor support the uptake of carbon offset projects. The South African government was out of touch with the situation in the carbon offset market and the challenges market actors faced in the market and project implementation.

The study revealed that the market was dominated by a few players who maintained intellectual control and generated profits. I found that the South African carbon market suffered from unequal power relations. While Eskom, which has close political ties to the government, had privileged access to speed up the registration of carbon offset projects, all other actors joined a long 'queue' and experienced delays in project approvals. The results showed that the carbon market was non-transparent. Due to complex carbon methodologies buyers could not differentiate between a 'bad' or a 'good' project even if they were verified. As a result, I argue that these projects need to be safeguarded by an independent association to protect the public good and ensure they are socially sound.

The majority of actors (55%) agreed that the introduction of the carbon tax and the carbon offset regulation was a step in the right direction. These regulations could force polluting industries to improve their operations and help the government achieve the emission reduction targets. However, the carbon tax seems to have been introduced for political reasons. The fact that Eskom and Sasol, which are the country's largest emitters, remained exempt from the carbon tax, shows that there is a loose commitment by the government to reduce GHG emissions. An actor called the carbon tax regulation a 'smokescreen' or just another tax to generate more revenue to fill up government coffers.

I found that overall actors' perceptions in relation to co-benefit provision in South Africa was positive. Market actors agreed that co-benefits depended on the type and size of carbon offset projects. For example, small-scale carbon offset projects, such as cookstoves, can create changes in livelihoods, e.g., provide physical artifacts, create social change and improve standard of living. In contrast, large-scale carbon offset projects, such as landfill gas projects, are perceived to have limited or no impact at all. Since there was no requirement to provide co-benefits by carbon offset projects, actors argued that co-benefits were underemphasised in project documents and promises were often not fulfilled by actors during project implementation. The study found that carbon revenue sharing remained limited due to a low carbon offset price and actors' vested interests to maximise profits.

Sub-question 2: How are carbon offset projects implemented in South Africa?

In Chapter 9, I examined experiences of project actors involved in project implementation processes of four carbon offset projects: the Wonderbag, Basa Magogo, Solar Water Heater and the Wood stove projects. The findings are based on semi-structured interviews with 24 project actors. The results revealed that carbon finance opportunities enabled project developers to create partnerships with financial institutions, carbon consultants and other companies in the consumer industry. These partnerships helped project developers raise finance, launch and create awareness of nascent technologies in the consumer market. However, partnerships were also influenced by actors' vested interests and mismatch of expectations. As low-carbon technologies were provided free of charge, partnerships seemed to have obscured the real costs of low-carbon technology and caused distortions in the consumer market, as was apparent in the Wonderbag project.

The results showed that carbon offset projects implemented using a community-based participatory approach created positive effects. They raised awareness about low-carbon technologies, provided training and educated potential users on how to use new technologies. However, project developers reported that they still experienced some resistance from community members. For example, it was reported that community members resisted the Basa Magogo method due to some sensitivity around household fire practices that were long-established within households.

Projects implemented from the top-down without community consultation, such as the Solar Water Heater, led to limited or no understanding of the new low-carbon technology at the consumer and installer level. The unequal distribution of the solar water heaters created tensions among community members. They developed deep resentment and mistrust towards the local government.

I found that all four carbon offset projects created employment and helped local communities develop specific skills. However, the employment was temporary and project actors experienced problems with their fieldworkers. There was low sentiment among workers and an unwillingness to get involved in the projects due to the laborious nature of the work. Furthermore, the study found that a patronage network was created during the employment process, favouring certain people over others (family members, friends). This behaviour led to tensions and misunderstandings among project developers and community members in Cosmo City township where the Solar Water Heater project was rolled out.

The study revealed that carbon offset projects were vulnerable to shocks, such as the collapse of the carbon prices in the CDM and EU ETS in 2012, withdrawal of subsidies, volatility in exchange rates and migration. The collapse of the carbon price caused financial losses and business models designed through partnerships fell apart. While some carbon offset projects, e.g., the Wonderbag project, could recover from this shock, others, such as the Solar Water Heater project did not survive. Since this project mainly relied on carbon finance and a subsidy, it collapsed as soon as these financing mechanisms were withdrawn.

Project developers seemed to have had good intentions when providing low-carbon technologies to users. The reported objective was to help improve the poverty status quo in project areas and the living standard of the technology users. However, the results also revealed that some project developers created asymmetric information during this process. They obfuscated information on carbon credits and the trading activities. This behaviour leads to the conclusion that they appropriated future carbon rights of technology users.

Lastly, the project implementation process of the four carbon offset projects was expensive. In comparison to the reported project costs, estimated emission reductions of these projects were small or negligible. The emission reductions of these projects were not guaranteed and depended on regular household use, findings of which are presented in the next section.

Sub-question 3: How are low-carbon technologies adopted within households in South Africa?

I interviewed 113 households in four carbon offset projects selected for this study. The findings showed that all households used low-carbon technologies on a regular basis. However, the integration of these technologies varied across projects and depended on factors, such as seasonal changes, maintenance requirements, daily practices and quality of the technology. I found that all low-carbon technologies (except the solar water heaters) were used more in winter than in summer periods for cooking and heating purposes. Due to seasonal differences in sunlight availability, the majority of households (71%) could only make use of the solar water heaters in summer.

The results indicated that some carbon offset projects offered poor quality and fragile technologies. In case of the Solar Water Heater technology, I found that 86% of households had continuous leaks. There was no appropriate technical support in the project area to maintain and fix the geysers. Since households were confronted with everyday struggles, such as unemployment and poverty, it was reported that they did not have funds to maintain the geysers. However, households still adopted the low-carbon technology, but ended up living with permanent issues.

In case of the wood stove, I observed that it was made out of organic materials, e.g., clay and cow dung. It was too fragile and required regular maintenance to be sustained in the long run. However, some users did not have the time to maintain the technology and considered the maintenance requirements to be too onerous. This was one of the main reasons why they abandoned the technology in the long run.

Furthermore, findings revealed that some low-carbon technologies, such as the Basa Magogo method and the Wood stove, made users contingent on the use of clean coal and dry wood. In the situation when the users did not have or could not afford to buy the required type of fuel sources, they discontinued their use.

I observed that there was a tendency to abandon the wood stove in the long run. Users initially accepted the wood stove because it was a 'prestige' technology worth having, which allowed women to be part of the project and strengthen social relations. However, as time passed, 82% of users (n=18) in Bonn village discontinued using the wood stove. This was due to practical reasons, as the technology was not suitable for traditional cooking practices. It did not allow households to cook with traditional pots/utensils for larger families. Users abandoned the wood stove as they did not have time to collect wood nor the money to buy it. Others did not enjoy using the wood stove and preferred open fire - as they had grown up using it.

I found that knowledge or skill on how to use low-carbon technologies in the Wood stove and the Basa Magogo projects was not transferred to family members. While reasons were unknown, the findings indicated that these technologies are not sustainable in the long run as their knowledge/skill is likely to be phased out. It was also apparent that the BM method did not spontaneously spread between households in the project area, as envisaged by the implementing NGO. Making fire was perceived as something personal. It was learnt during childhood and formed a core part of the households' daily routine. It was difficult to change people's habits and cultural norms. As a result, the BM method, was not adopted collectively in the project area, despite the benefits it offered.

I observed that younger people between 25 and 35 years old were less interested using low-carbon technologies. Respondents in the woodstove project (n=5) reported that younger people preferred to use electric stoves, which was easier, quicker and more comfortable. They were also inclined to use open fire, which they learnt during childhood. In the Basa Magogo project, it seemed that the social norm was that men did not like to learn from women, hence did not adopt the new fire technique. Since these findings are based on a few respondents, further research is needed to investigate how gender roles and age influence the adoption of low-carbon technologies.

Lastly, we found that low-carbon technologies did not fully displace the use of unsustainable fossil fuels within households during their cooking and heating activities. Households rotated their cooking practices, which is called 'fuel and stove stacking' between low-carbon technologies, traditional method (open fire) and 'modern' technologies (electricity).

Sub-question 4: How do livelihoods of households change as a result of carbon offset projects interventions in South Africa?

In Chapter 11, I examined the impacts low-carbon technologies have on households. The findings are based on 113 households interviewed in four carbon offset projects: the Wonderbag, Basa Magogo, Solar Water Heater and the Wood stove projects. The majority of respondents in the sample were women over 50 years old. They were either unemployed, self-employed or in temporary employment. The average monthly income reported by respondents was approximately R2,500 (€132) per month. This indicated that women were likely to be financially constrained and may have limited resources to complete their daily tasks.

The study revealed that overall, carbon offset projects created positive changes in livelihoods. Low-carbon technologies became valuable assets for households. All projects reduced households' energy consumption and costs. For example, in the Basa Magogo and Wood stove projects, we found that households could reduce their coal or firewood consumption and costs by approximately 40% per month in winter and summer seasons. This saving helped households diversify their livelihood activities and reduce vulnerability in meeting their basic needs, such as buying more food, electricity, paying for transportation and supporting their children. It was apparent that households appeared to be much more aware of their energy consumption and costs than before the project intervention. The technologies allowed them to better manage their budgets and reduce anxiety that they would run out of money in the middle of the month.

The findings showed that the Solar Water Heater technology helped users become self-sufficient during electricity blackouts and water cuts, despite the leak problem. 21% of households in the sample (n=6) shared water with their tenants and neighbours during electricity blackouts. A similar situation was observed in the Wonderbag project. Users shared their technology with extended families, who lived in the rural areas of the Eastern Cape, to help them with limited electricity supply.

All low-carbon technologies were perceived to make life easier and more convenient, helping women to perform their daily routines with greater ease. For example, technologies that related to food preparation reduced cooking time by approximately 2 hours in the Wonderbag and 1 hour in the Wood stove project. This allowed women to have more time to relax or spend with their children. Others allocated their time to other daily chores, such as cleaning and doing laundry. I found that 20% of respondents (n=8) in the sample could reduce the number of times they needed to collect firewood to fill a bakkie load from 6 to 3 times a year. Women (n=3), who collected firewood using a wheelbarrow reduced the frequency of their trips from once a week to once every 2 weeks. The reduction in number of trips not only saved time, but also reduced concerns about being mugged by criminals in remote forested areas.

In relation to the Solar Water Heater project, I found that the availability of hot water allowed 29% of women (n=8) to carry out household activities, such as cooking and cleaning, much faster. 21% of respondents (n=6) reported that they could prolong their sleep by approximately an hour, whereas 18% of respondents (n=5) could use water during water cuts for drinking, cooking and household chores. While health and wellbeing remained unchanged for the majority of users (71%) in the Solar Water Heater project, I observed that the technology caused an increase in water consumption, which indicated an improvement in sanitation and hygiene. I argued that a more efficient system like the solar water heater follows Jevons paradox. Convenience and efficiency of the technology generated increased demand on the limited natural resource, in this case, water. As a result, this may require regulation of use in order to safeguard and ensure equitable distribution of the limited resource.

Furthermore, the study found that the Basa Magogo and the Wood stove improved indoor air pollution and had positive effects on users' health and wellbeing. However, I argued that external factors, such as badly ventilated coal stoves, wet wood or households' use of plastic to ignite the fire had a negative effect on users' health. Although they generated smoke, further research is needed to investigate their contribution to indoor air pollution and the magnitude of benefits provided by low-carbon technologies

However, some low-carbon technologies, such as solar water heaters, also created negative effects on users. Due to technical issues (leaks), 50% of respondents (n=14) in the sample felt discontent and unsafe. Technical issues caused frustrations among users and exacerbated social relations in the project area. In the Wood Stove project, enthusiasm about the low-carbon technology seemed to be felt mostly by women, who were generally responsible for household chores. It was claimed that men did not pay attention to the rollout of this technology. Women created strong relations and seemed to support each other during the project implementation process.

The overarching conclusions of this study:

South Africa's small scale carbon offset projects have contributed to significant livelihood changes within the communities in which they were implemented. Beneficiary households were able to reduce energy use by 41% on average, reduce cooking time, increase convenience and more. However, not many within South Africa's 60 million-strong population are benefiting. The low-carbon innovations in this study remain niche and scaling up is not feasible due to lack of funding, high costs and low priority.

Beneficiary livelihood changes primarily depend on user adoption and continued use of the technology. As this chapter has shown, technology adoption is complex and influenced by users' social practices. It is difficult for users to change their behaviour and their routines due to culture, norms, social relations and individual preferences. Livelihood outcomes are also influenced by external factors, such as availability and affordability of the required type of fuel sources, and social relations.

Having analysed four carbon offset projects from a multiple-level perspective, the chapter concludes that these projects are not suitable interventions to pursue an incremental socio-technical transition. Their emissions reductions are not guaranteed as they depend on users' technology adoption. The carbon market is fragmented and 'locked-in' to bureaucratic and inefficient processes. It is dominated by actors' vested interests compromising on environmental integrity. Carbon offset projects are vulnerable to subsidies and carbon prices. They can easily collapse if no financial safety net is available. The project implementation process is expensive and creates asymmetric information. As a result, carbon offsetting is a tokenistic activity that obstructs a pathway to a real low-carbon energy transition.

13.3 Recommendations for further research

This study has offered an important insight into the functioning of the South African carbon offset market and small-scale household energy efficiency carbon offset projects implemented in different provinces across the country. It is hoped that this research is able to provide a contribution to the theoretical and empirical knowledge needed in the South African carbon offset market. Although the study reflected on high-level perspectives of actors in the carbon offset market and focused on specific case studies, the study is not exhaustive and further research is needed in the future to create more understanding of the mitigation options in South Africa. Recommendations for further research are stated as follows:

● Since this study focused on project implementation processes, more detailed analysis of each niche technology is needed to investigate how these low-carbon technologies were researched and developed and tested, including networks created in this process.

● Further research is needed to investigate why knowledge or a skill of low-carbon technologies analysed in this study was not passed on to other family members within households.

● Further research is needed to investigate how age influences the adoption of low-carbon technologies analysed in this study. To provide a comprehensive analysis, the analysis could focus on different age groups. Research could also elaborate how young people perceive low-carbon technologies analysed in this study.

● Further research is needed to deepen the knowledge of the community dynamics to see how carbon offset projects are perceived by community members and if they are rejected, why?

● Further research is needed to conduct a comparative field study analysis of small-scale household energy efficiency carbon offset projects in other African countries to evaluate livelihood changes within households.

● It is necessary to deepen the empirical knowledge and analyse other types of carbon offset projects, such as the Agriculture, Forestry and Other Land Use (AFOLU) projects, in South Africa and compare them with other African countries. In particular, the analysis could focus on governance of eco-system services and how these projects change livelihoods of communities living closely to project areas.

● Since the majority of households in this study were in similar income brackets, it was not clear how income level influenced the adoption of technologies under carbon offset projects. As a result, further research is needed to investigate if income can influence adoption of low-carbon technologies within households in South Africa.

● Further research is needed to examine awareness of environmental issues within households and how it influences the use of low-carbon technologies in South Africa.

● Since carbon standards create rules and procedures for the carbon offset projects, further research is needed into carbon standards and their due diligence processes, including understanding of local context.

This study generated fresh knowledge of the South African carbon offset market. It analysed multiple perspectives of different actors touching on topics, such as the functioning of the carbon offset market, its credibility, obstacles and constraints including the provision of sustainable livelihoods by carbon offset projects. The study provides an in-depth knowledge of different field studies and generated empirical knowledge on technology adoption of carbon offset projects in urban and rural areas of South Africa.

The findings of this study are important for a variety of different actors, such as policy makers, NGOs, project developers, funding institutions, carbon standards, carbon development consultants and academic institutions. Policy makers in South Africa may use the empirical knowledge generated by this study to reflect on dilemmas different actors still face in the carbon offset market and make changes to their policies and regulations. Furthermore, non-state actors can use this study to form their own opinion of carbon offset projects' complexities before they engage in the carbon offset market and decide to develop a carbon offset project in South Africa or beyond. This research is useful for academia. It contributes to the debate of socio-technical transition theory. This study integrated the Multi-Level Perspective with the Sustainable Livelihood Approach which can be applied to other countries and sectors for comparison reasons.

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Appendix

A1 Market actors interviewed in the carbon offset market

Classification	Participants
Academic institution	Participant 1
Financial and Legal institutions	Participant 2
	Participant 3
	Participant 4
Carbon development consultants	Participant 5
	Participant 6
	Participant 7
	Participant 8
	Participant 9
	Participant 10
	Participant 11
Government department	Participant 12
Local registry	Participant 13
Project developer	Participant 14
	Participant 15
	Participant 16
	Participant 17
Eskom	Participant 18
Municipalities	Participant 19 Participant 20 Participant 21 Participant 22
NGOs	Participant 23
	Participant 24
	Participant 25
Civil society organisations	Participant 26
	Participant 27

Source: Author's compilation

A2 Example of interview questions in the carbon offset market

Interview questions for actors in the carbon offset market

Date of the Interview:

Name of the Interviewee: ______________________________

Company/Organisation: ______________________________

Position: ______________________________

When did you begin working in the carbon industry? ________________

Introduction & ethical consent statement

Thank you for agreeing to participate in this study.

The study aims to assess the carbon offset market in South Africa and if carbon offset projects are effective at delivering sustainable livelihoods to local communities. Your participation will help to better understand the local carbon offset market and what contribution carbon offset projects make if any towards sustainable livelihoods in South Africa.

