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INFLUENCE OF BEHAVIOUR CENTRED DESIGN APPROACHES ON THE
DIFFUSION OF FLAME-BASED COOKSTOVES AMONG INDIGENT SOUTH
AFRICAN HOUSEHOLDS

by

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Thesis

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ABSTRACT

The use of energy-efficient, clean and safe cookstoves among poverty-stricken households can reduce mortality and poverty, and positively impact the protection of biodiversity and the climate (through reduced greenhouse gas emissions), as identified in the United Nations Sustainable Development Goals. Household air pollution from inefficient household cooking appliances is the third-highest global cause of disease and death, after only inadequate water, poor sanitation and malnutrition. Multiple stakeholders are implementing programmes to promote access to improved stoves and clean fuels, with the Global Alliance for Clean Cookstoves (GACC) being prominent in dissemination efforts. However, few interventions have borne fruit on a sufficiently significant scale over time, despite ample support in finding workable solutions. A sustainable transformation in household cookstove-related practices across diverse conditions requires innovative transdisciplinary social, technical and market-based approaches.

The design category of behavioural design suggests possible design approaches for addressing the complex, interrelated, social, economic and environmental challenges of energy impoverished communities in sub-Saharan Africa (SSA). Behaviour-focused design interventions exhibit the possibility of transcending disciplinary boundaries in holistic, collaborative, interactive and integrated approaches. The array of available behavioural design approaches explores the ability of a Behaviour-Centred Design (BCD) approach to change cookstove-related practices in the South African context. Furthermore, a behavioural intervention is designed and tested on a pilot scale in two representative South African sample areas.

The results demonstrate that a BCD approach can significantly change the culinary behaviours of flame-based cookstoves. This research responds to a vital evidence gap in efforts to shift inefficient cookstove-related behaviour. The study contributes evidence to applying design-led approaches in general, and BCD approaches in particular, in designing more effective dissemination strategies of improved flame-based cookstoves among impoverished communities. The BCD approach facilitated by a multiphase research design framework utilises a set of customised methods and instruments for designing, implementing and evaluating cookstove-related behavioural interventions in a South African low-income context.

Keywords: *behavioural design; behaviour centred design; household air pollution; improved cookstoves; indigent households; South Africa; sub-Saharan Africa; UN SDGs.*

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LIST OF ABBREVIATIONS AND GLOSSARY OF TERMS

Terms, Acronyms or Abbreviations	Definitions or Explanations
Adoption	refers to the taking up (i.e. ownership and initial usage) of any improved cookstove that meets the emission targets in the WHO Guidelines reliant on biomass, liquefied petroleum gas, biogas, solar, alcohol (ethanol and methanol), and electricity as an energy carrier (WHO, 2014).
BCD	Behaviour Centred Design.
BD	Behavioural Design.
Behaviour	Human behaviour in this thesis is defined as the observable sequence of actions performed by a person in relation to their environment to produce measurable results. In the context of improved cookstove dissemination interventions, a wide range of behaviours impact the causes and effects of using unimproved flame-based cookstoves.
Behaviour Centred Design (BCD)	focuses on all aspects of activities towards reconfiguring human behaviour in nutrition and health-related sectors, specifically water sanitation, nutrition, food hygiene, and recently the use of clean cookstoves. Key is the mapping of motivations in configuring an intervention.
Behavioural framework	This concept as used in this study is based on the perspective of Auger and Curtis (2014) and; considers the main factors that influence the behavioural challenge under investigation..
BoP	Bottom of the Pyramid.
Cooking	refers to the behaviours and practices embodied by cooks in preparing food for ingestion with flame-based cooking technologies.
DID	Difference in Differences.
Diffusion	refers to the targeted group of people performing a specific behaviour facilitating the diffusion of the behaviour through the population as suggested by Aunger (2006), drawing on Rogers (1995), and as applied by Barnes *et al.* (1993) and Lindgren (2020) in the cookstove-related context.
DoE	Department of Energy.
DTI	Department of Trade and Industry.
Empowerment	refers to enhancing an individual's or group's capacity to make strategic choices and translate them into beneficial actions and outcomes. This process involves improving their assets and capabilities to become agents of positive social change on their behalf.
Energy poverty	refers to poverty in developing countries associated with using modern energy services and dirty or polluting fuels.
FAO	Food and Agriculture Organization.
FBAE	Free Basic Alternative Energy.
FBE	Free Basic Electricity Programme.

Flame-based cookstoves	A household stove used for cooking, ranging from the most basic cookstoves that burn solid fuels such as biomass or coal to cookstoves that burn liquid and gaseous fuels such as paraffin or liquid petroleum gas.
FR	Formative Research.
GACC	Global Alliance for Clean Cookstoves.
Gender	Refers to the roles, behaviours and expectations of being male and female. Gender considers what a given society considers appropriate for men and women. It includes the responsibilities, social identities, power distribution and other relations between men and women. The term distinguishes the socially constructed aspects from the biologically determined aspects of being male and female (i.e. sex).
HCD	Human-Centred Design
HDI	Human Development Index
HH	Households.
Household air pollution (HAP)	The chemical, biological and physical contamination of indoor air resulting in adverse health effects. The primary source of indoor air pollution in developing countries is smoke (i.e., black soot, NO_2, SO_2, CO, formaldehyde and polycyclic aromatic hydrocarbons) from flame-based combustion stoves.
ICS	Improved Cookstove.
Igoqo	A firewood pile (symbolic designation of being a woman of good character - often used during *lobola* negotiations).
Implementation	refers to a scaled-down delivery of an intervention constructed, tested and improved over a short or long period drawing on Aunger *et al.* (2017).
Improved Cookstoves (ICS)	Stoves that require far less fuel (i.e., gas, charcoal or wood) to cook the same food quantity as a traditional stove and produce far lower emissions. An improved stove should provide significant savings and considerably reduce the amount of household air pollution.
Intervention design	encompasses the design of a structured series of interactions seeking to trigger a shift in behaviour. An intervention targets the motivations that influence our behaviour. The intervention is designed and assessed against the success in achieving the designated goal.
iziko	Xhosa translation designating a traditional fireplace.
izitshongo	Xhosa social practice of gathering firewood together in preparation for ceremonies.
LMICs	Low and Middle-Income Countries.
LPG	Liquid Petroleum Gas.
LSHTM	London School of Hygiene and Tropical Medicine.
Motivations	Motivations are the set of mental mechanisms that cause people to behave in a specific way. The fifteen motivations suggested by Aunger and Curtis (2014) are considered universal in human nature, triggering the performance of specific behavioural sequences.
NERSA	National Energy Regulator of South Africa.
NGO	Non-Governmental Organization.
NRCS	National Regulatory of Compulsory Specifications.

Participatory co-creative workshops	describe the action research method facilitating the active inclusion of final beneficiaries in designing a product or service, understanding that the final beneficiary is the expert of their own life and imagined futures. The method can empower people to imagine alternative ways of thinking and behaving and build those into their lives through products, services or systems in a simulated environment.
Pilot implementation	refers to a scaled-down delivery of an intervention constructed, tested and improved over a short period.
R Software	A software environment for statistical computing and graphics
RDP	Reconstruction and Development Programme.
RL	Reinforcement Learning.
SABS	South African Bureau of Standards.
SD	Standard Deviation.
SDGs	[United Nations] Sustainable Development Goals.
Sequences	Sequences refer to a combination of behavioural actions directed toward a particular goal
Solutions	The design process outcomes are referred to in the thesis as solutions and include physical products, services, experiences or systems.
SSA	Sub-Saharan Africa.
Sustainable development	A process for meeting human development goals while sustaining the ability of natural systems to continue to provide the natural resources and ecosystem services upon which the economy and society depend, focussing on economic development, social development and environmental protection.
Targeted population	refers to the defined sampled group of people eligible or ineligible for inclusion in the research focus to assist in the establishment of research objectives and generalise research findings.
Theory of Change (ToC)	Theory of Change (ToC) is a specific instrument for planning, participating in and evaluating behavioural change. ToC can define and map selected goals, conditions and processes and outline causal linkages for a Behaviour Centred initiative. ToCs are frequently accompanied by a mapped pathway outlining the causal linkages in a behavioural framework employed in this thesis.
Touchpoints	defined as the point of contact or interaction between people in an intervention, including experiences where there is no physical interaction.
Transdisciplinarity	Research efforts are conducted across different disciplines working jointly to create new conceptual, theoretical and methodological innovations that move beyond discipline-specific approaches to address a specific problem.
UNICEF	United Nations Children's Emergency Fund.
WHO	World Health Organization.
ZAR	South African Rand.

1 INTRODUCTION

A transition to clean and safe flame-based cookstoves among the global energy-poor could significantly advance the attainment of the Sustainable Development Goals (SDGs) adopted in 2015 by the United Nations (GACC, 2016; United Nations, 2016). This transition could reduce mortality and poverty and positively impact biodiversity and the climate through reduced greenhouse gas emissions (Martin & Euchner, 2012b; Anenberg *et al.*, 2013). Unimproved flame-based cookstoves are defined by the WHO (2011) as biomass, coal or paraffin fuelled household stoves used for cooking and heating using conventional technologies. Disproportionate deleterious health effects are attributed to these devices in low and middle-income countries worldwide. An estimated three billion people use unimproved cookstoves, resulting in 6 million premature deaths globally per year from household air pollution (HAP) alone (GACC, 2016; United Nations, 2016). The airborne pollutants affecting impoverished households are the fourth most significant cause of morbidity and mortality globally (excluding infectious diseases), after poor water quality, inadequate sanitation and malnutrition (Bruce *et al.*, 2013; Puzzolo *et al.*, 2013; WHO, 2014). By 2030, if current trends continue, HAP unimproved flame-based stoves will likely result in more premature deaths than malaria, tuberculosis or HIV/AIDS (Lim *et al.*, 2012; Yamey *et al.*, 2014).