I understand your participation in this research study is voluntary and you can stop the meeting at any time or withdraw from the research activity if you do not feel comfortable.

I would like to record this interview so that I can correctly capture your answers.

There are no financial incentives for your participation, but I will be keen to share my findings with you.

There are no risks involved in your participations in this study. All information will be kept confidential and your answers will be anonymised.

For any further questions or queries, you can reach me at J.Hofmann@uea.ac.uk

Theme: Background of participant

1. *What type of carbon offset market do/ did you operate in or have had experienced with?*
    1. *CDM*
    2. *Voluntary carbon market*
    3. *Any other:*

2. *What aspects of carbon offset projects do/did you specialise in? (e.g. auditing, trading, project development, regulatory, research etc.)*

----

3. *What type and size of carbon offset projects do/did you have experience with?*

----

4. *What is/was your aim in engaging in carbon offsetting in South Africa?*

Theme: Functioning of the carbon offset market in SA

5. *How well do you think the carbon market has developed in South Africa?*

----

6. *What has been your experience in engaging in carbon offset projects in South Africa?*

----

7. *Have you faced any challenges in the carbon market in South Africa? If yes, what kind?*

----

8. *From your perspective, how can these challenges be reduced?*

Theme: Geographical distribution of carbon offset projects

9. *From your perspective, what are the most important factors that determine the decision for the carbon offset project location?*

____

____

Theme: Sustainable livelihoods provision and local communities

10. *Referring to the carbon offset projects you have had experience with, do carbon offset projects help local communities on the ground?*

----

11. *What sustainable livelihoods do carbon offset projects provide to local communities?*

----

12. *From your perspective are/were there any problems (costs or negative aspects) of carbon projects for communities?*

----

13. *Is there anything else you can suggest that could be provided to local communities by carbon offset projects?*

Theme: Revenue distribution

14. *From your experience with carbon offset projects, do you know what happens to the revenue generated from carbon credits?*

----

15. *How can carbon offset projects be better designed to deliver sustainable livelihoods (if any) to local communities on the ground?*

Theme: Policy discussion

16. In your opinion, what sort of policies does South Africa need, if any to mitigate its greenhouse gas emissions?

----

17. Is there anything else you wish to add?

This is the end of the questionnaire, thank you for your time and assistance.

A3 Projects actors interviewed in the study, who were directly involved in project implementation processes of the selected carbon offset projects

Participant	Participant's role	Participant's position	Organisation type
Participant 1	Project developer	Founder and Chief Executive Officer (CEO)	Business
Participant 2	Project developer	Operations Manager	Business
Participant 3	Project developer	Managing Director	Business
Participant 4	Project developer	Floor manager	Business
Participant 5	Factory worker	Worker	Business
Participant 6	Manufacturer and Distributor	CEO	Business
Participant 7	Manufacturer and Distributor	Partner	Business
Participant 8	Installer	Worker	Business
Participant 9	Carbon consultant	Managing Director	Consultancy
Participant 10	Carbon consultant	Director	Consultancy
Participant 11	Financial institution	Director	Financial Institution
Participant 12	Business partner	Senior Behavioural Scientist	Business
Participant 13	Project developer	Chief Experience Officer (CXO)	NGO
Participant 14	Project developer	Managing Director	NGO
Participant 15	Project developer	CEO	NGO
Participant 16	Project developer	Chief Financial Officer (CFO)	NGO
Participant 17	Project developer	Operations Manager	NGO
Participant 18	Project developer	Chief Operating Officer (COO)	NGO
Participant 19	Project developer	Project Manager	NGO
Participant 20	Stove builder	Worker	NGO
Participant 21	Fieldworker	Worker	NGO
Participant 22	Induna	Induna	Burgersdorp
Participant 23	Induna	Induna	Burgersdorp
Participant 24	Induna	Induna	Bonn

Source: Author's compilation

A4 Example of interview questions during project implementation processes of the selected carbon offset projects

Interview questions for project participants in the selected in case studies

1. *What was your purpose to register the project as a carbon offset project?*

2. *Have you experienced any challenges throughout the carbon offset process? If yes, what kind of challenges did you experience?*

----

3. *From your perspective, how can we overcome these challenges?*

----

4. *How was the carbon offset project funded?*

----

5. *How much does it cost to register the carbon offset project, to monitor and verify the carbon credits?*

----

6. *How do you fund the upfront cost of the carbon offset process (monitoring and verification of carbon credits)?*

----

7. *What role do other project participant play if any in the project?*

----

8. How does the revenue of carbon credits help your business?

9. *How is the revenue of carbon credits distributed?*

----

10. How many people do you employ in the Wonderbag factory?

----

11. What is the proportion of women and men employed by the Wonderbag project?

----

12. Do you provide any training to your employees? If yes, what kind?

----

13. How long on average are your employees employed in the business?

----

14. Are there any skills people develop when they get involved in the project? If yes, what type of skills?

----

15. Is there anything else you would like tell me about the carbon offset project?

This is the end of our discussion. Thank you

A5 Household Questionnaires

Section 1: Pre-Interview and Consent

Introduction Hello, my name is [assistants name] and this is [my name]. We are doing a study for Jana Hofmann, who is a student at University of East Anglia, UK. May I speak to someone who is the head of the household or knows about the Solar Water Heater? Good day! Do you have about 40min to spare for our questions? We are doing some research on [state the project] and would like to find out about your experience with the [state technology]. May we ask you some questions about your household and questions about the [technology]? Your participation in this research study is voluntary and you can stop the interview at any time or withdraw from it if you do not feel comfortable. You do not need to answer a question if you do not want to. All answers will be kept confidential. There are no risks involved in your participation. Only researchers will know your name and your answers will be anonymised. If you have any questions, you can contact the researcher, [my name] at [telephone number] and [assistants name] at [telephone number]. We will disseminate the results of our study through a local leadership, who will then get in touch with you to tell you what we found. May I have your permission to start the questionnaire? Does the respondent agree to the survey? (CIRCULATE) Yes or No

Section 1: General Information

Date of the Interview:	
Time of the interview started:	
Time of the interview ended:	
Location (Street Number, Township Name):	

Name of the Participant:	Contact Tel Number:		
Gender:	Male	Female	
Ethnical group of the respondent: (NOTE: DO NOT READ OUT LOUD, SIMPLY MARK)	Black African Coloured	Indian/Asian White Not specified	
How many children under the age of 18 live in your house?	Number:		
How many adults live in your household?	Number:		
For the purpose of this survey, can I ask your age?	Number:		
What is your present marital status?	Married Single Divorced or separated	Widow/Widower Living together like husband and wife	Not applicable
What is your highest level of education?	No schooling Primary school (1-7) Secondary school (8-12)	Certificate/Diploma Degree (Bachelors, Masters) Other:	
Do you rent or own the house? (If Owned, go to Q10, otherwise skip 1 question)	Owned Rented	Other: Occupied rent-free	
How did you obtain the house?	Qualified for free house	Bought it	Other:
When did you move into the house?	Date:		
Section 1: General Information			
How many bedrooms do you have in the house?	One Bedroom 3 Bedrooms	*02* Bedrooms 4 +	
How would you describe your dwelling?	Freestanding house (RDP house) Freestanding house (extended RDP house) Free standing not RDP house		

NOTE: Please do not ask this question immediately. Mark the category that best describes the MAIN house. If not sure, please ask the question.	Flat or apartment in a block of flats Hostel Informal dwelling/shack in backyard Stand-alone informal dwelling/shack Room/flatlet not in backyard, but on a shared property Other:	
What materials are used to construct the main dwelling? DO NOT READ OUT LOUD: Observe	Cement block/Concrete/Brick Corrugated iron/zinc Wood	Mud (rural housing) Other:
What do you do for living? [Open Question]		
Do you work:	Full time Part-time Temporary / Seasonal Housewife/Househusband	Unemployed Retired Disabled Other:
What is the income category that best describes your household income per month? **NOTE:** If the household has multiple sources of income, please enter the TOTAL here.	No income R1 – R400 R401 – R800 R801 – R1 600 R1 601 – R3 200 R3 201 – R6 400	R6 401 – R12 800 R12 801 – R25 600 R25 601 or more Refuse to answer Do not know Other:
What is your household expenditure category per month?	No expenditure R1 – R199 R200 – R399 R400 – R799 R800 – R1 199 R1 200 – R1 799	R1 800 – R2 499 R 5000 – R 9 999 R 10 000 or more Do not know Refuse to answer Other:

Section 2: Wonderbag Questionnaire

Questions	Answers			
Which type of energy source do you mainly use for	**Cooking:**			
	Electricity	LPG Gas	Paraffin	Other:
	Lighting			
	Electricity	LPG Gas	Paraffin	Other:
	Heating			
	Electricity	LPG Gas	Paraffin	Other:
1. Are you the one who does most of the cooking in the household?	1. YES 2. NO			
02. How are you related to the head of the household (ABANDON THIS QUESTION)	1. Self (Household head) 2. Wife/Husband/Partner 3. Son/Daughter 4. Son/Daughter-in-Law 5. Mother/Father	6. Brother/Sister 7. Brother/Sister-in-law 8. Grandmother/Grandfather 10.Aunt/Uncle 11.Newphew/Niece 12.Other:		
3. Do you have a Wonderbag?	YES	NO		
02. Do you use it? **NOTE:** If Answer is NO, please go to 5, otherwise continue to 6.	1. YES	Why:		
	2. NO			
5. Why do you not use it?	It's broken I gave it away to: It was borrowed and never returned	I do not like it I do not know how to use it I lost it Other:		
6. What do you use the Wonderbag for?				
7. Since when do you have a Wonderbag?	Period (in months, years):			
8. How many Wonderbags do you have?	One Wonderbag Two Wonderbags	Three Wonderbags Three +		
9. What size is/was your Wonderbag?	Standard Wonderbag (3-12 liters) Baby Wonderbag (2 liters or less)	Catering Wonderbag (30 liters) Other:		
02. How did you obtain the Wonderbag?	1. Bought it	Price:		

	Borrowed from someone else Received as a gift from: Received it at the workshop organised by:	Cannot remember Other:
12. Does anyone else in your household use the Wonderbag?	1. Only myself (Household head) 2.Wife/Husband/Partner 3. Son/Daughter 4. Son/Daughter-in-Law 5. Mother/Father	6. Brother/Sister 7. Brother/Sister-in-law 8. Grandmother/Grandfather 9.Aunt/Uncle 10.Newphew/Niece 11.Other:
13. Did someone tell you how to use it?	1. YES	Who:
	2. NO	How did you learn how to use it? *[Explain]*
14. Was there a workshop/training organised about the Wonderbag in your area?	1. Yes	What type of workshop:
		Who organised:
		What did you learn:
	2. NO	
15. What do you like about the Wonderbag?		
16. Is there anything that you do not like about the Wonderbag? *[Open Question]*		
17. Is there anything that you would change about the Wonderbag?		

Section 6: Impact – Impact Assessment (Financial, Human, Social, Natural and Physical Capitals)

<table>
<tr><th>Questions</th><th colspan="5">Answers</th></tr>
<tr><td>1. How do you obtain your electricity?</td><td colspan="2">1. No electricity supply
2. Pre-paid</td><td colspan="2">3. Metered
4. Share/Borrow/Extension</td><td>Solar generators
6. Other:</td></tr>
<tr><td>02. What type of stove do use for cooking?</td><td colspan="4">Wood/Charcoal stove
Paraffin stove
Gas stove</td><td>Electric hot-plate (2 plates)
Electric stove (hob and oven)
Other:</td></tr>
<tr><td>3. When was the last time you used the Wonderbag?</td><td colspan="5"></td></tr>
<tr><td rowspan="2">4. Do you use the Wonderbag:</td><td colspan="2">More in Winter
Less in Winter</td><td colspan="2" rowspan="2">The same all year round</td><td>More in Summer
Less in Summer</td></tr>
<tr><td colspan="2">Explain why:</td><td>Explain why:</td></tr>
<tr><td rowspan="2">5. What meals do you cook with the Wonderbag?</td><td>Meals</td><td>How often:</td><td>How long do you use the stove before cooking a meal in the Wonderbag (in minutes):</td><td>How long does it take you to cook these meals on the stove (from start to finish)?</td><td>What energy sources do you use, to cook these meals (from start to finish)?</td></tr>
<tr><td>1.
2.
3.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>6. What do you do when the meal is cooking in the Wonderbag?</td><td colspan="5"></td></tr>
<tr><td rowspan="2">7. How much water do you use for these meals when you cook on the stove only?

(in regular cups or standard kettle size 1.5l or 1.7l)</td><td colspan="3">Meals:</td><td colspan="2">Any water added to the meals while cooking on the stove? How much?</td></tr>
<tr><td colspan="3">1.
2.</td><td colspan="2"></td></tr>
<tr><td>8. Does your household have a water bill in your household?</td><td colspan="5">Yes
No, why not:</td></tr>
<tr><td>9. How much do you pay for water per month?</td><td colspan="5">In Rand:</td></tr>
</table>

10. Have you noticed any difference in your water bill since using the Wonderbag?	1. YES	What is different *[Explain]:*			
	2. NO	Why not *[Explain]*:			
11. **Electricity users:** Do you know how much electricity do you typically use: (50units/KWh are free)		2. Per month: (units/KWh)		3. Do not know	
12. How much do you typically spend on electricity a month?		In Rand:			
13. Does your electricity use vary across seasons i.e. winter and summer?	1. YES	1.1. Winter: How much?		1.2 Summer: How much?	
	2. NO				
14. How long does the pre-paid electricity typically last you?	Exactly a month	Longer than a month		Less than a month	Other:
15. If you run out of electricity at the end of the month, what do you do?	Buy more How much:	Wait until next month	Change to other fuel sources		Other:
			Which one:		
16. Do you notice any difference in your monthly electricity consumption since using the Wonderbag?	1. YES	What is different *[Explain]*:			
	2. NO	Why no difference *[Explain]*:			
17. Since using the WB, does the monthly electricity last you typically	Longer than a month		Less than a month	No difference	
18. Do you notice any difference in your monthly electricity payments since using the Wonderbag?	1. YES	What is different *[Explain]:*			
	2. NO	Why no difference *[Explain]*:			
19. Since using the WB, do you typically top up electricity	More often	Less often	No difference		
20. **Gas users**: Do you know how much gas do typically you use:		1. For cooking:	2. Per month: (kg/cylinder)	3. Do not know	
21. How much do you typically spend on gas a month?		In Rand:			
22. Does your gas use vary across seasons i.e. winter and summer?	1. YES	1.1. Winter: more/less		1.2. Summer: more/less	
	2. NO				

23. How long does the gas cylinder last you?	Exactly one month	More than one month		Less than one month	Other:
24. If you run out of gas at the end of the month, what do you do?	Buy more How much:	Wait until next month	Change to another fuel source Which one:		Other:
25. Do you notice any difference in your monthly gas consumption since using the Wonderbag?	1. YES	What is different *[Explain]*:			
	2. NO	Why no difference *[Explain]*:			
26. Since using the WB, does the gas cylinder last you:	Longer than a month	Less than a month		No difference	
27. Do you notice any difference in your monthly gas payments since using the Wonderbag?	1. YES	What is different *[Explain]*:			
	2. NO	Why no difference *[Explain]*:			
28. Since using the WB, do you typically buy gas:	More often	Less often		No difference	
29. **Paraffin users:** Do you know how much paraffin do you typically use:		1. For cooking	2. Per month (kg/cylinder):	3. Do not know	
30. How much do you typically spend on paraffin a month?		In Rand:			
31. Does your paraffin use vary across seasons i.e. winter and summer?	1. YES	1.1. Winter: more/less	1.2. Summer: more/less		
	2. NO				
32. How long does the paraffin typically last you?	Exactly one month	More than one month	Less than one month	Other:	
33. If you run out of paraffin at the end of the month, what do you do?	Buy more	Wait until next month	Change to another fuel source	Other	
	How much:		Which one:		
34. Do you notice any difference in your monthly paraffin consumption since using the Wonderbag?	1. YES	What is different *[Explain]*:			
	2. NO	Why no difference *[Explain]*:			
35. Since using the WB, does the paraffin last you:	Longer than a month	Less than a month	No difference		
	1. YES	What is different *[Explain]*:			

36. Do you notice any difference in your monthly paraffin payments since using the Wonderbag?			
	2. NO	Why no difference *[Explain]*:	
37. Since using the WB, do you typically buy paraffin	More often	Less often	No difference
40. From your experience, do you save any money from the Wonderbag every month? *[Open Question]*	1. YES	How much:	
		What energy source:	
		How do you use your saved money?	
	2. NO	Why not *[Explain]:*	
41. Do you experience a regular blackout in electricity? **NOTE:** If Answer is Yes, please go to 42, otherwise continue with 44	1. YES	How long for:	
	2. NO		
42. How do you cook during the electricity blackout?	I change to paraffin I change to gas I do not cook / I get take-away	I cook with the Wonderbag I wait for the electricity to come back on Other:	
43. Have you experienced any accidents/burns while cooking?	1. YES		
	2. NO		
44. Do you have any problem with smoke inside your home while cooking? **NOTE:** If Answer is YES, please go to 45, otherwise continue with 47.	Yes	2. No	
45. How does the smoke affect your health? **NOTE:** If Answer is YES, please go to 47, otherwise continue 47	Stinging eyes Headache Cough Makes kitchen dirty	Difficulty in breathing Other: Does not effect my health	

46. Do you notice any difference in smoke in the house when using the Wonderbag?	1. YES	What is difference:	
	2. NO		
47. From your experience how important is the Wonderbag for your household? Explain	Extremely important Very important Important Somewhat important Not at all important		Explain why:
48. Do you talk about your Wonderbag experience to other people in the area?	1. Yes	Who do you talk to:	
		What about:	
	2. No		
49. If the Wonderbag breaks, what do you do with it? *[Open Question]*			
50. Is there anything else you could tell us about your experience with the Wonderbag?			

Solar Water Heater Questionnaire

Questions	**Answers**						
	Cooking						
What energy source do you mainly use for:	Electricity	Gas	Paraffin	Coal	Wood	Other:	
	Lighting						
	Electricity	Gas	Paraffin	Coal	Wood	Other:	
	Heating						
	Electricity	Paraffin	Wood	Candles	Other:		
How did you get the Solar Water Heater in your house? (If Installed for free, go to Q2.1-Q2.2, otherwise go to Q3)	Installed for free						
	SWH was already there, when moved in						
2.1 When did you receive the Solar Water Heater?	Date:						
2.2 Who installed the Solar Water Heater?							
Is your Solar Water Heater working?	YES	NO (If NO, go to PAST-USER SECTION)					
What do you use hot water from the geyser for? (if one or to options only, ask why not the others	Washing clothes	Washing dishes	Cooking	Bathing	Cleaning the house	Making Tea/ Coffee	Other:
How often do they use hot water from the geyser per day?	1-2 times per day	3-4 times per day	5 or more times per day	As needed			
At what times do you usually use hot water from the SWH?	5-8 a.m.	8-12 a.m.	12 -3 p.m.	3-7 p.m.	7-9 p.m.		
Is there anyone else in your house who also uses hot water from the SWH?	YES	WHO	What for:				
	NO						
How often do they use hot water from the SWH per day?	1-2 times per day	3-4 times per day	5 or more times per day	As needed			
At what times do they usually use hot water from the SWH?	5-8 a.m.	8-12 a.m.	12 -3 p.m.	3-7 p.m.	7-9 p.m.		
While having the geyser, do you still boil water? (If YES, go to Q14, otherwise continue)	YES	NO					

What do you boil the water with?	Electricity (electric stove)	Electricity (electric kettle)	Gas stove	Paraffin stove	Other:		
What do you usually use boiled water for?	Washing clothes	Washing dishes	Cooking	Bathing	Cleaning the house	Making Tea/Coffee	Other:
How many times do you boil water per day?	1-2 times per day	3-4 times per day	5 or more times per day	As needed			
What are the things that you like about the geyser?	YES	How:					
	NO						
Is there anything you have experienced that you do not like about the SWH?	[Explain]:						
Have you had any problem(s) with the SWH?	YES	What problem(s):					
	NO						
When did you start having a problem with the SWH?	Date:						
How long have you had the problem(s) for?	Period:						
Did the problem affect your everyday life?	YES	HOW:					
	NO						
Did you fix the problem(s)?	YES	HOW:					
	NO, the problem persists						

Impact – Impact Assessment (Financial, Human, Social, Natural and Physical Capitals)

Questions	Answers			
Seasonality/ Water/Energy consumption				
Do you notice any difference in water temperature coming from the geyser in Winter and Summer? (If YES, go to Q2, otherwise continue)	YES	Winter:	Summer:	
	NO			
How do you manage the water in this situation?	*[Explain]*			
How much water from the geyser do you use in:	Winter:	Summer:	The same all year round	Do not notice
How much water do you need for one bath:	Using boiled and cold water	Using the SWH	Do not know	Do not notice
Do you use:	A bathtub	A bucket		
Do you have a water bill in your household?	Yes			
	No	Why not:		
How much do you pay for water per month?	In Rand:			
Do you notice any difference in your water bill when using the Solar Water Heater?	YES	What is different:		
	NO			
	Do not know			
If you only use boiled and cold water for bathing, how often do you bath per day?	Frequency: (find out if it is less, more or the same as with the SWH)			
How do you obtain your electricity?	Pre-paid No electricity supply	Metered Share/Borrow/Extension	Solar generators Other:	
How much do you usually pay for electricity per month/per week/per day?	In Winter (in Rand):	In Summer (in Rand):	Do not know	
Do you notice any difference in your electricity payments when you use the geyser?	YES	What is different:		
	NO§			
	Do not know			
Do you experience any blackouts of electricity? (If YES, go to Q19-Q20, otherwise continue)	YES			
	NO			
How often does it happen? (e.g. once a month/a week/a day)	Period:			

How long does the blackout last?	Period:					
How do you manage having hot water in your house if the electricity is not available?	Change to paraffin	Change to gas	Change to wood	*Other:*	Do nothing	
Do you have any smell in the house when you boil water using paraffin / gas?	YES					
	NO					
Does the smell effect your health?	YES	HOW				
	NO					
Do you have any smoke when you use wood to boil water?	YES					
	NO					
Does the smoke affect your health?	YES	HOW				
	NO					
Do you experience any water cuts? (If YES, go to Q22-Q20, otherwise continue)	YES					
	NO					
How often does it happen? (e.g. once a month/a week/a day)	Period:					
How do you manage water in your house in this situation?	*[Explain]*					
How long does it take you to: (If time is saved, go to Q23)	Bath with the SWH (in min):	Boil, mix water and bath (in min):	Do not know	Do not notice		
By having regular hot water from the geyser, do you notice any difference in your health and well-being? (e.g. any improvements or deterioration in health?)	YES	What difference:				
	NO	Why not:				
	Do not know					
Have you or your family members experienced any burns/accidents when boiling water for bathing?	YES	*[Explain]:*				
	NO					
Have you experienced any accidents/burns with the Solar Water Heater?	YES	What kind:				
	NO					
Do you feel safe having the Solar Water Heater on the roof now that you lived with it for some time?	YES					
	NO	*[Give Reasons]:*				
Do you maintain your Solar Water Heater? E.g clean it from time to time (If NO, go to Q30, otherwise continue)	YES	How:	How often:			
	NO					
Do you know how to maintain/clean it?	YES	How:				

	NO	
Is there anyone in your household who benefits from the geyser the most?	Who:	
	Why	
	Do not know	
What do people think about the Solar Water Heaters in your area? (e.g. anything they talk about?)	[Explain]:	
	Do not know	
Do you know anyone is this area who did not receive the Solar Water Heater?	YES	Who:
	NO	
Why did they not receive the solar water heater?	Reason:	
	Do not know	
By having the Solar Water Heater on the roof, do you anticipate your house: (If Increase/Decrease got to Q35.1, otherwise continue)	To increase in value	[Reason]
	To decrease in value	[Reason]
	To make no difference in value	
	Do not know	
35.1 How much do you think your house would increase or decrease in value approximately?	In % or Rand:	Do not know
Is there anything else you could tell us about your experience with the Solar Water Heater?		

Basa Magogo Questionnaire

Questions	Answers				
Vulnerability Assessment					
What type of fuel source do you mainly use for:	**Heating:**				
	Coal	Gas	Paraffin	Solar	
	Electricity	Wood	Dung	Other:	
	Cooking:				
	Coal	Gas	Paraffin	Solar	
	Electricity	Wood	Dung	Other:	
2. What type of a device do you make coal fire in?	1. Brazier	2. Welded stove	3. Cast iron stove	4. Fireplace	5. Other:
3. Could you tell me where do you usually make a coal fire?	1. Separate room/kitchen	2. Outdoors/Open area		3. Both (kitchen and outdoors)	
4. Who makes fire in your house?	Myself Wife/Husband/Partner Son/Daughter Son/Daughter-in-law	Mother/Father Mother/Father-in-law Brother/Sister Brother/Sister-in-law		Grandmother/Grandfather Aunt/Uncle Nephew/Nice Other:	
02. How do you make your coal fire?	Explain:				
6. Have you heard about the Basa Magogo technique (new top-up approach)? If Answer is YES, continue with questions. If NO, close the interview.	1. YES	Who from:			
	2. NO				
7. How did you learn how to use Basa Magogo technique?					
8. Do you use Basa Magogo technique?	1. YES	How often do you make fire per day:			
	2. NO	Why not:			

9. When did you start using Basa Magogo technique?	Date:		
10. When was the last time you made your coal fire in BM way?	Date:		
02. Why did you use the new technique such a long time ago? (ONLY ASK if fire was made long time ago with BM technique)	Explain:		
12. Why do you like Basa Magogo technique?			
13. Do you still make your coal fire using the traditional technique? (If Answer is YES, ask Question 14, otherwise continue)	1. YES	How often (per day):	
		What purpose:	
	2. NO		
14. Why do you like using the traditional technique?			
15. Have you experienced any problems making coal fire in Basa Magogo style?	1. YES	What problems:	
	2. NO		
16. How do others in your family make the coal fire?	1. Use old technique		2. Use Basa Magogo method
17. How often do they make fire?	Per day/per week:		
02. Did they hear about the BM method? (Ask only if old method is used) (If Answer is YES, go to Question 17)	1. YES	Who from:	
	2. NO		
17. Why do they not use the BM method?	Explain:		
02. How did they learn how to use the BM method? (Ask only if BM method is used)	Explain:		

Impact – Impact Assessment

<table>
<tr><th>Questions</th><th colspan="3">Answers</th></tr>
<tr><td>02. How do you get coal for your household?
(if Answer is 3, please go to Question 2, otherwise continue)</td><td>Buy from:</td><td>Collect from:</td><td>3. Buy and collect</td></tr>
<tr><td>2. What is your proportion of buying and collecting coal?</td><td>1. More coal collected</td><td>2. Half-half</td><td>3. More coal bought</td></tr>
<tr><td>3. Who in your household is responsible for getting coal?</td><td>Myself
Wife/Husband/Partner
Son/Daughter
Son/Daughter-in-law
Mother/Father
Mother/Father-in-law</td><td>Brother/Sister
Brother/Sister-in-law
Grandmother/Grandfather
Aunt/Uncle
Nephew/Nice</td><td>12. Shared responsibility between:</td></tr>
<tr><td colspan="4">Current Basa Magogo Users</td></tr>
</table>

<table>
<tr><td>1. In what form do you buy coal?</td><td>1. Big bag</td><td>2. Small bag</td><td>3. Tin</td><td>4. Large drum</td><td>5. Other:</td></tr>
<tr><td>2. How much does a unit of coal cost? (big, small bag etc.)</td><td colspan="5">Price: (in Rand)</td></tr>
<tr><td rowspan="2">3. How much coal do you usually use to make a fire?</td><td colspan="2">Using BM method</td><td colspan="3">Using old technique</td></tr>
<tr><td colspan="2">in Litres:</td><td colspan="2">in Litres</td><td>cannot remember</td></tr>
<tr><td rowspan="3">02. How many bags of coal do you usually buy?
(per week, per month, as needed)</td><td colspan="2">Using BM method</td><td colspan="3">Using old technique</td></tr>
<tr><td>Number:
(in liters)</td><td>How often:</td><td>Number:
(in liters)</td><td>How often:</td><td rowspan="2">cannot remember</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">02. How much do you spend on coal:
(per week, per month, as needed)
(DO NOT ASK, CALCULATE YOURSELF)</td><td colspan="2">Using BM method</td><td colspan="3">Using old technique</td></tr>
<tr><td colspan="2">In Rand:</td><td colspan="2">In Rand:</td><td>cannot remember</td></tr>
<tr><td rowspan="2">6. Do you notice any difference in terms of money you spend on coal since you started using the BM technique?</td><td>1. YES</td><td colspan="4">What difference:</td></tr>
<tr><td>2. NO</td><td colspan="4">Why not:</td></tr>
<tr><td>7. How do you use the saved money? What do you do with your savings?</td><td colspan="5">Explain:</td></tr>
<tr><td></td><td colspan="2">Using BM method</td><td colspan="3">Using old technique</td></tr>
</table>

8. Once you light up the fire, how long does it take for the stove/brazier to heat up? (best estimate in minutes)					Cannot remember
9. How long does the heat last?	**Using BM method**		**Using old technique**		
					Cannot remember
02. Do you have any problems with smoke in the house? (If Answer is YES, go to 11, otherwise continue)	**Using BM method**		**Using old technique**		
	1. YES	2. NO	1. YES	2. NO	Cannot remember
11. Does the smoke effects your health? (e.g. coughing, stinging eyes, headache, difficulty in breathing)	1. YES	HOW:			
	2. NO				
12. How often do you make fire in Winter per day?					
13. How many bags of coal do you usually buy in Winter? (per week, per month, as needed)	**Using BM method:**		**Using old technique:**		
	Number: (in litres)	How often:	Number: (in litres)	How often:	Cannot remember
14. What is the price of coal in	In Winter: (in Rand)			in Summer: (in Rand)	
15. If the price for coal goes up, does this change the amount of coal you use?	1. YES	HOW:			
	2. NO	Why not:			
16. If the price for coal goes up, do you use any alternative fuel instead of coal?	1. YES	What alternative:			
	2. NO				
17. Do you hear people talking about BM technique in your area?	1. YES	Who:			
		What about:			
	2. NO				
18. Do you talk about BM method to others?	1. YES	Who:			
		What about:			
	2. NO				
19. Is there anything else you could tell us about your experience with the BM technique?	Explain:				

Brickstar Wood Stove Questionnaire

Questions	**Answers**					
Which type of energy source do you mainly use for:	Cooking:					
	Electricity	LPG Gas	Paraffin	Coal	Wood	Other:
	Lighting					
	Electricity	LPG Gas	Paraffin	Coal	Wood	Other:
	Heating					
	Electricity	LPG Gas	Paraffin	Coal	Wood	Other:
How did you get the wood stove in the house?						
When did you get the wood stove?	Date:					
Where did you get bricks from?	*Explain:*					
Did you spend any money on bricks?	YES	How much:				
	NO					
What material did you use to make the bricks?	*Explain:*					
Where did you get the material?	*Explain:*					
Did someone tell you how to use the stove?	YES	Who:				
	NO	How did you learn how to use the stove:				
Do you use your wood stove?	YES			NO		
When was the last time you used the wood stove?	Date:					
What do you use the wood stove for?	Cooking	Boiling water for:		Space Heating	Other:	
How often do you use the wood stove: If the wood stove is not used daily, please go to Q13 and continue If the wood stove is used daily, please go to Q14, otherwise continue	Every day/per week/per month/as needed:					
How often do you cook?	Per day:					
Why do you not use the wood stove daily?	*Give Reason:*					

Is there anyone else apart from you who also cook in the house?	YES	Who:				
	NO					
What does this person use for cooking?	Electric stove	Electric 2 plate	Wood stove	LPG Gas stove	Other:	
How often does this person cook?	Every day/per week/per month/as needed:					
What is it that you like about the wood stove?	Explain:					
Is there anything you do not like about the wood stove?	*Explain:*					
How do you use the wood stove in winter and summer? E.g. is there any difference?	Winter (every day/week/month):					
	Summer (every day/week/month):					
Have you had any problems with the wood stove? If YES, please go to Q22-24	YES	What kind:				
	NO					
When did you start having a problem?	Date:					
Have you tried to fix the problem?	YES	HOW:				
	NO	Why not:				
How did you cook before having the wood stove?	Use electric stove	Use electric 2 plates	Use LPG gas stove	Use paraffin stove	Use open fire	Other:
Do you still use this stove? If Yes, go to Q27	YES			NO		
What do you use the stove for?	Cooking	Boiling water	Warming up food	Other:		
How often do you use the stove?	Every day/per week/per month/as needed:					
Why do you like using the electric/gas/ stove?						
Do you use the wood stove and the electric/LPG gas stove at the same time?	YES	NO	Not applicable			
How often do you use them at the same time?	Every day/per week/per month/as needed:					
In what situations do you use them at the same time?	Explain:					
Do you still use the open fire?	YES	NO				
What do you use the open fire for?	Cooking	Boiling water	Ceremonies/Funeral/Parties	Other:		
How often do you use the open fire?	Every day/per week/per month:					

Why do you like using the open fire?	Explain:		
Do you use the wood stove and the open fire at the same time?	YES	NO	Not applicable
How often do you use them at the same time?	Every day/per week/per month/as needed:		
In what situations do you use them at the same time?	Explain:		

Impact – Impact Assessment (Financial, Human, Social, Natural and Physical Capitals)

Questions	**Answers**				
Where do you usually cook?	Inside the house	Extended room of the house	Outside kitchen	Outdoor in a permanent structure	Other:
What do you use to start the fire in the wood stove?	*Explain:*				
How do you get the wood? If 'Buy and collect firewood', go to Q4, otherwise continue.	Buy wood	Collect wood	Buy and collect wood		
What is your proportion of buying and collecting wood?	More wood collected	Half-half	More wood bought		
If wood collected, how many times do you collect the wood?	Every day/per week/per month/as needed:				
How much wood do you usually collect?	Load/wheelbarrow/bundle:				
How long does the wood last you?	Period:				
How far do you need to go to collect the wood?	Distance (in km):				
Who in your family usually collects the wood?					
Do you face any challenges when collecting the wood?	YES	What kind:			
	NO				
How did you get the wood before having the wood stove?	Buy wood	Collect wood			
How many times did you collect the wood, before having the wood stove? If there is any difference in wood collection frequency, go to Q13	Every day/per week/per month/as needed:				
How much wood did you collect before having the wood stove	Load/wheelbarrow/bundle:				
What do you do now that you do not need to collect the wood that often?	Explain:				
If wood bought, How much does it cost you to buy the wood?	Price/load:				
Where do you buy the wood?	*Explain:*				
How long does the wood last you?	Period:				
How many times did you buy the wood before having the wood stove?	Per month/per year/ as needed:				