The leading international agency in this endeavour is the Global Alliance for Clean Cookstoves (GACC) (2016), in 2018 renamed the Clean Cooking Alliance (CCA) (CCA, 2021)[1]. The GACC/CCA contends that targeted cookstove-related interventions indirectly contribute to the entire Agenda 2030 and directly impact the ten SDGs depicted in Figure 1.1. Particularly pertinent are the goals related to addressing mortality and energy poverty and positively impacting the protection of biodiversity and the climate through reduced greenhouse gas emissions. Interventions for reducing health and safety risks being developed by governments, multinational companies and non-governmental organisations must be directed at the source of the pollution (e.g., the dissemination of improved cookstoves [ICS] and fuel switching), the household environment (e.g., improved ventilation through chimneys and eaves) and changes in cookstove-related behaviour (e.g., shifting household preferences to alternatives or learning how to dry fuelwood) (Mortimer & Balmes, 2018; Shupler *et al.*, 2019; CCA, 2021).

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[1] The legal status of the Global Alliance for Clean Cookstoves and the renamed Clean Cooking Alliance is as an operating unit within a USA registered company *United Nations Foundation.* The GACC and CCA are not registered as independent corporate persona. The United Nations Foundation, despite its name, does not have any direct legal or other link as an agency or subsidiary of the United Nations.

Figure 1.1:   Ten cookstove-related Sustainable Development Goals (adapted from GACC, 2016)

Concerning achieving the ten cookstove-related SDGs, the design category of behavioural design has received increasing attention (Goodwin *et al.*, 2015; Brown *et al.*, 2017; Dieye, 2018; Jürisoo *et al.*, 2018). Over the past five years, the United Nations Development Program, UNICEF, UN Women and the United Nations Institute for Training and Research, in partnership with related agencies, have embarked on experimenting with behavioural approaches embedded in human-centred design interventions as part of a comprehensive SDG-focused approach (Kumpf & Foster, 2017). The trial designing of localised, behaviourally informed policies, programmes and initiatives to address the SDGs, specifically for gender-based violence, environmental protection and financial assistance, have shown promise (Dieye, 2018; UNHCR, 2019a, 2019b). The current focus of behavioural design approaches in cookstove-related interventions is to explore the various factors that determine the individual and household behaviours that are linked to the increased diffusion of new cooking appliances (Mosler, 2012; Johnson *et al.*, 2015; Lambe & Senyagwa, 2015; Greenland *et al.*, 2016). This attention is attributable to the success that behavioural design approaches have achieved in the related water and sanitation fields (Briscoe & Aboud, 2012; Rhodes *et al.*, 2014; Goodwin *et al.*, 2015; Strömberg *et al.*, 2015; Greenland *et al.*, 2016; Niedderer *et al.*, 2016).

1.1 Study Description

The current study investigates the role of a Behaviour Centred Design (BCD) approach in designing a shift in cookstove-related behaviour patterns in the context of under-resourced communities in South African. A localised South African research study indicated that a behavioural intervention reduced the exposure of children to hazardous air pollution by between 31% and 94% (Barnes, 2011). However, a successful shift in cookstove-related behaviour requires hybrid and flexible approaches to designing a behavioural intervention (Rhodes *et al.*, 2014; Stanistreet *et al.*, 2015). Hybrid design approaches, comprising a multiplicity of frameworks, processes, methods and tools, have become an increasingly common way of integrating theoretical models pertaining to influencing human behaviour in under-resourced contexts similar to that of South Africa (Kelley & Littman, 2001; Taha, 2011; Martin & Euchner, 2012a; Winter, 2013; Aunger & Curtis, 2015a; IDEO, 2015; Frog Design, 2018; IDEO, 2018). The design approaches in a sub-Saharan Africa (SSA) context differ significantly from the familiar approaches in industrialised economies (Seriki, 2007). The diversity and complexity of social, psychological and physical motivations, needs and desires require hybrid and flexible approaches (Castillo *et al.*, 2012). Most successful design-led interventions have applied holistic discipline-agnostic methods that facilitate creative problem-solving techniques with the primary beneficiaries resulting in tailored solutions to meet the behavioural challenge (Seriki, 2007). In this regard, the BCD approach provides flexibility in accommodating established behavioural components, with significant efforts underway to adapt the BCD approach for a variety of diverse applications (Kok *et al.*, 2016; Michie *et al.*, 2018) and build a systematised evidence base from practice-based experience (Peters *et al.*, 2015).