How much wood did you buy before having the wood stove?	Load/wheelbarrow:					
Have you noticed any difference in your spending for wood when you use the wood stove? If Answer is YES, please go to Q21, otherwise continue	YES	What difference:				
	NO					
What do you use the spare money for?	*Explain:*					
How many pieces of wood do you use to make a fire using:	Wood stove	Open fire				
What meals do you usually cook with the wood stove?						
How long does it take you on average to cook these meals on: If there is any time saving, please go to Q25, otherwise continue	Wood stove (in min/hours):	Open fire (in min/hours):	Electric stove (in min/hours):			
What do you do with your spare time now?	*Explain:*					
How do you obtain electricity in your house?	Pre-paid No electricity supply	Metered Share/Borrow/Extension	Solar generators Other:			
How much do you pay for electricity per week/ per month?	In Rand/month:					
How much did you pay for electricity before you had the wood stove?	In Rand/month:					
Have you noticed any difference in your electricity payments since you started using the wood stove? If Answer is YES, please go to Q30, otherwise continue	YES	What difference:				
	NO					
What do you use the saved money for?	*Explain:*					
Do you experience any blackouts of electricity? If YES, go to Q32-Q34, otherwise continue	YES	NO				
How often does it happen?	Period (per week/month):					
How long does the blackout last?	Period					
How do you cook during this time?	Use paraffin stove	Use LPG gas stove	Use wood stove	Use open fire	Do nothing	Not applicable
How much do you pay for LPG Gas?	In Rand/kg:					
How often do you buy LPG Gas?	Period (per month/year):					

How often did you buy the LPG Gas before having the wood stove?	Period (per month/year):				
Do you notice any difference in your LPG Gas spending since you started using the wood stove?	YES	What difference:			
	NO				
What do you use the saved money for?	Explain:				
How do you obtain water? If water is bought, please go to Q41-46	From the tap on my stand		Collect water from the communal borehole	Buy water	Have a borehole
How much does it cost you to buy the water?	In Rand:				
How much water do you buy?	Amount:				
How often do you buy water?	Per day/week/month:				
Who do you buy the water from?	Explain:				
Have you noticed any impact on water when you use the wood stove? (e.g. is there any difference?)	YES	What is different:			
	NO				
When you finish cooking, do you switch off the fire in the wood stove? If YES, go to Q47-49, otherwise continue	YES				NO
How do you switch off the fire in the wood stove?	Explain:				
How much water do you use to switch off the fire in the wood stove?	In cups/jug:				
When you use the open fire, do you use any water to switch off the open fire?	YES	How much: (in litres):			
	NO				
Do you maintain or look after your wood stove? If YES, please go to Q51-53, otherwise continue If NO, please go to Q55, otherwise continue	YES	How:			
	NO				
How often do you maintain the wood stove?	Per week/per month:				
How long does it take for the wood stove to dry?	Period:				
How do you cook during this time?	Explain:				
Do you know how to maintain or look after your wood stove?	YES	How:			
	NO				
Do you have any smoke when using the open fire?	YES				
	NO				
Does the smoke affect your health?	YES	How:			

	NO	
Have you noticed any difference in smoke when you use the wood stove?	YES	What difference:
	NO	
Do you feel safe using the wood stove?	YES	
	NO	Why not:
Have you experienced any accidents/burns when using the wood stove?	YES	What kind:
	NO	
Have you experienced any accidents/burns when cooking on the open fire?	YES	What kind:
	NO	
Has anyone in your household experienced any accidents/burns when cooking on the open fire?	YES	What kind:
	NO	
What do people think about the wood stove in your area? (e.g. anything they talk about?)	Explain:	
	Do not know	
Is there anyone in your neighbourhood, who does not have the wood stove?	YES	Who:
	NO	
Why do they not have the wood stove?	Explain	
	Do not know	
Is there anything else you could tell us about your experience with the wood stove?	*Explain:*	

A6 Full list of carbon offset projects

CDM carbon offset projects

Title	Host country	Status	Project type	Project size	Date of registration	Total issuance (kCERs) 2008-2021
Kuyasa low-cost urban housing energy upgrade project, Khayelitsha (Cape Town; South Africa)	South Africa	Registered	EE households	Small-scale	27-Aug-05	10
Lawley Fuel Switch Project	South Africa	Registered	Fossil fuel switch	Large-scale	06-Mar-06	188
Rosslyn Brewery Fuel- Switching Project	South Africa	Registered	Fossil fuel switch	Large-scale	29-Sep-06	
PetroSA biogas to energy	South Africa	Registered	Methane avoidance	Small-scale	29-Sep-06	33
Durban Landfill-gas-to-electricity project – Mariannhill and La Mercy Landfills	South Africa	Registered	Landfill gas	Large-scale	15-Dec-06	355
Omnia Fertilizer Limited Nitrous Oxide (N2O) Reduction Project	South Africa	Registered	N2O	Large-scale	03-May-07	3440
Tugela Mill Fuel Switching Project	South Africa	Registered	Biomass energy	Small-scale	12-Feb-07	105
EnviroServ Chloorkop Landfill Gas Recovery Project.	South Africa	Registered	Landfill gas	Large-scale	27-Apr-07	1194
Sasol Nitrous Oxide Abatement Project	South Africa	Registered	N2O	Large-scale	25-May-07	4340
Mondi Richards Bay Biomass Project	South Africa	Registered	Biomass energy	Large-scale	20-May-07	
Transalloys Manganese Alloy Smelter Energy Efficiency Project	South Africa	Registered	EE industry	Large-scale	19-Oct-07	649
Project for the catalytic reduction of N2O emissions with a secondary catalyst inside the ammonia reactor of the No. 9 nitric acid plant at African Explosives Ltd ("AEL"), South Africa	South Africa	Registered	N2O	Large-scale	05-Nov-07	348
N2O abatement project at nitric acid plant No. 11 at African Explosives Ltd. (AEL), South Africa	South Africa	Registered	N2O	Large-scale	08-Feb-08	2376
Kanhym Farm manure to energy project	South Africa	Registered	Methane avoidance	Small-scale	18-Jul-08	
Durban Landfill-Gas Bisasar Road	South Africa	Registered	Landfill gas	Large-scale	26-Mar-09	1540
Alton Landfill Gas to Energy Project	South Africa	Registered	Landfill gas	Small-scale	24-Aug-09	
Bethlehem Hydroelectric project	South Africa	Registered	Hydro	Small-scale	08-Oct-09	205
Fuel switch project on the Gluten 20 dryer of Tongaat Hulett Starch Pty (Ltd) Germiston Mill	South Africa	Registered	Fossil fuel switch	Small-scale	25-Dec-10	
Ekurhuleni Landfill Gas Recovery Project – South Africa	South Africa	Registered	Landfill gas	Large-scale	26-Oct-10	63
The Capture and Utilisation of Methane at the GFI Mining South Africa owned Beatrix Mine in South Africa	South Africa	Registered	Fugitive	Large-scale	10-Jun-11	90
Nelson Mandela Bay Metropolitan's Landfill Gas Project	South Africa	Registered	Landfill gas	Large-scale	24-May-12	
Use of waste gas at Namakwa Sands in South Africa	South Africa	Registered	EE own generation	Large-scale	18-Dec-12	285
Omnia N2O Abatement Project II	South Africa	Registered	N2O	Large-scale	30-Apr-12	1696
IFM Integrated Clean Energy Project	South Africa	Registered	EE own generation		24-Jun-13	
Joburg Landfill Gas to Energy Project	South Africa	Registered	Landfill gas	Large-scale	12-Nov-12	346
Bokpoort CSP (Concentrating Solar Power) Project, South Africa	South Africa	Registered	Solar	Large-scale	26-Oct-12	340

North West, KwaZulu-Natal & Eastern Cape CFL Replacement Project (2) in South Africa	South Africa	Registered	EE households	Large-scale	11-Dec-12	
Lomati Biomass Power Generation Project in Mpumalanga Province	South Africa	Registered	Biomass energy	Small-scale	20-Dec-12	
Gauteng, Free State, Mpumalanga, Limpopo & Northern Cape CFL Replacement Project (1) in South Africa	South Africa	Registered	EE households	Small-scale	10-Oct-12	
Prieska Grid Connected 20 MW Solar Park, South Africa	South Africa	Registered	Solar	Large-scale	05-Dec-12	
Kathu Grid Connected 100 MW Solar Park, South Africa	South Africa	Registered	Solar	Large-scale	13-Dec-12	
Neusberg Grid Connected Hydroelectric Power Plant, South Africa	South Africa	Registered	Hydro	Small-scale	05-Nov-12	
Amakhala Emoyeni Grid Connected 138.6 MW Wind Farm, Phase 1, South Africa	South Africa	Registered	Wind	Large-scale	31-Dec-12	
De Aar Grid Connected 10 MW Solar Park, South Africa	South Africa	Registered	Solar	Small-scale	22-Oct-12	
Red Cap Kouga Wind Farm	South Africa	Registered	Wind	Large-scale	10-Oct-12	
Hopefield wind energy facility in South Africa	South Africa	Registered	Wind	Large-scale	14-Nov-12	
Dundee Biogas Power (Pty) Ltd	South Africa	Registered	Methane avoidance	Small-scale	15-Nov-12	
Karoo Renewable Energy Facility (Nobelsfontein Wind)	South Africa	Registered	Wind	Large-scale	14-Nov-12	
Dassieklip Wind Energy Facility in South Africa	South Africa	Registered	Wind	Large-scale	23-Nov-12	
Karoo Renewable Energy Facility (Nobelsfontein Solar PV)	South Africa	Registered	Solar	Large-scale	14-Nov-12	
Cookhouse Wind Farm in South Africa	South Africa	Registered	Wind	Large-scale	24-Dec-12	
Rheboksfontein Wind Energy Facility	South Africa	Registered	Wind	Large-scale	13-Dec-12	
Manufacture and utilization of bio-coal briquettes in Stutterheim, South Africa	South Africa	Registered	Biomass energy	Large-scale	22-May-14	
Grahamstown Invasive Biomass Power Project	South Africa	Registered	Biomass energy	Small-scale	27-Dec-12	
West Coast 1 Wind Farm in South Africa	South Africa	Registered	Wind	Large-scale	13-Dec-12	
Samancor Chrome Middelburg Electricity from Waste Gas	South Africa	Registered	EE own generation	Large-scale	12-Dec-12	
Samancor Chrome Witbank Electricity from Waste Gas	South Africa	Registered	EE own generation	Large-scale	12-Dec-12	
SA Calcium Carbide Furnace Waste Gas to Electricity CDM Project	South Africa	Registered	EE own generation	Large-scale	31-Dec-12	
TWE Golden Valley Wind Power Project	South Africa	Registered	Wind	Large-scale	31-Dec-12	
Coega IDZ Windfarm	South Africa	Registered	Wind	Large-scale	24-Dec-12	
Hernic's Electricity Generation from Waste Gas Project	South Africa	Registered	EE own generation	Large-scale	15-Jul-13	
Distributed Energy Generation's Waste Heat to Power Project at XAWO	South Africa	Registered	EE own generation	Large-scale	27-Dec-12	
Tongaat Hulett Sugar Refinery Steam Optimisation Project	South Africa	Registered	EE industry	Large-scale	28-Dec-12	
Installation of energy efficient ventilation fans at South Deep and Beatrix Gold Mines in South Africa	South Africa	Registered	EE industry	Small-scale	28-Dec-12	
Trigeneration at Mobile Telephone Networks (MTN), 14th Avenue Commercial Site South Africa	South Africa	Registered	EE service	Small-scale	29-Dec-12	
Fuel Switch at Corobrik's Driefontein Brick Factory in South Africa	South Africa	Registered	Fossil fuel switch		20-Dec-14	
ACP Thermal Harvesting™ Project	South Africa	Registered	EE own generation		30-May-17	
Total						**17 602**

Programme of Activities – CDM

Title	Host country	Status	PoA-Type	Sub-type	Project size	Date of registration	POA Lifetime	Total number of PoAs	Total issuance (kCERs) 2014-2021
SASSA Low Pressure Solar Water Heater Programme	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	12-Mar-11	28	1	99
SASSA Low Pressure Solar Water Heater Programme – CPA- 001	South Africa	Registered		Solar water heating					83
SASSA Low Pressure Solar Water Heater Programme – CPA- 002	South Africa	Registered		Solar water heating					16
SASSA Low Pressure Solar Water Heater Programme – CPA- 003	South Africa	Registered		Solar water heating					0
SASSA Low Pressure Solar Water Heater Programme – CPA-004	South Africa	Registered		Solar water heating					0
SASSA Low Pressure Solar Water Heater Programme – CPA-005	South Africa	Registered		Solar water heating					0
SASSA Low Pressure Solar Water Heater Programme – CPA-006	South Africa	Registered		Solar water heating					0
SASSA Low Pressure Solar Water Heater Programme – CPA-007	South Africa	Registered		Solar water heating					0
LED's kick-off	South Africa	Registered	EE households	Lighting in service	Small-scale	05-Dec-12	28	1	0
CPA0001 "Mining retrofit"	South Africa	Registered		Lighting in service					0
ETA Solar Water Heater Programme in South Africa	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	25-Jul-12	28	1	0
Nelson Mandela Bay Municipality Solar Water Heating Project – NMBM CPA - 001	South Africa	Registered		Solar water heating					0
Cogeneration and/or trigeneration at commercial sites.	South Africa	Registered	EE service & supply side	Cogeneration	Small-scale	31-Dec-12	28	1	0
Cogeneration and/or trigeneration at commercial sites, number 001, Centurion.	South Africa	Registered		Cogeneration					0
Standard Bank Energy Efficient Commercial Lighting Programme of Activities	South Africa	Registered	EE service & supply side	Lighting in service	Small-scale	05-Aug-13	28	1	0
Standard Bank of South Africa – Head Office lighting refurbishment (SBSA-EECL-CPA-0001)	South Africa	Registered		Lighting in service					0
Southern Africa Solar Thermal Energy (SASTE) Programme	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	15-May-13	28	1	0
Southern Africa Solar Thermal Energy (SASTE) Programme – Ellies Gauteng SSC-CPA	South Africa	Registered		Solar water heating					0

Sustainability CFL Replacement Programme of Activities in South Africa	South Africa	Registered	EE households	Lighting	Small-scale	19-Dec-12	28	1	0
CLF Replacement Project Western Cape - CPA-01	South Africa	Registered		Lighting					0
Anaerobic Digestion and Renewable Energy Generation in South Africa	South Africa	Registered	Methane avoidance	Manure	Small-scale	22-Aug-13	28	1	0
CPA FSCAD001 – Under the PoA "Anaerobic Digestion and Renewable Energy in South Africa"	South Africa	Registered		Manure					0
Southern African Renewable Energy (SARE) Programme	South Africa	Registered	Wind and solar	Solar & wind & other	Large-scale	25-Jan-13	28	1	0
Southern African Renewable Energy (SARE) Programme – African Rainbow Energy PV CPA	South Africa	Registered		Solar PV					0
South African Grid Connected Wind Farm Programme	South Africa	Registered	Wind and solar	Wind	Large-scale	13-Dec-12	28	1	0
CPA 001 under PoA 'South African Grid Connected Wind Farm Programme'	South Africa	Registered		Wind					0
CPA-002 under PoA 'South African Grid Connected Wind Farm Programme' (CPA-002)	South Africa	Registered		Wind					0
CDM Africa Wind and Solar Programme of Activities for South Africa	South Africa	Registered	Wind and solar	Solar & wind	Large-scale	21-Nov-12	28	1	0
Jeffrey's Bay Wind Energy Project in South Africa	South Africa	Registered		Wind					0
Droogfontein Solar PV Project	South Africa	Registered		Solar PV					0
De Aar Solar PV Project	South Africa	Registered		Solar PV					0
Khobab Wind Farm	South Africa	Registered		Wind					0
Loeriesfontein 2 Wind Farm	South Africa	Registered		Wind					0
Nojoli Wind Farm	South Africa	Registered		Wind					0
Noupoort Wind Farm	South Africa	Registered		Wind					0
Green Power for South Africa	South Africa	Registered	Wind and solar	Solar PV	Large-scale	14-Dec-12	28	1	598
Scatec Solar Linde CPA-001 ("SSL CPA-001").	South Africa	Registered		Solar PV					87
Scatec Solar Kalkbult CPA-002 ("SSK CPA-002")	South Africa	Registered		Solar PV					257
AE-AMD Herbert CPA-003 ("AEH CPA-003")	South Africa	Registered		Solar PV					0
Erika Energy Soutpan CPA-004 ("EES CPA-004").	South Africa	Registered		Solar PV					0
Core Energy Witkop CPA-005 ("CEW CPA-005").	South Africa	Registered		Solar PV					0
Solar Capital De Aar 1 CPA-006 ("SCDA1 CPA-006")	South Africa	Registered		Solar PV					134
Solar Capital De Aar 3 CPA-007 ("SCDA3 CPA-007")	South Africa	Registered		Solar PV					0
Lesedi 74.96 MW Solar PV Project CPA-008	South Africa	Registered		Solar PV					0
Letsatsi 74.96 MW Solar PV Project CPA-009	South Africa	Registered		Solar PV					0
Scatec Solar Dreunberg CPA-010	South Africa	Registered		Solar PV					120
Boshof Solar Park CPA-011	South Africa	Registered		Solar PV					0
South Africa Wind Energy	South Africa	Registered	Wind and solar	Wind	Large-scale	14-Sep-12	28	1	0
Copperton Wind Farm	South Africa	Registered		Wind					0
Small Scale Grid-connected Solar Power Programme	South Africa	Registered	Wind and solar	Solar PV	Small-scale	24-Dec-12	28	1	0
CPA RSA0001 - Merino Photovoltaic Power Station, Republic of South Africa	South Africa	Registered		Solar PV					0
CPA- SA-001-South Africa	South Africa	Registered		Stoves					0
Small-scale solar electrical programme, South Africa	South Africa	Registered	Wind and solar	Solar PV	Small-scale	26-Nov-12	28	1	0