1.2 Problem Statement

Despite broad support for finding solutions to inefficient and dangerous cookstove-related practices, only a limited number of interventions have shown success at scale after primary donor funding has ended (Hanna *et al.*, 2012; Urmee & Gyamfi, 2014; Abdelnour *et al.*, 2020; Brakema *et al.*, 2020; Lindgren, 2020). The majority of improved cooking initiatives in SSA are characterised by a singular improved stove design introduced to resource-poor populations encompassing more than one billion individuals speaking more than 2 000 languages (Pilcher, 2016; Quinn *et al.*, 2016).

Multiple challenges remain in the successful implementation of improved cookstove interventions (Hanna *et al.*, 2012; Brakema *et al.*, 2020; Lindgren, 2020). Among the myriad of reasons cited for the lack of success is the lack of affordable improved cookstoves and fuels (Quinn *et al.*, 2016; Lindgren, 2020). Purchasing an improved cookstove is not a priority due to limited financial resources and the traditionally gendered household dynamics (Quinn *et al.*, 2016). A further reason is the lack of market-based approaches (Quinn *et al.*, 2016). The erratic quality and durability of locally available cookstoves

is a further barrier in addition to the lack of local stove distribution and marketing infrastructure (Quinn *et al.*, 2016).

An additional shortcoming of a wide range of unsuccessful cookstove dissemination programmes in the field has been the absence of appropriate behavioural design-led approaches (Barnes *et al.*, 1994, 2015; Shafer, 2019; Abdelnour *et al.*, 2020; Lindgren, 2020). Behaviour-focused approaches have frequently been relegated to the role of support mechanisms for the dissemination of a preferred stove design with little success. Most of these interventions incorporate behavioural aspects as secondary adjunct measures to the cookstove dissemination efforts (Puzzolo *et al.*, 2013). The failed approaches frequently rely on inappropriate "rational mind" approaches and "safety awareness campaigns" lacking practical knowledge on how to use, service and repair the designated improved stove (Hargreaves, 2011; Abdelnour, 2015; Barnes *et al.*, 2015; Goodwin *et al.*, 2015). Some authors attribute this lack of appropriate behavioural approaches in the design of interventions to an overreliance on technology-driven design approaches (i.e., a new, improved cookstove design) applied to complex and, at times, adversarial behavioural settings (Leggewie & Welzer, 2008; Abdelnour, 2015; Lambe *et al.*, 2018). Abdelnour (2015) ascribes this phenomenon in clean cookstove interventions to *techno-saviourism,* where an improved cookstove is expected to solve a myriad of complex and interrelated problems, while the culinary needs of impoverished women cooks are overlooked. Past interventions have frequently relied on silo-based product-centred approaches (Brezet, 1997; Brezet *et al.*, 2001; Keskin *et al.*, 2014; Khadilkar, 2017; Wood, 2017). No evidence has been found of cookstove-related initiatives in SSA intentionally using behavioural design approaches that have successfully been applied in related fields (Biran *et al.*, 2014; Goodwin *et al.*, 2015). This gap indicates a need for investigating the employment of behavioural design approaches in disseminating novel cookstove designs (Goodwin *et al.*, 2015; Johnson *et al.*, 2015; Hallsworth, 2017; Shupler *et al.*, 2019; Abdelnour *et al.*, 2020).

1.2.1 Hazards associated with flame-based cookstove use in South Africa

The failure to transition to modern household energy carriers in response to large-scale interventions in South Africa has followed the same trajectory in similar socio-economic contexts (WHO, 2009; Kimemia & Van Niekerk, 2017). Traditional solid biomass and liquid paraffin as cooking fuels persist among energy-impoverished South African households (Gevaart-Durkin *et al.*, 2014; Kimemia *et al.*, 2014). In such cases, women and young children are the household members most exposed to emissions from flame-based cookstoves (Gevaart-Durkin *et al.*, 2014; Kimemia *et al.*, 2014). Poor access to safe cooking alternatives, crowded living conditions and insufficient knowledge of the cooking fuel risks are responsible for the deleterious effects (Kimemia, 2013; Kimemia & van Niekerk, 2017). A WHO Burden of Disease meta-analysis on the hazards of HAP resulting from unimproved flame-based cookstoves estimated that HAP caused 2 500 deaths in South Africa in 2008 (Barnes *et al.*, 2009). Further negative health implications associated with the continued use of paraffin cookstoves include

burns, scalds and poisonings (Kimemia *et al.*, 2014). A significant proportion of burns in South Africa are directly linked to the conflagration of poorly designed and manufactured paraffin devices (Kimemia *et al.*, 2014). The rising burden of burn injuries has become a public health priority (Mock *et al.*, 2009; Van Niekerk *et al.*, 2022). Globally each year, over 300 000 people succumb to severe burn injuries, of which an estimated 95% occur in low and medium-income countries similar to South Africa (Mock *et al.*, 2008). Burns are among the leading causes of disability in these countries, with an estimated 11 million people worldwide requiring medical attention in 2004 (Mock *et al.*, 2008). South Africa records 1.6 million burn victims annually, 3 200 of whom require medical attention (Allorto *et al.*, 2018). The annual cost of medical care for flame-based cookstove-related burns alone is estimated to be over R320 million (WHO, 2018). The mortality rate in South Africa linked to cookstove-related burn injuries is considered one of the highest globally (Allorto *et al.*, 2018). The indirect effects include loss of income, physical disability and psychological trauma (Allorto *et al.*, 2018).

1.2.2 Behavioural design approaches in cookstove-related interventions

Over the last four decades, the need for a fundamental shift in cookstove-related behaviour in SSA in general and South Africa particularly has been identified (Barnes, 2011; Department of Energy, 2013; Evans *et al.*, 2017; Kar & Zerriffi, 2018). In this regard, the field of design can influence the interrelated patterns of human behaviour along various pathways and milestones to accomplish specific goals (Norman, 1990; Hanington, 2003; Tromp *et al.*, 2011; Hanington & Martin, 2012; Lockton *et al.*, 2012; Aunger & Curtis, 2016; Niedderer *et al.*, 2017). Irwin *et al.* (2015) and von Anshelm (2015) stress the importance of designers in exploring new paths and designing alternative approaches to meeting the challenges of securing a sustainable future. There has been an intensive and vibrant discourse on the possibilities of design influencing behaviour in under-resourced contexts (Seriki, 2007; Aunger *et al.*, 2010; Barnes, 2010; Bidwell *et al.*, 2011; Jürisoo *et al.*, 2019).

The suggested intervention approaches to assist in the transition to clean cooking solutions include direct interventions that introduce improved cookstoves, fuels and physical changes in the household setting, complemented by interventions to modify behaviour (Puzzolo *et al.*, 2013; GACC, 2016; Quinn *et al.*, 2016). The interventions mainly aim to switch to alternative fuels and uptake of improved cooking stoves (Anenberg *et al.*, 2013; Quinn *et al.*, 2016). Adopting improved cooking stoves can significantly reduce harmful emissions, provided the stoves are designed to combust locally available fuels, leading to improved combustion, reduced emissions and a better cooking experience (Bruce *et al.*, 2013; Puzzolo *et al.*, 2013). The least expensive intervention for reducing emissions is the installation of chimneys, smoke hoods, and eaves in the design of the behavioural setting (Bruce *et al.*, 2013; Puzzolo *et al.*, 2013). After that, the most significant reductions in HAP can be achieved by switching to cleaner and more efficient fuels and technologies – such as liquid petroleum gas (LPG), biogas, electricity and solar power (Bruce *et al.*, 2013; Puzzolo *et al.*, 2013). Paraffin has been excluded as a preferred

alternative fuel because of mounting evidence concerning the adverse health effects associated with the emission of fine carbon particles during its combustion (Bruce *et al.*, 2013; Puzzolo *et al.*, 2013; Van Niekerk *et al.*, 2022).

Interventions aimed at changing the cookstove-related behaviour of users can play a major role in reducing harmful emissions (Bruce *et al.*, 2013; Puzzolo *et al.*, 2013; Barnes *et al.*, 2015). Such interventions can include drying fuel wood before use or limiting the exposure of children to smoke (Quinn *et al.*, 2018). Furthermore, the behavioural approaches can prevent the incorrect use of cleaner-burning stoves and fuels observed to produce higher levels of smoke and carbon monoxide (Smith *et al.*, 2007). Nonetheless, behavioural approaches have typically been regarded as supplementary measures for cookstove-related interventions (Bruce *et al.*, 2013; Puzzolo *et al.*, 2013). Some have argued that behaviour-focused initiatives should be the initial and most important component of such interventions (Barnes *et al.*, 1994; Goodwin *et al.*, 2015; Johnson *et al.*, 2015).

Numerous applications of behavioural approaches in cookstove-related interventions have been – and continue to be – developed (Michie *et al.*, 2011; Goodwin *et al.*, 2015; Johnson *et al.*, 2015; Lambe & Senyagwa, 2015; Lambe *et al.*, 2018). However, extensive reviews of improved cookstove dissemination interventions conducted in under-resourced contexts, borne out by the empirical evidence accumulated over the last forty years, have identified a litany of failed behavioural approaches (Goodwin *et al.*, 2015; Johnson *et al.*, 2015; Evans *et al.*, 2017; Kar & Zerriffi, 2018; Lambe *et al.*, 2018). The most common behaviour-focused cookstove interventions have unsuccessfully employed rational decision-making theories focusing on the executive control system, with little evidence of success (Goodwin *et al.*, 2015).

Moreover, limited success has been attributed to applying hybrid behavioural approaches supporting the iterative design process of cookstove-related interventions (Goodwin *et al.*, 2015; Johnson *et al.*, 2015; Rosenthal *et al.*, 2017; Shan *et al.*, 2017; Jürisoo *et al.*, 2018). Interventions focusing on the human motivations for using an improved cookstove, as described by Aunger and Curtis (2016), are non-existent.