Small-scale solar electrical programme, South Africa – CPA-001	South Africa	Registered		Solar PV					0
Southern African Solar LED Programme	South Africa	Registered	Wind and solar	Solar lamps	Small-scale	31-Dec-12	28	1	0
Southern African Solar LED Programme – South Africa CPA	South Africa	Registered		Solar lamps					0
Hot Water Heating Programme for South Africa	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	15-Oct-12	28	1	0
Hot Water Heating Programme for South Africa – CPA-001	South Africa	Registered		Solar water heating					0
Wind and solar PoA in South Africa	South Africa	Registered	Wind and solar	Solar & wind	Large-scale	26-Dec-12	28	1	0
Wind and solar PoA in South Africa – Solar – Kakama	South Africa	Registered		Solar PV					0
South Africa Renewable Energy Programme (SA-REP)	South Africa	Registered	Wind and solar	Solar & wind & other	Small-scale	10-Sep-12	28	1	0
SAREP – Greefspan 10MW Solar PV Project	South Africa	Registered		Solar PV					0
SA-REP – Aries 10 MW Solar PV Project	South Africa	Registered		Solar PV					0
SA-REP – Konkoonsies 10 MW Solar PV Project	South Africa	Registered		Solar PV					0
NuPlanet Small Scale Hydropower PoA	South Africa	Registered	Hydro	Run of river	Small-scale	21-Dec-12	28	1	0
NuPlanet Small Scale Hydropower PoA - CPA1Stortemelk	South Africa	Registered		Existing dam					0
South African Large Scale Grid Connected Solar Park Programme	South Africa	Registered	Wind and solar	Solar PV	Large-scale	02-Jan-13	28	1	0
CPA 001 under PoA 'South African Large Scale Grid Connected Solar Park Programme	South Africa	Registered		Solar PV					0
City of Cape Town Landfill Gas Extraction and Utilisation Programme	South Africa	Registered	Landfill gas	Landfill power	Large-scale	16-Sep-14	28	1	0
Landfill Gas Extraction and Utilisation at Coastal Park Landfill	South Africa	Registered		Landfill power					0
Landfill Gas Extraction and Utilisation at Bellville South	South Africa	Registered		Landfill power					0
Landfill Gas Extraction and Utilisation at Vissershok	South Africa	Registered		Landfill power					0
Grid Connected Photovoltaic (PV) Renewable Electricity Generating Facilities PoA	South Africa	Registered	Wind and solar	Solar PV	Large-scale	18-Dec-12	28	1	0
Grid Connected Photovoltaic (PV) Renewable Electricity Generating Facilities Programme CPA 1 (One)	South Africa	Registered		Solar PV					0
Energy Efficient Cook stoves in South Africa	South Africa	Registered	EE households	Stoves	Small-scale	12-Dec-12	28	1	0
Installation of Energy Efficient Cookstoves in Umtata, Butterworth, King Williams town and Mqanduli in Eastern Cape, South Africa: CPA 001	South Africa	Registered		Stoves					0
South African Wind Power Projects	South Africa	Registered	Wind and solar	Wind	Large-scale	18-Dec-12	28	1	0
CPA1 under PoA 'South African Wind Power Projects'	South Africa	Registered		Wind					0
Renewable Energy Carbon Programme for Africa (RECPA)	South Africa	Registered	Wind and solar	Solar & wind	Large-scale	28-Dec-12	28	1	0
Haverfontein 82.5 MW Wind Power Project (CPA-001)	South Africa	Registered		Wind					0

Solar Energy Programme for South Africa	South Africa	Registered	Wind and solar	Solar thermal power	Large-scale	18-Dec-12	28	1	0
Solar Energy Programme for South Africa CPA 1	South Africa	Registered		Solar thermal power					0
Small Scale Renewable Energy Carbon Programme (SRECP)	South Africa	Registered	Wind and solar	Solar & wind & hydro	Small-scale	28-Dec-12	28	1	0
Toitdale Concentrated Photovoltaic Project (CPA-001)	South Africa	Registered		Solar PV					0
Residential Hot Water Efficiency Programme in South Africa	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	31-Dec-12	28	1	0
eThekwini Municipality Residential Hot Water Efficiency Programme – CPA1	South Africa	Registered		Solar water heating					0
Biomass residues power generation Programme	South Africa	Registered	Biomass energy	Agricultural residues: other kinds	Large-scale	15-Nov-13	28	1	0
Amatikulu CPA - Renewable Energy Generation Facility	South Africa	Registered		Bagasse power					0
Standard Bank Low Pressure Solar water heater Programme for South Africa	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	24-Apr-12	28	1	0
Standard Bank Low Pressure Solar Water Heater Programme for South Africa – CPA-001	South Africa	Registered		Solar water heating					
Standard Bank Low Pressure Solar Water Heater Programme for South Africa - CPA-002	South Africa	Registered		Solar water heating					
Standard Bank Low Pressure Solar Water Hearter Programme for South Africa - CPA-003	South Africa	Registered		Solar water heating					
Standard Bank Low Pressure Solar Water Heater Programme for South Africa – CPA-004	South Africa	Registered		Solar water heating					
Standard Bank Low Pressure Solar Water Heater Programme for South Africa – CPA-005	South Africa	Registered		Solar water heating					
							Total	31	1395

Verra carbon offset projects

Verra Projects	Status	Registration	Project types	Date of registration	Total issuance ($MtCO_2e$)
Joburg Landfill Gas to Energy Project	Registered	large-scale	Landfill gas	30-Mar-17	369 682
Lighting up Africa	Registered	small-scale	EE households	12-Jan-16	0
Renencom Afforestation/Reforestation Grouped Project	Registered	small-scale	AFOLU	14-Nov-14	0
Kuzuko Lodge Private Game Reserve thicket restoration project	Registered	large-scale	AFOLU	28-Mar-17	0
Interwaste Landfill gas Grouped Project	Registered	small-scale	Landfill gas	23-Dec-19	126 007
Reliance Composting Project in Cape Town	Registered	small-scale	Waste disposal	29-Jul-19	162 069
N2O ABATEMENT PROJECT AT AEL 11_	Registered	large-scale	N2O	29-May-19	151 457
N2O ABATEMENT PROJECT AT AEL 9_	Registered	large-scale	N2O	29-May-19	0
Longyuan Mulilo De Aar Maanhaarberg Wind Energy Facility	Registered	large-scale	Wind	14-Apr-20	1 189 376
Longyuan Mulilo De Aar 2 North Wind Energy Facility	Registered	large-scale	Wind	14-Apr-20	1 894 230
Recipe for Change Grouped Project	Registered	small-scale	EE households	12-May-21	126 587
BRT REA VAYA PHASE A AND 1B, SOUTH AFRICA	Registered	large-scale	Transport	11-May-17	0
Tree Planting in South African townships	Registered	small-scale	AFOLU	10-May-17	0
Peri-urban bamboo planting around South African townships	Registered	small-scale	AFOLU	09-May-17	0
Durban Landfill-Gas Bisasar Road	Registered	large-scale	Landfill gas	05-May-17	124 884
Saving the Planet, one stew at a time	Registered	small-scale	EE households	13-Jul-17	218 967
The Capture and Utilisation of Methane at the GFI Mining South Africa owned Beatrix Mine in South Africa	Registered	large-scale	Fugitive	03-Apr-17	9 643
				Total	**4 372 902**

Gold Standard projects

Title	Status	Project type	Project size	Registration Year	Total Issuance (kCO2e)
Kuyasa low-cost urban housing energy upgrade project, Khayelitsha (Cape Town; South Africa)	Registered	EE households	small-scale	2008	9 341
Bokpoort CSP (Concentrating Solar Power) Project, South Africa	Registered	Solar	large-scale	2010	0
Highveld Air Quality - Wesselton project	Registered	EE households	small-scale	2010	30 118
Highveld Air Quality - Seme project	Registered	EE households	small-scale	2010	27 249
Highveld Air Quality - Sakhile project	Registered	EE households	small-scale	2010	5 455
Highveld Air Quality - EMM south project	Registered	EE households	small-scale	2010	4 034
Highveld Air Quality - EMM central project	Registered	EE households	small-scale	2010	25 113
Highveld Air Quality - EMM north project	Registered	EE households	small-scale	2010	41 141
Highveld Air Quality - Emfuleni project	Registered	EE households	small-scale	2009	11 589
Highveld Air Quality - NFS project	Registered	EE households	small-scale	2009	8 377
Highveld Air Quality - Phumula project	Registered	EE households	small-scale	2010	8 436
Letaba Biomass to Energy Project	Registered	Biomass	small-scale	2012	10 355
Brickstar Wood Stove - Mahlaba Area	Registered	EE households	small-scale	2017	2 045
GS1141 CLF Replacement Project Western Cape - CPA-01	Registered	EE households	small-scale	2014	0
Highveld Air Quality - eMbalenhle Project	Registered	EE households	small-scale	2011	13 813
Historical Roll Out GS Large Scale VER Project	Registered	EE households	large-scale	2015	0
CFL Replacement Programme of Activities in South Africa	Registered	EE households	small-scale	2014	0
North West, KwaZulu-Natal & Eastern Cape CFL Replacement Project (2) in South Africa	Registered	EE households	small-scale	2014	0
Gauteng, Free State, Mpumalanga, Limpopo & Northern Cape CFL Replacement Project (1) in South Africa	Registered	EE households	small-scale	2011	0
Highveld Air Quality - Standerton project	Registered	EE households	small-scale	2011	1 140
Maluti Air Quality Project - West	Registered	EE households	small-scale	2010	6 432
Highveld Air Quality - Maluti East	Registered	EE households	small-scale	2010	13 841
Maluti Air Quality Project - South	Registered	EE households	small-scale	2010	3 149

Highveld Air Quality - Highveld Central Project	Registered	EE households	small-scale	2012	16 365
				Total	**237 993**

A7 Household energy efficiency carbon offset projects analysed in the study

CDM carbon offset projects

Title	Host country	Status	Project type	Project size	Date of registration	Total issuance (kCERs) 2008-2021
Kuyasa low-cost urban housing energy upgrade project, Khayelitsha (Cape Town; South Africa)	South Africa	Registered	EE households	Small-scale	27-Aug-05	10
North West, KwaZulu-Natal & Eastern Cape CFL Replacement Project (2) in South Africa	South Africa	Registered	EE households	Large-scale	11-Dec-12	
Gauteng, Free State, Mpumalanga, Limpopo & Northern Cape CFL Replacement Project (1) in South Africa	South Africa	Registered	EE households	Small-scale	10-Oct-12	
Total						**10**

**One CER is equivalent to one metric tonne of carbon dioxide (CO2) avoided or reduced (1tCO2e=1CER).*

Programme of Activities – CDM

Title	Host country	Status	PoA-Type	Sub-type	Project size	Date of registration	POA Lifetime	Total number of PoAs	Total issuance (kCERs) 2014-2021
SASSA Low Pressure Solar Water Heater Programme	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	12-Mar-11	28	1	99
LED's kick-off	South Africa	Registered	EE households	Lighting in service	Small-scale	05-Dec-12	28	1	0
ETA Solar Water Heater Programme in South Africa	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	25-Jul-12	28	1	0
Cogeneration and/or trigeneration at commercial sites.	South Africa	Registered	EE service & supply side	Cogeneration	Small-scale	31-Dec-12	28	1	0
Standard Bank Energy Efficient Commercial Lighting Programme of Activities	South Africa	Registered	EE service & supply side	Lighting in service	Small-scale	05-Aug-13	28	1	0
Southern Africa Solar Thermal Energy (SASTE) Programme	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	15-May-13	28	1	0
Sustainability CFL Replacement Programme of Activities in South Africa	South Africa	Registered	EE households	Lighting	Small-scale	19-Dec-12	28	1	0
Southern African Renewable Energy (SARE) Programme	South Africa	Registered	Wind and solar	Solar & wind & other	Large-scale	25-Jan-13	28	1	0
South African Grid Connected Wind Farm Programme	South Africa	Registered	Wind and solar	Wind	Large-scale	13-Dec-12	28	1	0
CDM Africa Wind and Solar Programme of Activities for South Africa	South Africa	Registered	Wind and solar	Solar & wind	Large-scale	21-Nov-12	28	1	0
Green Power for South Africa	South Africa	Registered	Wind and solar	Solar PV	Large-scale	14-Dec-12	28	1	598
South Africa Wind Energy	South Africa	Registered	Wind and solar	Wind	Large-scale	14-Sep-12	28	1	0
Small Scale Grid-connected Solar Power Programme	South Africa	Registered	Wind and solar	Solar PV	Small-scale	24-Dec-12	28	1	0
Small-scale solar electrical programme, South Africa	South Africa	Registered	Wind and solar	Solar PV	Small-scale	26-Nov-12	28	1	0
Southern African Solar LED Programme	South Africa	Registered	Wind and solar	Solar lamps	Small-scale	31-Dec-12	28	1	0
Hot Water Heating Programme for South Africa	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	15-Oct-12	28	1	0
Wind and solar PoA in South Africa	South Africa	Registered	Wind and solar	Solar & wind	Large-scale	26-Dec-12	28	1	0
South Africa Renewable Energy Programme (SA-REP)	South Africa	Registered	Wind and solar	Solar & wind & other	Small-scale	10-Sep-12	28	1	0
South African Large Scale Grid Connected Solar Park Programme	South Africa	Registered	Wind and solar	Solar PV	Large-scale	02-Jan-13	28	1	0
Grid Connected Photovoltaic (PV) Renewable Electricity Generating Facilities PoA	South Africa	Registered	Wind and solar	Solar PV	Large-scale	18-Dec-12	28	1	0
Energy Efficient Cook stoves in South Africa	South Africa	Registered	EE households	Stoves	Small-scale	12-Dec-12	28	1	0
South African Wind Power Projects	South Africa	Registered	Wind and solar	Wind	Large-scale	18-Dec-12	28	1	0
Renewable Energy Carbon Programme for Africa (RECPA)	South Africa	Registered	Wind and solar	Solar & wind	Large-scale	28-Dec-12	28	1	0
Solar Energy Programme for South Africa	South Africa	Registered	Wind and solar	Solar thermal power	Large-scale	18-Dec-12	28	1	0
Small Scale Renewable Energy Carbon Programme (SRECP)	South Africa	Registered	Wind and solar	Solar & wind & hydro	Small-scale	28-Dec-12	28	1	0

Residential Hot Water Efficiency Programme in South Africa	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	31-Dec-12	28	1	0
Standard Bank Low Pressure Solar water heater Programme for South Africa	South Africa	Registered	Residential SWH Programme	Solar water heating	Small-scale	24-Apr-12	28	1	0
							Total	27	698

Verra carbon offset projects

Verra Projects	Status	Registration	Project types	Date of registration	Total issuance ($MtCO_2e$)
Lighting up Africa	Registered	small-scale	EE households	12-Jan-16	0
Recipe for Change Grouped Project	Registered	small-scale	EE households	12-May-21	126,587
Saving the Planet, one stew at a time	Registered	small-scale	EE households	13-Jul-17	218,967
				Total	**345,554**

Gold Standard projects

Title	Status	Project type	Project size	Registration Year	Total Issuance (kCO2e)
Kuyasa low-cost urban housing energy upgrade project, Khayelitsha (Cape Town; South Africa)	Registered	EE households	small-scale	2008	9,341
Highveld Air Quality - Wesselton project	Registered	EE households	small-scale	2010	30,118
Highveld Air Quality - Seme project	Registered	EE households	small-scale	2010	27,249
Highveld Air Quality - Sakhile project	Registered	EE households	small-scale	2010	5,455
Highveld Air Quality - EMM south project	Registered	EE households	small-scale	2010	4,034
Highveld Air Quality - EMM central project	Registered	EE households	small-scale	2010	25,113
Highveld Air Quality - EMM north project	Registered	EE households	small-scale	2010	41,141
Highveld Air Quality - Emfuleni project	Registered	EE households	small-scale	2009	11,589
Highveld Air Quality - NFS project	Registered	EE households	small-scale	2009	8,377
Highveld Air Quality - Phumula project	Registered	EE households	small-scale	2010	8,436
Brickstar Wood Stove - Mahlaba Area	Registered	EE households	small-scale	2017	2,045
GS1141 CLF Replacement Project Western Cape - CPA-01	Registered	EE households	small-scale	2014	0
Highveld Air Quality - eMbalenhle Project	Registered	EE households	small-scale	2011	13,813
Historical Roll Out GS Large Scale VER Project	Registered	EE households	large-scale	2015	0
CFL Replacement Programme of Activities in South Africa	Registered	EE households	small-scale	2014	0
North West, KwaZulu-Natal & Eastern Cape CFL Replacement Project (2) in South Africa	Registered	EE households	small-scale	2014	0
Gauteng, Free State, Mpumalanga, Limpopo & Northern Cape CFL Replacement Project (1) in South Africa	Registered	EE households	small-scale	2011	0
Highveld Air Quality - Standerton project	Registered	EE households	small-scale	2011	1,140
Maluti Air Quality Project - West	Registered	EE households	small-scale	2010	6,432
Highveld Air Quality - Maluti East	Registered	EE households	small-scale	2010	13,841
Maluti Air Quality Project - South	Registered	EE households	small-scale	2010	3,149
Highveld Air Quality - Highveld Central Project	Registered	EE households	small-scale	2012	16,365
				Total	**227,638**

A8 Ethical clearance

REVIEW REPORT AND DECISION - PART B
UNIVERSITY OF EAST ANGLIA
INTERNATIONAL DEVELOPMENT RESEARCH ETHICS COMMITTEE

University of East Anglia

APPLICANT INFORMATION
To be completed by the applicant

Forename	Jana
Surname	Hofmann
Student ID number *(if applicable)*	100108550
UG, PGT or PGR *(if applicable)*	PGR
Supervisor *(if applicable)*	Dr. Oliver Springate-Baginski and Dr. Heike Schroeder
Project Title	Are carbon offset projects effective at delivering sustainable livelihood benefits in South Africa?