1.2.3   Behavioural design approaches

Behavioural design approaches encompass the design of interventions to encourage the diffusion of the desired behaviours (Catania *et al.*, 1990; McDonald *et al.*, 2002; Bhamra *et al.*, 2011; Tromp & Hekkert, 2014, 2017, 2018; Aunger & Curtis, 2016; Niedderer *et al.*, 2016; Cash *et al.*, 2017). Behavioural design approaches are not limited to describing behaviour; as Simon (1969) argues, they engage in changing behaviour. The growing importance of a behaviour-focused approach to designing products, services or systems indicates a significant shift in the relationship between design and the behavioural sciences (Unteidig *et al.*, 2017). As a result, design theory and practice have transitioned from the design of individual products to examining and influencing the increasingly complex relationships between

products and people, encompassing physical, psychological, social and cultural elements (Laurel, 2003; Gamman *et al.*, 2007; Morelli, 2007; Saco & Goncalves, 2008). In this regard, a growing body of design-led approaches seeks to facilitate sustained changes in human behaviour (Cottam, 1997; Sangiorgi, 2011; Ceschin, 2014; Pufé, 2014; Vezzoli *et al.*, 2014; Burns *et al.*, 2015; Erlhoff, 2015; Niedderer *et al.*, 2016).

The design of experiences and services has highlighted the increasing need to understand the relevant behavioural determinants and desired behavioural outcomes that affect the lives of the people the designer intends to serve – identifying and classifying influences that shape behaviour are frequently employed in designing user experiences (Tromp *et al.*, 2011). Therefore, the concomitant deliberate focus on changing behaviour required the redefinition of the designer's role (Tromp *et al.*, 2011). In this regard, a behavioural design approach has demonstrated the ability to design interventions that encourage or inhibit the performance of a desired behavioural pattern (Catania *et al.*, 1990; McDonald *et al.*, 2002; Bhamra *et al.*, 2011; Tromp *et al.*, 2011; Tromp & Hekkert, 2014, 2017, 2018; Aunger & Curtis, 2016; Niedderer *et al.*, 2016; Cash *et al.*, 2017).

Nonetheless, the design of interventions for influencing behaviour has been based – in most cases unintentionally – on various underlying behavioural theories (Becker, 1974; Bandura, 1986; Ajzen, 1991; Schwarzer, 2008; Michie *et al.*, 2011; Mosler, 2012). Designers frequently appropriate behavioural theories to influence behaviour, using practical behaviour centred approaches in both private and public sectors (Coughlan *et al.*, 2007; Junginger *et al.*, 2009; Wendel, 2013; Skowno, 2016; Fischer, 2017; Niedderer *et al.*, 2017). Numerous theoretical approaches exist to design behavioural interventions that mediate between the underlying theoretical inconsistencies and the perceived limitations of the specific theoretical approach applied in practice (Niedderer *et al.*, 2016). The theoretical approaches to designing for behaviour change applied in design practice span a broad spectrum and are broadly drawn from psychology, sociology, economics, marketing and the natural sciences (Nutbeam *et al.*, 2010; Niedderer *et al.*, 2017).

Expanding on the definition of behavioural design introduced by Norman (1990), the category of behavioural design encompasses a wide array of design approaches which have emerged over the last decade to effect a behaviour change (Lockton *et al.*, 2013; Aunger & Curtis, 2016; Niedderer *et al.*, 2017). A comprehensive review of all the theoretical approaches underpinning design-led behavioural approaches is considered impossible (Goodwin *et al.*, 2015; Niedderer *et al.*, 2017). Notably, Davis *et al.* (2015) identified 83 broad theoretical approaches with 1 725 frameworks or models in the peer-reviewed literature. In addition, many theoretical approaches are mutually incompatible, relying on contradictory theoretical foundations (Fehr & Gintis, 2007). However, using the categories that influence behaviour suggested by Niedderer *et al.* (2017), design-led interventions are distinguished by individual psychological approaches, context-based socioeconomic approaches, and hybrid

combinations of the individual and context-based approaches discussed below. A concise overview of behavioural theories, approaches, models and frameworks is provided in Appendix II.

Individual behavioural approaches

Individual approaches in behavioural design interventions frequently focus on creating a conscious awareness of a specific problem or targeting a specific pattern of behaviour or area of interest (Lilley, 2009; Fogg & Hreha, 2010; Niedderer *et al.*, 2016). Common in design-led interventions is the appropriation of individual psychology-based behavioural approaches to assist the designer as an agent in understanding the needs and desires (i.e., mindsets, personas or roles) of a targeted segment of the population (Young, 2008; Loeffler *et al.*, 2013; Norman, 2014; Sax & Clack, 2015; Hurtienne, 2017). Despite weak empirical evidence of success, numerous individual behavioural approaches, derived models, and frameworks have been observed in practice (Becker, 1974; Rosenstock *et al.*, 1994; Nutbeam *et al.*, 2010). The failure has been attributed to the lack of a clear link between the perceived severity of the problem and the perceived benefits of and barriers to a change in the behaviour of the targeted individual (Becker, 1974; Rosenstock *et al.*, 1994; Nutbeam *et al.*, 2010). The failure has also been attributed to a lack of consideration for other contextual factors of the material and social environment (Becker, 1974; Rosenstock *et al.*, 1994; Nutbeam *et al.*, 2010). The most prominent behavioural approaches include the theory of planned behaviour, the health belief model, and the stages of change model (Ajzen, 1991; Rosenstock *et al.*, 1994; Ludden & Hekkert, 2014; Tidwell *et al.*, 2019a) and its many derivatives (Velicer & Prochaska, 2008).

Over the last four decades, individual behavioural approaches in SSA improved cookstove-related interventions have resembled predominantly conscious cognitive behavioural approaches rooted in rational choice theory (Bicchieri, 2016). The approaches have primarily relied on providing information and increasing knowledge about the health risks when using flame-based cookstoves through safety awareness campaigns (Brug *et al.*, 2008; Mosler, 2012). Such conscious cognitive approaches are frequently based on the rational choice theory of value exchange, which assumes that individuals rationally and consciously make decisions to maximise their benefit and happiness (Tversky & Kahneman, 1981; Sen, 1994; Kahneman, 2003; French & Gordon, 2015). To this end, financial subsidies for cleaner cooking fuels are frequently applied to promote diffusion among impoverished communities (Shankar *et al.*, 2014). The financial subsidies intend to connect to the human behavioural response of setting goals linked to household aspirations by linking the suggested use of cooking appliances to receiving future financial rewards (Shankar *et al.*, 2014).

Context-based behavioural approaches

Most behavioural design interventions that seek to influence behaviour draw on context-based theoretical approaches (Niedderer *et al.*, 2017). Context-based approaches focus on the surrounding context of material and institutional elements required for enacting a set of behaviours (Hargreaves,

2011; Montani *et al.*, 2014). Contextually driven models attempt to understand, overcome or exploit cognitive biases by structuring the environmental context (Thaler *et al.*, 2014; Niedderer *et al.*, 2017). Incorporating a context-based approach to engaging with local culinary behaviours is foundational for successful intervention for disseminating improved cookstove-related behaviours (Akintan, 2014; Barnes, 2014; Simon *et al.*, 2014; Soini & Coe, 2014; Akintan *et al.*, 2018). Past interventions have failed to consider that cookstove-related behaviour is situated in a complex behavioural context and influenced by interrelated socio-institutional and physical factors (Lambe *et al.*, 2018). The lack of focus on local culinary behavioural contexts is especially evident in failed initiatives, with novel cookstove designs promising improved health being parachuted into communities accompanied by ill-conceived and superficial awareness campaigns (Xu *et al.*, 2003; Thurber *et al.*, 2013; Golden *et al.*, 2015; Rosenthal, 2015). Examples of context-driven theoretical models include the mental models approach (Lockton *et al.*, 2012, 2013; Chatterton & Wilson, 2014). References have been made to the nomenclature of the choice architecture model (i.e., the "nudge" approach) for cookstove-related interventions, yet no clear theoretical links have been made between either model and such interventions (Smith *et al.*, 2007; Dolan *et al.*, 2012; Chatterton & Wilson, 2014; Thaler *et al.*, 2014; Cash *et al.*, 2017).

Hybrid behavioural approaches

There is increasing recognition of the need to combine behavioural theory individual and contextual aspects to provide a hybrid approach that addresses the complexities of designing for behaviour change (Niedderer *et al.*, 2016). A flexible and hybrid approach can assist in guarding against the danger of the implicit assumptions of the intervention designer (or group of designers who originate from different social backgrounds) influencing the intervention design process and outcome, leading to remote design interventions parachuted in with little effect (McClelland & Suri, 2005; Ramirez, 2010; Ambole *et al.*, 2012; Castillo *et al.*, 2012). Hybrid behavioural approaches are frequently applied in practice, including the motivation, opportunity and ability model of Rothschild (1999) and the community-based social marketing model of McKenzie-Mohr (2000). Recent hybrid theoretical approaches incorporating behavioural economics, social marketing and evolutionary psychology have demonstrated modest success (Sunstein & Thaler, 2008; Brown, 2009; Anand & Lea, 2011; Aunger & Curtis, 2016). Hybrid approaches applied in under-resourced contexts include aspects of social cognitive theory (Meichenbaum, 1977; Bandura, 1986), social practice theory (Shove *et al.*, 2012), social marketing (Lee & Kotler, 2011) and behaviour centred design (Aunger & Curtis, 2016).