RESUBMISSIONS – IF YOU ARE ASKED TO RESUBMIT YOUR APPLICATION FOLLOWING REVIEW BY THE COMMITTEE PLEASE ALSO ATTACH **A LETTER** WITH YOUR REVISED APPLICATION DETAILING HOW YOU HAVE RESPONDED TO THE COMMITTEE'S COMMENTS. Students please ensure your supervisor has approved your revisions before resubmission.

REVIEWERS' RECOMMENDATION (✓)
To be completed by the Ethics Committee

Accept	✓
Request modifications	
Reject	

REVIEWERS' CHECKLIST *Delete as appropriate*

Risks and inconvenience to participants are minimised and not unreasonable given the research question/ project purpose.	✓	
All relevant ethical issues are acknowledged and understood by the researcher.	✓	
Procedures for informed consent are sufficient and appropriate	✓	

REVIEWERS' COMMENTS

The consent form clearly states that participants can withdraw at any time.
The risks associated with researching a sensitive subject are noted in section 3; in this section it's not clear what will happen if governmental departments will not share information (the paragraph is not clear) but I assume the researcher will gain the information she can and use what she has.

5. Households who participate in carbon offset projects are in a dependent relationship with the provider who the researcher might be identified with so care will need to be taken to ensure that they feel able to refuse to participate.

17. 'I will also translate the short summary report to local languages and make it available to any participants (community leaders) that are keen to find out about my findings' - this is a good start, but need to ensure that leaders disseminate more widely if the researcher wants to reach other participants

Ethical approval form February 2014 Page | 1

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UEA University of East Anglia

REVIEW REPORT AND DECISION - PART B

UNIVERSITY OF EAST ANGLIA
INTERNATIONAL DEVELOPMENT RESEARCH ETHICS COMMITTEE

REVIEWERS' COMMENTS

Correct consent form - 'There are financial incentives for your participation' should presumably read 'There are no financial incentives for your participation'

COMMITTEE'S RECOMMENDATION

Ethical clearance granted, but please correct the error on the consent form

SIGNATURE (CHAIR OF THE INTERNATIONAL DEVELOPMENT ETHICS COMMITTEE)

Signature	Date
L Camfield	26/01/17

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A9 Monthly electricity expenses

Table A9.1: Type of market actors with critical perceptions on carbon offset project implementation

Not enough carbon offset projects implemented		
Main actors	Frequency of the responses	Number of actors
Carbon consultants	4	4
Municipality	3	3
Financial institution	1	1
Local registry	1	1
Eskom	1	1
Total	**10**	**10**

Source: Author's compilation

Table A9.2: Type of actors with supportive perceptions on the functioning of the carbon market

Functional market		
Market actors	Frequency of responses	Number of actors
Financial institutions	3	1
Eskom	1	1
Total	**4**	**2**

Source: Author's compilation

Table A9.3: Type of actors with critical perceptions on government support with carbon offset projects

No Government support		
Market actors	Frequency of responses	Number of actors
Legal	5	1
Carbon consultants	4	4
Financial institutions	4	1
NGO	3	2
Project developers	1	1
Total	**17**	**9**

Source: Author's compilation

Table A9.4: Type of actors with critical perceptions on profit maximising activities in the carbon market

Profit maximising activity		
Market actors	Frequency of responses	Number of actors
Municipalities	4	2
Civil society	4	2
Project developers	3	1
Carbon consultants	3	2
Legal	3	1
Financial institutions	1	1
NGO	1	1
Academia	1	1
Total	**20**	**11**

Source: Author's compilation

Table A9.5 Type of actors with critical perceptions on credibility of the carbon market

Carbon market not credible		
Market actors	Frequency of responses	Number of actors
Municipalities	10	1
Civil society	10	2
Academia	6	1
NGO	4	1
Carbon consultants	2	1
Total	**32**	**6**

Source: Author's compilation

Table A9.6: Type of actors with critical perceptions on understanding of carbon offset projects in SA

No understanding of carbon offset projects		
Market actors	Frequency of responses	Number of actors
Carbon consultants	10	5
Local registry	3	1
NGOs	3	1
Municipalities	1	1
Project developers	1	1
Financial institutions	1	1
Eskom	1	1
Total	**20**	**11**

Source: Author's compilation

Table A9.7: Type of actors with critical perceptions on the availability of local expertise in SA

Limited local expertise in the country		
Market actors	Frequency of responses	Number of actors
Municipalities	13	3
Carbon consultants	6	2
Financial institutions	3	2
Eskom	1	1
Total	**23**	**8**

Source: Author's compilation

Table A9.8: Summary of market actors' perceptions on local expertise in SA

Market actors' storylines	**Frequency of Responses**	**Number of actors**
Inexperienced carbon practitioners	10	3
Limited or no technical knowledge/skill	8	3
Insufficient knowledge at the governmental level	4	3
Insufficient focus or technical accuracy at the project developers' level	1	1
Total	**23**	**10**

Source: Interviews with market actors, 2017

Table A9.9: Type of actors with critical perceptions on bureaucracy experienced with projects

Bureaucratic Process		
Market actors	Frequency of responses	Number of actors
Project developer	6	3
Financial institution	3	2
Local registry	1	1
NGO	1	1
Carbon consultant	1	1
Municipalities	1	1
Total	**13**	**9**

Source: Author's compilation

Table A9.10: Type of actors with supportive perceptions on bureaucracy

Bureaucracy needed		
Market actors	Frequency of responses	Number of actors
Consultants	7	3

Source: Author's compilation

Table A9.11: Type of actors providing their perceptions on project costs

Costly		
Actors	Frequency of responses	Number of actors
Financial institution	6	2
Carbon consultant	6	6
NGO	5	2
Municipality	5	3
Local registry	2	1
Project developer	2	1
Total	**26**	**15**

Source: Author's compilation

Table A9.11: Type of actors providing their perceptions on project risks

Projects are risky		
Market actors	Frequency of responses	Number of actors
Project developer	6	3
NGO	4	2
Carbon consultant	3	2
Financial institution	1	1
Municipalities	1	1
Local registry	1	1
Total	**16**	**10**

Source: Author's compilation

TableA9.12: Summary of market actors' perceptions on project risks

Market actors' storylines	Frequency of responses
Climate-related risks (drought, fires)	5
Financial Risks (low carbon price)	4
Political risks (unwillingness to solve climate change problems)	3
Economic risks (technical recession)	1
Policy uncertainties (limited life of the Kyoto Protocol)	1
No guarantee of long-term land management	1
Land tenure risk	1
Total	**16**

Source: Interview with market actors, 2017

Table A9.13: Type of actors providing critical perceptions on technology transfer

Limited technology transfer		
Market actors	Frequency of responses	Number of actors
Municipality	3	1
Project developer	1	1
Legal	1	1
Total	**5**	**3**

Source: Author's compilation

Table A9.14: Type of actors supporting the introduction of the carbon tax

Supportive of Carbon tax		
Market actors	Frequency of responses	Number of actors
Carbon consultant	8	5
NGO	5	3
Financial institution	3	1
Project developer	2	1
Municipality	2	2
Legal	2	1
Local registry	1	1
National gov	1	1
Total	**24**	**15**

Source: Author's compilation

Table A9.15 Type of actors providing critical perceptions on the carbon tax

Carbon tax ineffective		
Market actors	Frequency of responses	Number of actors
Carbon consultants	6	1
Financial institution	4	1
Academia	2	1
Municipality	2	1
Total	**14**	**4**

Source: Author's compilation

Table A9.16: Overview of market actors' comments on the topic of co-benefits provision

Market actors	Number of actors	Percentage (%)
Supportive Perceptions	15	56
Critical Perceptions	8	30
Ambivalent Perceptions	3	11
No opinion	1	3
Total	**27**	**100**

Source: Author's compilation

Table A9.17: Type of actors with supportive perceptions on co-benefits provision

Direct and Indirect Co-benefits provision		
Market actors	Frequency of responses	Number of actors
Municipalities	16	4
NGOs	6	3
Local registry	6	1
Project developers	4	2
Carbon consultants	3	3
Eskom	2	1
National Government	1	1
Total	**38**	**15**

Source: Author's compilation

Table A9.18: Type of actors with critical perceptions on co-benefits provision

Limited or no co-benefits provision		
Market actors	Frequency of responses	Number of actors
Legal	6	1
Carbon consultants	6	1
Project developers	4	2
Civil society	4	2
Financial institution	3	2
Academia	1	1
Total	**24**	**9**

Source: Author's compilation

Table A9.19: *Type of actors with supportive perceptions on carbon revenue sharing*

Carbon Revenue sharing		
Market actors	Frequency of responses	Number of actors
Local registry	7	1
Municipality	6	1
Project developers	1	1
NGO	1	1
Carbon consultants	1	1
Total	**16**	**5**

Source: Authors' compilation

Table A9.20: Market actors' supportive perceptions on carbon revenue sharing

Market actors' storylines	Frequency of responses
'Share carbon revenue with workers'	7
'Reduce service rates and taxes'	6
'Carbon revenue helped with installation and maintenance'	2
'5% of carbon revenue allocated to a trust fund'	1
Total	**16**

Source: Interview with market actors, 2017

Table A9.21: *Type of actors with critical perceptions on carbon revenue sharing*

No carbon revenue sharing		
Main actors	Frequency of responses	Number of actors
Municipalities	6	2
Carbon consultants	3	3
Project developers	3	2
Civil society	2	2
Legal	1	1
Academia	1	1
Eskom	1	1
Total	**17**	**12**

Source: Author's compilation

Table A9.22: Market actors' critical perceptions on carbon revenue sharing

Market actors' storylines	Frequency of responses
'Carbon revenue lost in the municipal centralised accounting system'	6
'Carbon revenue covers costs, pay taxes and satisfies investors'	5
'Carbon revenue is used to pay higher salaries and bonuses'	4
'Carbon revenue is shared with carbon consultants'	1
Total	**17**

Source: Author's compilation

Table A9.23: Type of actors with supportive perceptions on job creation and skills

Job creation and sills		
Market actors	Frequency of responses	Number of actors
Carbon consultants	4	2
Municipality	3	1
Project developers	2	2
NGOs	2	1
Eskom	2	1
National Government	2	1
Legal	1	1
Local registry	1	1
Total	**10**	**17**

Source: Actors' compilation

Table A9.24: Type of actors with critical perceptions on job creation and skills

Limited Job creation and skills		
Main actors	Frequency of responses	Number of actors
Municipalities	5	2
Project developers	2	2
Carbon consultant	5	1
Total	**12**	**5**

Source: Author's compilation

Appendix A10: Technology use within South African households

Table A10.1: Respondents' comments on the WB use

Respondents' comments	Frequency of responses	Percentage (%)
'Cook warm meals with the WB'	16	84
'Use the WB to keep food warm'	3	16
Total	**19**	**100**

Source: Field Survey, 2017, Langa

Table A10.2: Respondents' comments on the last time the WB was used

Last time the WB used	Frequency of responses	Percentage (%)	Aggregated frequency of use (%)
Yesterday	2	11	63
Two days ago	1	5	
Last week	6	32	
2 weeks ago	1	5	
Last month	2	11	
2 months ago	1	5	37
3 months ago	2	10	
6 months ago	1	5	
1 year ago	2	11	
2 years ago	1	5	
Total	**19**	**100**	**100**

Source: Field Survey, 2017, Langa

Table A10.3: Respondents' comments on converting to the BM method

Respondents' comments	Frequency of responses	Percentage (%)
'Use only BM method'	22	88
'Use traditional method occasionally'	3	12
Total	**25**	**100**

Source: Field Survey, 2017 Wesselton township

Table A10.3: Respondents' comments on transferring their BM knowledge and skills to family members

Respondents' comments	Frequency of responses	Percentage (%)
'Taught BM method, everyone uses it'	7	28
'Taught BM method, but they do not use it'	7	28
'Did not teach the BM method'	11	44
Total	**25**	**100**

Source: Field Survey, 2017, Wesselton Township

Table A10.4: Respondents' comments on the use of hot water from the SWH during seasons

Respondents' comments	Frequency of responses	Percentage (%)
'Use the SWH more in Summer'	20	71
'Use the SWH equally throughout the year'	8	29
Total	**28**	**100**

Source: Field Survey, 2018, Cosmo City

Table A10.5: Respondents' comments on the issues experienced with SWHs

Respondents' comments	Frequency of responses	Percentage (%)
'The SWH leaks'	24	86
'Do not have a leak'	4	14
Total	**28**	**100**

Source: Field Survey, 2018, Cosmo City

Table A10.6: Respondents' comments on the wood stove use during winter and summer

Respondents' comments	Frequency of responses	Percentage (%)
'Use the wood stove more in winter'	21	51
'There is no difference in seasonality'	17	42
Not applicable[64]	3	7
Total	**41**	**100**

Source: Field Survey, 2018, Burgersdorp and Bonn

Table A10.7: Respondents' comments on the use of the open fire

Respondents' comments	Frequency of responses	Percentage (%)
'Do not use open fire'	28	68
'Use open fire'	13	32
Total	**41**	**100**

Source: Field Survey, 2018, Burgersdorp and Bonn

Table A10.8: Respondents' comments on teaching their family members on how to use the wood stove

Respondents' comments	Frequency of responses	Percentage (%)
'Did not teach my family members how to use the wood stove'	25	61
'Taught my family members how to use the wood stove'	16	39
Total	**41**	**100**

Source: Field Survey, 2018, Burgersdorp and Bonn

TableA10.9: Key words used by respondents to describe the value of the 'Wonderbag'

Key words used by respondents	Frequency of responses[65]	Percentage of responses (%)
'Best', 'Neat', 'Perfect', 'Very useful', 'Easy', 'It' number one', 'Like it too much'	7	30
'Precious baby', 'Handy', 'Magic'	6	26
'Helps me'	6	26
'Very important'	4	18
Total	**23**	**100**
Total respondents	**19**	**100**

Source: Field Survey, 2017, Langa

[64] Two respondents received the wood stove 6 months before the survey; hence they did not have any experience with seasonal changes (WSR 2,20). Another respondent used the wood stove in winter until the stove broke down. She did not have any experience with the wood stove in the summer period (Respondent 9). As a result, the responses were denoted as 'Not Applicable'.

[65] The respondents provided more than one response

Table A10.10: Respondents' comments on the value of the 'Wonderbag'

Respondents' comments	Frequency of responses[66]	Percentage of responses (%)
'Saves electricity'	12	50
'Keeps food warm'	4	17
'Saves time'	2	8
'Saves water'	1	4
Total	**24**	**100**
Total Respondents	**14**	**74**
No opinion	**5**	**26**
Total sample size	**19**	**100**

Source: Field Survey, 2017, Langa

Table A10.11: Respondents' comments on the value of the SWHs

Respondents' comments	Frequency of responses[67]	Percentage of responses (%)
'Saves electricity'	8	23
'Hot water helps with everything'	8	23
'Only helps in summer, but not winter'	7	20
'Good to have hot water'	4	11
'Helps with electricity cuts'	3	9
'Does not have value, provided for free'	2	6
'Not enough hot water in the tank'	1	3
'Saves time'	1	3
'Life is easier'	1	3
Total	**35**	**100**
Total respondents	**28**	**100**

Source: Field Survey, 2018, Cosmo City

Table A10.12: Respondents' comments on the value of the 'BM method'

Respondents' comments	Frequency of responses[68]	Percentage of responses (%)
'Saves coal'	9	26
'Does not produce a lot of smoke'	9	26
'Easy method'	4	12
'Provides heat'	3	9
'Heat remains for a long time'	3	9
'Make more food with the same fire'	2	6
'Heat is generated fast'	2	6
'Avoids TB'	1	3
'Heat is generated slow'	1	3
Total	**34**	**100**
Total respondents	**25**	**100**

Source: Field Survey, 2018, Cosmo City

[66] Ibid.
[67] Ibid.
[68] Ibid.

Table A10.13: Respondents' comments on the value of the 'Wood stove'

Respondents' comments	Frequency of responses	Percentage of responses (%)
'Consumes less wood'	14	34
'Cooking is comfortable'	8	20
'Produces less smoke'	6	15
'Pots do not get burned'	5	12
'Food tastes good'	2	5
'The heat lasts long'	2	5
'Helps with electricity blackout'	1	2
'Saves electricity'	1	2
'No burns'	1	2
'Makes the kitchen dirty'	1	2
Total	**41**	**100**

Source: Field Survey, 2018, Burgersdorp and Bonn

Table A10.14: Respondents' comments on electricity savings using the 'Wonderbag'

Respondents' comments	Frequency of responses	Percentage of responses (%)
'Not sure, how much electricity I save'	7	37
'Cannot tell, but WB saves electricity'	5	26
'There is a difference in my electricity'	3	16
'Do not check, but WB saves electricity'	2	11
'Do not know, but the WB saves electricity'	2	11
Total	**19**	**100**

Source: Field Survey, 2017, Langa

Table A10.15: Respondents' comments on cooking time before and after the 'Wonderbag' carbon offset project intervention

Respondents' comments	Frequency of responses	Percentage of responses (%)
'See difference in cooking time'	16	84
NA - 'only use to keep food warm'	3	16
Total	**19**	**100**

Source: Field Survey, 2017, Langa

Table A10.16: Respondents' comments on cooking with the wood stove

Respondents' comments	Frequency of responses	Percentage of responses (%)
'Wood stove is faster than open fire'	19	46
'No difference'	15	37
'Do not know'	4	17
'Wood stove is slower than open fire'	3	7
Total	**41**	**100**

Source: Field Survey, 2018, Burgersdorp and Bonn

Table A10.17: Respondents' comments on activities undertaken when using the 'Wonderbag'

Respondents' comments	Frequency of responses[69]
'Relax / Sleep / Read / Watch TV'	8
'Go to work'	6
'Do housework (laundry, cleaning, going shopping)'	2
'Visiting friends'	2
'Spend time with children'	1
Total	**19**
Total respondents	**14**
No opinion	**1**
Sample size for cooking samp	**15**

Source: Field Survey, 2017, Langa

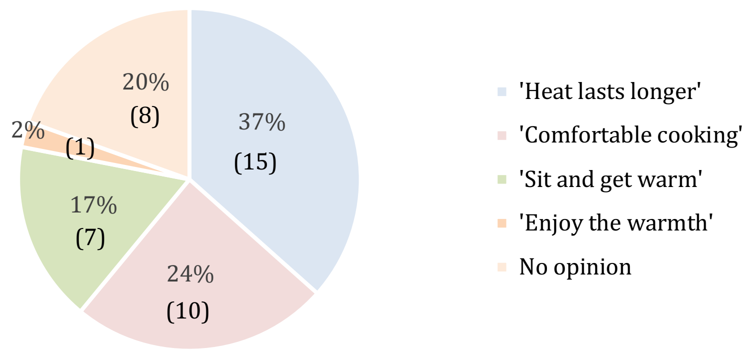

Figure A10.18: Respondents comments on the convenience factors of the wood stove. Source: Field Survey, 20 18, Burgersdorp and Bonn

[69] Ibid.

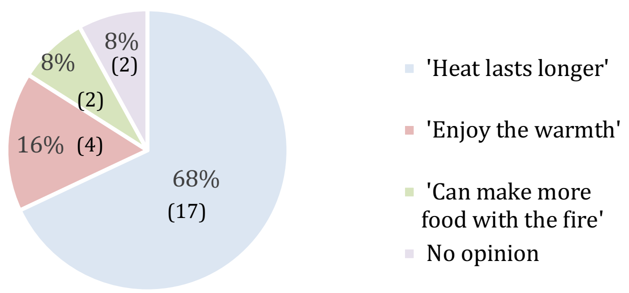

Figure A10.19: Respondents' comments on the convenience factors of the BM method Source: Field Survey, 2017, Wesselton Township

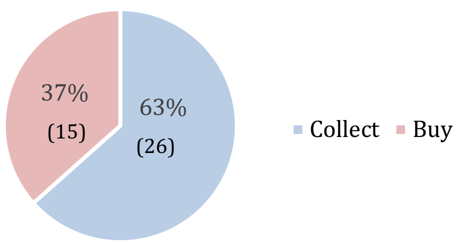

Figure A10.20: Methods of obtaining firewood reported by respondents in Burgersdorp and Bonn. Source: Field Survey, 2018, Burgersdorp and Bonn

Table A10.21 Respondent's comments on health impacts when using the wood stove

Respondents' comments	Frequency of responses	Percentage of responses (%)
'Does not affect my health'	18	44
'No difference'	11	27
'No cough, sneezing or tearing eyes'	4	10
'Safe for health'	1	2
No opinion	7	17
Total	**41**	**100**

Source: Source: Field Survey, 2018, Burgersdorp and Bonn

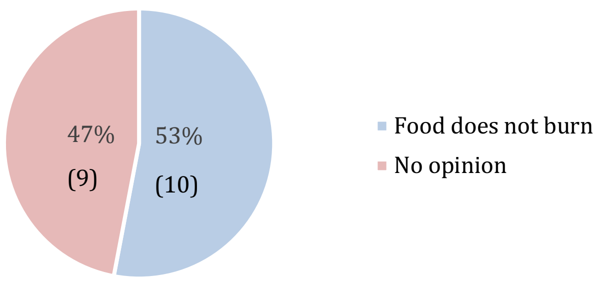

Figure A10.22: Respondents' comments on the perceived safety of the Wonderbag. Source: Field Survey, 2017, Langa

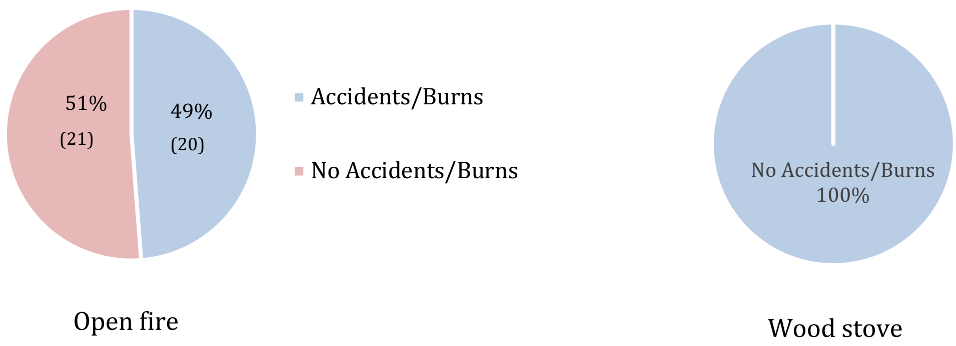

Figure A10.23: Accidents/Burns reported by respondents with the open fire and the wood stove Source: Field Survey, 2018, Burgersdorp and Bonn

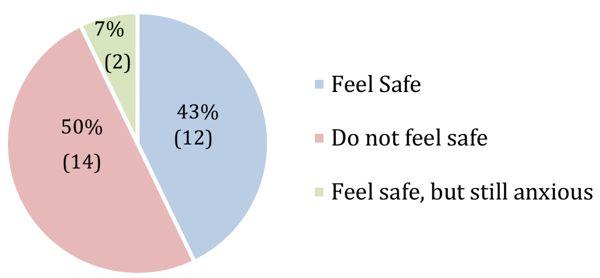

Figure A10.24: Issues reported by respondents with the SWHs. Source: Field Survey, 2017, Cosmo City

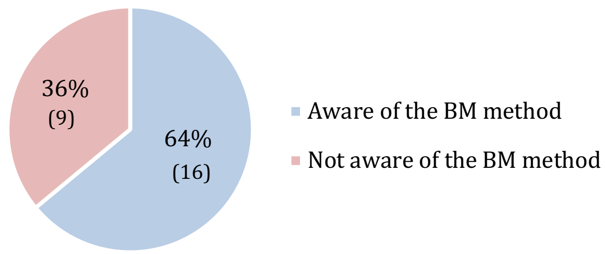

Figure A10.25: Awareness of the BM method reported by respondents in Wesselton township. Source: Field Survey, 2017, Wesselton. Township

Table A10.26: Social interactions reported by respondents in relation to the Wonderbag

Social interactions			
Respondents' comments	Frequency of responses	Percentage of responses (%)	Aggregated percentage of responses
'Talk about the WB'	8	42	63%
'Share the WB with others'	4	21	
'Do not share the WB'	4	21	37%
'Do not talk about the WB'	3	16	
Total	**19**	**100**	**100**

Source: Field Survey, 2017, Langa

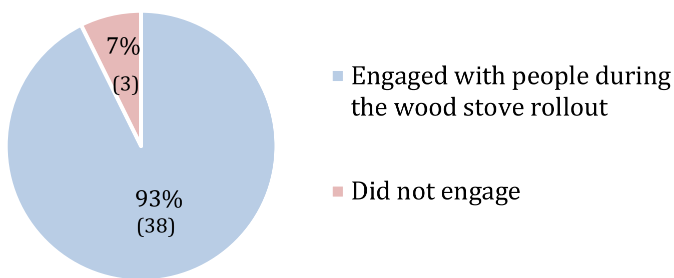

Figure A10.27: Social relations reported by the respondents in relation to the Brickstar wood stove. Source: Field Survey, 2018, Burgersdorp and Bonn

Table A10.28: Respondents' comments on the distribution of the SWHs in Cosmo City

SWH distribution		
Respondents' comments	Frequency of responses	Percentage of responses (%)
'Many people did not receive the SWH'	21	75
'Do not know'	7	25
Total	**28**	**100**

Source: Field Survey, 2018, Cosmo City

A11 Monthly coal consumption of Basa Magogo carbon offset project

Monthly coal consumption per household in the winter period before and after the BM carbon offset project intervention

Date	Respondent (n=25)	Unit[70]	Big Bag before BM method, per month	Big Bag with BM method, per month	Coal consumption before BM, per month, in kg	Coal consumption with BM, per month, in kg	Coal saving (kg)
28-Oct-17	Respondent 2	Small bag	do not know	4	do not know	80	NA
30-Oct-17	Respondent 3	Big bag	do not notice	4	do not notice	200	NA
30-Oct-17	Respondent 5	Big bag	do not know	8	do not know	400	NA
04-Nov-17	Respondent 6	Big bag	do not know	do not know	do not know	do not know	NA
16-Nov-17	Respondent 13	Van (10-11 big bags)	do not know/ buy in bulk	5	do not know	250	NA
16-Nov-17	Respondent 14	Truck	do not know/buy in bulk	do not know	do not know	do not know	NA
17-Nov-17	Respondent 15	Big bag	do not know	5	do not know	250	NA
18-Nov-17	Respondent 19	Van (10-11 big bags)	do not know	do not know	do not know	do not know	NA
18-Nov-17	Respondent 20	Big bag	do not know/ used paraffin	1	do not know / used paraffin	50	NA
18-Nov-17	Respondent 21	Big bag	do not know/ used paraffin	2	do not know/ used paraffin	100	NA
19-Nov-17	Respondent 22	Truck	do not know/ buy in bulk	do not know/ buy in bulk	do not know/ buy in bulk	do not know/buy in bulk	NA
04-Dec-17	Respondent 25	Big bag	do not know	do not know	do not know	do not know	NA
27-Oct-17	Respondent 1	Big bag	6	4	300	200	100
30-Oct-17	Respondent 4	Big bag	5	2	250	100	150
04-Nov-17	Respondent 7	Big bag	2	1	100	50	50
06-Nov-17	Respondent 8	Big bag	5	2	250	100	150
06-Nov-17	Respondent 9	Big bag	6	4	300	200	100
08-Nov-17	Respondent 10	Wheelbarrow	6	4	120	80	40
08-Nov-17	Respondent 11	Big bag	2	1	100	50	50
16-Nov-17	Respondent 12	Van (10-11 big bags)	2	1	100	50	50
17-Nov-17	Respondent 16	Big bag	11	8	550	400	150
17-Nov-17	Respondent 17	Small bags	5	3	100	60	40
17-Nov-17	Respondent 18	Big bag	4	2	200	100	100
02-Dec-17	Respondent 23	Big bag	8	6	400	300	100
02-Dec-17	Respondent 24	Big bag	9	6	450	300	150
		Total Average	**5**	**3**	**248**	**153**	**95**
		Total respondents	**13**				
		Not specified	**12**				
		Grand total	**25**				

Source: Field Survey, 2017, Wesselton township

[70] Volume of a big bag is 50kg; wheelbarrow and a small coal bag weight 20kg Source: Field Survey, 2017, Wesselton township

Monthly coal consumption per household in the summer period before and with the BM method

Date	Respondent (n=25)	Unit	Big Bags before BM method per month	Big Bags with BM method per month	Coal consumption before BM, per month, in kg	Coal consumption with BM, per month, in kg	Coal saving (kg)
28-Oct-17	Respondent 2	Small bag	do not know	do not know	do not know	do not know	NA
30-Oct-17	Respondent 5	Big bag	do not know	2	do not know	180	NA
08-Nov-17	Respondent 10	Wheelbarrow	do not know	do not know	do not know	do not know	NA
16-Nov-17	Respondent 13	Van (10-11 bags)	do not know/ buy in bulk	3	do not know	270	NA
16-Nov-17	Respondent 14	Truck	do not know/ buy in bulk	do not know/ buy in bulk	do not know	do not know	NA
17-Nov-17	Respondent 15	Big bag	do not know	1	do not know	90	NA
18-Nov-17	Respondent 19	Van (10-11 bags)	do not know/buy in bulk	do not know/buy in bulk	do not know	do not know	NA
18-Nov-17	Respondent 20	Big bag	do not know/ used paraffin	1	do not know/ used paraffin	90	NA
18-Nov-17	Respondent 21	Big bag	do not know/ used paraffin	2	do not know/ used paraffin	180	NA
19-Nov-17	Respondent 22	Truck	do not know/ buy in bulk	do not know /buy in bulk	do not know/ buy in bulk	do not know/ buy in bulk	NA
02-Dec-17	Respondent 23	Big bag	do not know/do not count	2	do not know	180	NA
04-Dec-17	Respondent 25	Big bag	do not know	do not know	do not know	do not know	NA
30-Oct-17	Respondent 1	Big bag	2	1	100	50	50
04-Nov-17	Respondent 3	Small bag	5	3	100	60	40
06-Nov-17	Respondent 4	Big bag	2	1	100	50	50
06-Nov-17	Respondent 6	Big bag	5	3	250	150	100
08-Nov-17	Respondent 7	Big bag	2	1	100	50	50
16-Nov-17	Respondent 8	Big bag	2	1	100	50	50
17-Nov-17	Respondent 9	Big bag	2	1	100	50	50
17-Nov-17	Respondent 11	Big bag	2	1	100	50	50
17-Nov-17	Respondent 12	Van (10-11 bags)	2	1	100	50	50
02-Dec-17	Respondent 16	Big bag	6	4	300	200	100
02-Dec-17	Respondent 17	Small bags	2	1	40	20	20
17-Nov-17	Respondent 18	Big bag	2	1	100	50	50
02-Dec-17	Respondent 24	Big bag	6	4	300	200	100
		Total average	**3**	**2**	**138**	**79**	**58**
		Total respondents	**13**				
		Not specified	**12**				
		Grand total	**25**				

Source: Field Survey, 2017, Wesselton township

A12 Monthly A12 of the Basa Magogo carbon offset project

Monthly coal savings per household in the winter period before and after the BM carbon offset project intervention

Date	Respondent (n=25)	Unit[71]	Bags before BM Winter, per month	Bags with BM Winter, per month	Coal cost, per bag in Rand	Total costs before BM, in Rand (winter)	Total costs with BM, in Rand (Winter)	Savings in Rand
28-Oct-17	Respondent 2	Small bag	do not know	4	20	do not know	80	NA
30-Oct-17	Respondent 3	Big bag	do not notice	4	90	do not notice	360	NA
30-Oct-17	Respondent 5	Big bag	do not know	8	95	do not know	380	NA
04-Nov-17	Respondent 6	Big bag	do not know	do not know	do not know	do not know	do not know	NA
16-Nov-17	Respondent 13	Van (10-11 bags)	do not know/ buy in bulk	5	75	do not know/ buy in bulk	375	NA
16-Nov-17	Respondent 14	Truck	do not know/buy in bulk	do not know	Not disclosed	do not know/ buy in bulk	do not know/ buy in bulk	NA
17-Nov-17	Respondent 15	Big bag	do not know	5	100	do not know	500	NA
18-Nov-17	Respondent 19	Van (10-11 bags)	do not know	do not know	700	do not know	do not know	NA
18-Nov-17	Respondent 20	Big bag	do not know/ used paraffin	1	110	do not know	110	NA
18-Nov-17	Respondent 21	Big bag	do not know/ used paraffin	2	90	do not know/ used paraffin	180	NA
19-Nov-17	Respondent 22	Truck	do not know/ buy in bulk	do not know/ buy in bulk	Not disclosed	do not know/ buy in bulk	do not know/ buy in bulk	NA
04-Dec-17	Respondent 25	Big bag	do not know	do not know	90	do not know	do not know	NA
27-Oct-17	Respondent 1	Big bag	6	4	80	480	320	160
30-Oct-17	Respondent 4	Big bag	5	2	100	500	200	300
04-Nov-17	Respondent 7	Big bag	2	1	95	190	95	95
06-Nov-17	Respondent 8	Big bag	5	2	90	450	180	270
06-Nov-17	Respondent 9	Big bag	6	4	80	480	320	160
08-Nov-17	Respondent 10	Wheelbarrow	6	4	100	600	400	200
08-Nov-17	Respondent 11	Big bag	2	1	90	180	90	90
16-Nov-17	Respondent 12	Van (10-11 bags)	2	1	90	180	90	90
17-Nov-17	Respondent 16	Big bag	11	8	90	990	720	270
17-Nov-17	Respondent 17	Small bags	5	3	20	100	60	40
17-Nov-17	Respondent 18	Big bag	4	2	90	360	180	180
02-Dec-17	Respondent 23	Wheelbarrow	8	6	60	480	360	120
02-Dec-17	Respondent 24	Big bag	9	6	120	1,080	720	360
		Total average	**5**	**3**	**85**	**465**	**287**	**180**
		Total respondents	**13**					
		Not specified	**12**					
		Grand total	**25**					

Source: Field Survey, 2017, Wesselton township

[71] A big coal bag cost R90; a small coal bag R20 and a van cost approximately R700-750. Source: Field Survey, 2017, Wesselton Township

Monthly A12 and savings per household in the summer period before and after the BM carbon offset project intervention

Date	Respondent (n=25)	Unit	Bags before BM method per month	Bags with BM method per month	Coal cost, per bag in Rand per month	Total costs before BM, in Rand per month	Total costs with BM, in Rand per month	Savings in Rand per month
28-Oct-17	Respondent 2	Small bag	do not know	do not know	do not know	do not know	do not know	NA
30-Oct-17	Respondent 5	Big bag	do not know	do not know	95	do not know	do not know	NA
08-Nov-17	Respondent 10	Wheelbarrow	do not know	do not know	100	do not know	NA	NA
16-Nov-17	Respondent 13	Van (10-11 bags)	do not know/ buy in bulk	3	75	do not know/ buy in bulk	225	NA
16-Nov-17	Respondent 14	Truck	do not know/ buy in bulk	do not know/ buy in bulk	Not disclosed	do not know/ buy in bulk	do not know/ buy in bulk	NA
17-Nov-17	Respondent 15	Big bag	do not know	1	100	do not know	100	NA
18-Nov-17	Respondent 19	Van (10-11 bags)	do not know/buy in bulk	1	75	Do not know/buy in bulk	75	NA
18-Nov-17	Respondent 20	Big bag	do not know/ used paraffin	1	110	do not know/ used paraffin	110	NA
18-Nov-17	Respondent 21	Big bag	do not know/ buy in bulk	2	90	do not know/ used paraffin	180	NA
19-Nov-17	Respondent 22	Truck	do not know/ buy in bulk	2	Not disclosed	do not know/ buy in bulk	do not know/ buy in bulk	NA
02-Dec-17	Respondent 23	Big Bag	Do not know/do not count	2	60	Do not know/do not count	120	NA
04-Dec-17	Respondent 25	Big bag	do not know	do not know	do not know	do not know	do not know	NA
27-Oct-17	Respondent 1	Big bag	2	1	80	160	80	80
30-Oct-17	Respondent 3	Small bag	5	3	20	100	60	40
30-Oct-17	Respondent 4	Big bag	2	1	20	40	20	20
04-Nov-17	Respondent 6	Big bag	5	3	95	475	285	190
04-Nov-17	Respondent 7	Big bag	2	1	95	190	95	95
06-Nov-17	Respondent 8	Big bag	2	1	90	180	90	90
06-Nov-17	Respondent 9	Big bag	2	1	80	160	80	80
08-Nov-17	Respondent 11	Big bag	2	1	90	180	90	90
16-Nov-17	Respondent 12	Van (10-11 bags)	2	1	90	180	90	90
17-Nov-17	Respondent 16	Big bag	6	4	90	540	360	180
17-Nov-17	Respondent 17	Small bags	2	1	20	40	20	20
17-Nov-17	Respondent 18	Big bag	2	1	90	180	90	90
02-Dec-17	Respondent 24	Big bag	6	4	120	720	480	240
		Total Average	**3**	**2**		**240**	**141**	**100**
		Total respondents	**13**					
		Not specified	**12**					
		Grand total	**25**					

Source: Field Survey, 2017, Wesselton township

A13 Monthly wood consumption of the Brickstar Wood stove carbon offset project

Monthly wood consumption and savings estimated per household in Burgersdorp and Bonn before and after the wood stove intervention

Date	Respondent (n=41)	Method of obtaining wood	Unit[72]	Open fire (kg/ month)	Wood stove (kg/ month)	Savings (kg/month)
28-Aug-18	Respondent 2	Buy	bakkie load	do not know	do not know	NA
29-Aug-18	Respondent 4	Buy	bakkie load	do not know	185	NA
30-Aug-18	Respondent 5	collect	bakkie load	do not know	185	NA
01-Sep-18	Respondent 10	Buy	bakkie load	do not know	do not know	NA
01-Sep-18	Respondent 11	collect	bakkie load	do not know	do not know	NA
12-Sep-18	Respondent 12	collect	bakkie load	undefined	undefined	NA
12-Sep-18	Respondent14	Buy	bakkie load	do not know	do not know	NA
12-Sep-18	Respondent 15	Buy	bakkie load	do not know	do not know	NA
13-Sep-18	Respondent 17	collect	bakkie load	do not know	do not know	NA
13-Sep-18	Respondent 20	Buy	bakkie load	do not know	370	NA
14-Sep-18	Respondent 22	Buy	bakkie load	do not know	do not know	NA
08-Oct-18	Respondent 27	collect	wheelbarrow	do not know	do not know	NA
08-Oct-18	Respondent 28	collect	wheelbarrow	undefined	undefined	NA
09-Oct-18	Respondent 30	collect	head	do not know	do not know	NA
09-Oct-18	Respondent 31	Buy	bakkie load	do not know	do not know	NA
10-Oct-18	Respondent 33	collect	wheelbarrow	do not know	do not know	NA
10-Oct-18	Respondent 34	collect	bakkie load	do not know	do not know	NA
10-Oct-18	Respondent 35	collect	bakkie load	do not know	do not know	NA
10-Oct-18	Respondent 36	collect	bakkie load	do not know	123	NA
11-Oct-18	Respondent 38	collect	wheelbarrow	do not know	do not know	NA
11-Oct-18	Respondent 40	collect	wheelbarrow	do not know	do not know	NA
11-Oct-18	Respondent 41	collect	bakkie load	undefined	undefined	NA
28-Aug-18	Respondent 1	buy	bakkie load	185	123	62
28-Aug-18	Respondent 3	collect	wheelbarrow	180	90	90
31-Aug-18	Respondent 6	buy	bakkie load	493	370	123
31-Aug-18	Respondent 7	collect	bakkie load	370	247	123
31-Aug-18	Respondent 8	collect	bakkie load	370	185	185
31-Aug-18	Respondent 9	buy	bakkie load	247	135	112
12-Sep-18	Respondent 13	buy	bakkie load	370	185	185
12-Sep-18	Respondent 16	collect	bakkie load	185	93	93
13-Sep-18	Respondent 18	collect	bakkie load	247	123	123
13-Sep-18	Respondent 19	collect	bakkie load	93	62	31

[72] Volume of a bakkie load is 370 kg. (Source: Gold Standard, Brickstar Wood Stove - Mahlaba Area, GS4536, June 2017, version 1). Volume of the wheelbarrow is 45kg. (Source: Dovie at al. 2007).

14-Sep-18	Respondent 21	buy	bakkie load	123	46	77
15-Sep-18	Respondent 23	buy	bakkie load	185	123	62
07-Oct-18	Respondent 24	collect	bakkie load	123	62	62
08-Oct-18	Respondent 25	collect	bakkie load	370	185	185
08-Oct-18	Respondent 26	collect	bakkie load	123	62	62
09-Oct-18	Respondent 29	collect	wheelbarrow	180	90	90
09-Oct-18	Respondent 32	buy	bakkie load	123	74	49
11-Oct-18	Respondent 37	collect	wheelbarrow	180	68	113
11-Oct-18	Respondent 39	collect	wheelbarrow	180	90	90
			Total Average	**228**	**127**	**101**
			Total respondents	**19**		
			Not specified	**22**		
			Grand total	**41**		

Source: Field Survey, 2018, Burgersdrop and Bonn

A14 Monthly wood expenses of the Brickstar wood stove carbon offset project

Monthly wood expenses and savings estimated per household in Burgersdorp and Bonn before and after the wood stove intervention

Date	Respondent (n=41)	Unit	Open fire (Rand/month)	WS (Rand/month)	Saving (Rand/month)
28-Aug-18	Respondent 2	bakkie load	do not know	300	NA
28-Aug-18	Respondent 3	wheelbarrow	NA	NA	NA
29-Aug-18	Respondent 4	bakkie load	do not know	do not know	NA
30-Aug-18	Respondent 5	bakkie load	do not know	do not know	NA
01-Sep-18	Respondent 10	bakkie load	do not know	do not know	NA
01-Sep-18	Respondent 11	bakkie load	do not know	75	NA
12-Sep-18	Respondent 12	wheelbarrow	NA	NA	NA
12-Sep-18	Respondent 14	bakkie load	do not know	550	NA
12-Sep-18	Respondent 15	bakkie load	do not know	do not know	NA
13-Sep-18	Respondent 17	bakkie load	do not know	do not know	NA
13-Sep-18	Respondent 20	bakkie load	do not know	do not know	NA
14-Sep-18	Respondent 22	bakkie load	do not know	do not know	NA
08-Oct-18	Respondent 27	wheelbarrow	do not know	do not know	NA
08-Oct-18	Respondent 28	wheelbarrow	NA	NA	NA
09-Oct-18	Respondent 29	wheelbarrow	NA	NA	NA
09-Oct-18	Respondent 30	head	NA	NA	NA
09-Oct-18	Respondent 31	bakkie load	do not know	133	NA
10-Oct-18	Respondent 33	wheelbarrow	NA	NA	NA
10-Oct-18	Respondent 34	bakkie load	do not know	130	NA
10-Oct-18	Respondent 35	bakkie load	do not know	160	NA
10-Oct-18	Respondent 36	bakkie load	do not know	150	NA
11-Oct-18	Respondent 37	wheelbarrow	NA	NA	NA
11-Oct-18	Respondent 38	wheelbarrow	NA	NA	NA
11-Oct-18	Respondent 39	wheelbarrow	NA	NA	NA
11-Oct-18	Respondent 40	wheelbarrow	NA	NA	NA
11-Oct-18	Respondent 41	bakkie load	do not know	80	NA
28-Aug-18	Respondent 1	bakkie load	250	167	83
31-Aug-18	Respondent 6	bakkie load	625	500	125
31-Aug-18	Respondent 7	bakkie load	250	167	83
31-Aug-18	Respondent 8	bakkie load	550	275	275
31-Aug-18	Respondent 9	bakkie load	400	218	182
12-Sep-18	Respondent13	bakkie load	500	250	250
12-Sep-18	Respondent 16	bakkie load	350	175	175
13-Sep-18	Respondent 18	bakkie load	167	83	84
13-Sep-18	Respondent 19	bakkie load	113	75	38
14-Sep-18	Respondent 21	bakkie load	167	63	104
15-Sep-18	Respondent 23	bakkie load	200	133	67
07-Oct-18	Respondent 24	bakkie load	67	33	34
08-Oct-18	Respondent 25	bakkie load	160	80	80
08-Oct-18	Respondent 26	bakkie load	137	68	69
09-Oct-18	Respondent 32	bakkie load	100	60	40
		Total Average	**269**	**156**	**113**
		Total respondents	**15**		
		Not specified	**26**		
		Grand total	**41**		

Source: Field Survey, 2018, Burgersdrop and Bonn

A15 Impact on cooking time by the carbon offset projects

A15.1 Cooking time for a single meal (samp) reported by respondents with and without the WB

Date	Respondent	Cooking time before WB (hours)	Cooking time after WB (hours)	Difference
17-Jun-17	Respondent 1	2.00	0.50	1.50
17-Jun-17	Respondent 2	4.00	0.50	3.50
24-Jun-17	Respondent 3	2.00	0.50	1.50
20-Jul-17	Respondent 4	4.00	0.30	3.70
20-Jul-17	Respondent 5	5.00	0.50	4.50
21-Jul-17	Respondent 6	3.00	0.50	2.50
22-Jul-17	Respondent 7	5.00	3.00	2.00
03-Aug-17	Respondent 8	3.00	1.50	1.50
06-Aug-17	Respondent 10	2.50	0.50	2.00
06-Aug-17	Respondent 11	2.00	1.00	1.00
08-Aug-17	Respondent 12	3.50	1.50	2.00
08-Aug-17	Respondent 13	2.00	0.50	1.50
09-Aug-17	Respondent14	3.00	2.00	1.00
09-Aug-17	Respondent 15	5.00	1.00	4.00
03-Aug-17	Respondent18	2.00	0.70	1.30
	Total Average	**3.20**	**0.97**	**2.23**
	Total respondents	**15**		

Source: Field Survey, 2017, Langa

A15.2 Cooking time for a single meal (pap) reported by respondents with and without the Wood stove

Date	Respondent	Cooking time with open fire (hours)	Cooking time with WS (hours)	Difference
28-Aug-18	Respondent 1	1.5	1.0	0.5
28-Aug-18	Respondent 3	2.0	1.0	1.0
30-Aug-18	Participant 5	2.5	1.5	1.0
31-Aug-18	Participant 6	1.5	0.75	0.8
31-Aug-18	Participant 9	2.0	1.0	1.0
12-Sep-18	Participant 12	2.0	1.0	1.0
12-Sep-18	Participant 13	1.5	1.0	0.5
12-Sep-18	Participant 16	3.0	2.0	1.0
13-Sep-18	Participant 17	0.5	0.3	0.2
13-Sep-18	Participant 18	1.0	0.75	0.3
13-Sep-18	Participant 19	2.0	1.0	1.0
13-Sep-18	Participant 20	1.0	0.5	0.5
07-Oct-18	Participant 24	1.0	0.6	0.4
08-Oct-18	Participant 28	4.0	1.0	3.0
09-Oct-18	Participant 32	1.5	1.0	0.5
10-Oct-18	Participant 33	1.0	0.5	0.5
11-Oct-18	Participant 37	1.5	1.0	0.5
11-Oct-18	Participant 38	0.7	0.5	0.3
11-Oct-18	Participant 40	1.0	0.5	0.5
	Total average	**1.64**	**0.89**	**0.76**
	Total respondents	**19**		

Source: Field Survey, 2018, Bugersdorp and Bonn

A16 Estimated water consumption for one bath per person before and after SWH carbon offset project intervention

Respondents	Bathing facility	Heating method	Capacity (litres)	Water consumption before SWH (litres)	Water consumption with SWH (litres)	Difference (litres)
Respondent 2	bathtub	Electric bucket	20	do not know	do not know	NA
Respondent 24	bathtub	Electric Kettle	1.7	8.5	do not measure/ just open the tap	NA
Respondent 1	bathtub	Electric bucket	20	20	45	25
Respondent 4	bathtub	Electric bucket	20	20	45	25
Respondent 5	bathtub	Pot & Kettle	6	10	10	0
Respondent 11	bathtub	Pot & Kettle	7.4	10	45	35
Respondent 12	bathtub	Electric Kettle	1.7	20	20	0
Respondent 18	bathtub	Electric bucket	20	25	90	65
Respondent 19	bathtub	Electric bucket	20	15	20	5
Respondent 20	bathtub	Electric bucket	20	18	45	27
Respondent 21	bathtub	Electric bucket	20	10	20	10
Respondent 22	bathtub	Electric bucket	20	30	60	30
Respondent 23	bathtub	Pot	9	9	15	6
Respondent 26	bathtub	Electric Kettle	1.7	20	25	5
			Average water consumption	**17.25**	**36.67**	**19.42**
			Total number of respondents	**14**		

Source: Field Survey, 2017, Cosmo City

Respondents	Bathing facility	Heating method	Capacity (litres)	Water consumption without SWH (litres)	Water consumption with SWH (litres)	Difference
Respondent 6	dish/basin	Electric Kettle	1.7	5	do not know	NA
Respondent 3	dish/basin	Electric Kettle	1.5	13	20	7
Respondent 7	dish/basin	Electric Kettle	1.7	10	10	0
Respondent 8	dish/basin	Electric Kettle	1.7	10	10	0
Respondent 9	dish/basin	Electric Kettle	1.7	5	5	0
Respondent 10	dish/basin	Electric Kettle	1.7	5	5	0
Respondent 13	dish/basin	Electric Kettle	1.7	10	15	5
Respondent 14	dish/basin	Electric Kettle	1.7	5	5	0
Respondent 15	dish/basin	Electric Bucket	20	15	15	0
Respondent 16	dish/basin	Tin	4	15	15	0
Respondent 17	dish/basin	Tin	4	7	7	0
Respondent 25	dish/basin	Electric Kettle	1.7	10	10	0
Respondent 27	dish/basin	Tin	4	10	20	30
Respondent 28	dish/basin	Electric Kettle	1.7	5	10	5
			Average Water consumption	**9.23**	**10.58**	**3.62**
			Total respondents	**14**		

Source: Field Survey, 2017, Cosmo City