1.2.4 Behaviour centred design approaches for a low-income context

Of the SDG-focused approaches being explored in practice, the Behaviour Centred Design (BCD) approach, in particular, has been successfully applied in interventions aimed at disseminating desired

behaviours (Biran *et al.*, 2014; Doyle, 2016; Greenland *et al.*, 2016; White *et al.*, 2016; Gautam *et al.*, 2017; Tidwell *et al.*, 2019b; Morton *et al.*, 2020).
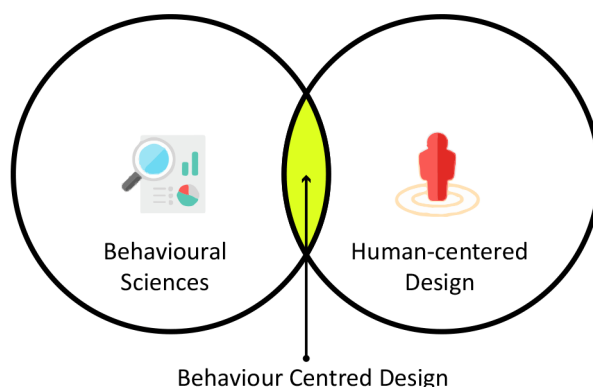
Figure 1.2:   Behaviour Centred Design (BCD) approach in context (Aunger & Curtis, 2016)

The BCD approach has succeeded in WASH (water, sanitation and health) interventions in low-income contexts, including India, Zambia, Nepal and Indonesia (Biran *et al.*, 2014; Rajaraman *et al.*, 2014; Greenland *et al.*, 2016). Successful applications include the *SuperAmma* programme in rural India, which successfully linked handwashing with soap to being a nurturing mother, assisted by the placement of stickers depicting pairs of watchful eyes in washing areas and reported an increase in handwashing with soap from 1% at baseline to 29% a year later (Biran *et al.*, 2014; Gautam *et al.*, 2017). In urban Zambia, the *Komboni Housewives* project, which revalued the prevention of diarrhoea prevention behaviour through live and filmed performances of a group of gossiping neighbours, achieved lower levels of success, which were attributed to the limited reach achieved by the interventions into the community (Gautam, 2015; Greenland *et al.*, 2016; Greenland, 2017).

The BCD approach (Figure 1.2) developed by the London School of Hygiene and Tropical Medicine includes a human-centred design process drawing on design thinking and creative practice pioneered by the design and consulting firm IDEO (Coughlan *et al.*, 2007; Aunger & Curtis, 2016); and a constructive research approach drawing on the current developments in behavioural science (Aunger & Curtis, 2016). The BCD approach combines aspects of behavioural and environmental psychology with social marketing to design and evaluate innovative behavioural interventions (Aunger & Curtis, 2016). The approach considers how the multiple behaviour-related biophysical, social and material environments influence the individual human brain and body within a specific context (Neal *et al.*, 2006; Wood & Neal, 2007; Rajaraman *et al.*, 2014; Greenland *et al.*, 2016; White *et al.*, 2016; Gautam *et al.*, 2017; Burns *et al.*, 2018; Tidwell *et al.*, 2019a). The model accentuates the role of motivations and the critical aspects in a local behaviour setting to ensure the repeated performance of a targeted behavioural goal (Aunger & Curtis, 2014).

1.3 Main Research Question

The main research question is to ascertain whether a BCD approach can influence the diffusion of improved domestic flame-based cooking technologies among impoverished South African households. To begin with, which aspects of a BCD approach are critical in successful behavioural interventions disseminating improved cookstoves in a South African context? Moreover, can the critical aspects of a BCD intervention for influencing a positive shift in South African flame-based cookstove-related behaviour be developed? Can selected aspects of a BCD intervention successfully influence flame-based cookstove-related behaviour leading to the increased dissemination of improved flame-based cookstoves by a representative sample of impoverished South Africans? Finally, the question arises whether applying a BCD approach can achieve a significant dissemination of improved flame-based cookstoves in a representative South African context.

1.4 Aim and Objectives

The main research aim of this thesis is to establish a BCD approach as an effective intervention strategy for positively influencing the dissemination of improved flame-based cooking technologies among a representative sample of impoverished South African households.

The following research objectives have been identified:

i. To carry out a literature-based appraisal of the critical aspects of a BCD approach appropriate for behavioural interventions seeking to increase the diffusion of improved cooking technologies in impoverished contexts similar to South Africa.

ii. To design a research framework for evaluating a BCD approach to positively influence the dissemination of improved flame-based cooking technologies in a South African context.

iii. To conduct a case study-based assessment of selected aspects of a BCD approach seeking to influence cookstove-related behaviours linked to the dissemination of improved flame-based cookstoves in a representative South African community.

iv. To assess the effectiveness of a pilot implementation of a BCD intervention in influencing flame-based cookstove-related behaviour in two selected South African communities.

v. To evaluate whether a BCD approach can contribute to achieving a significant dissemination of improved flame-based cookstoves in a representative South African context.

1.5 Research Scope

The research scope of the study spans the design category of behavioural design, BCD, flame-based cookstove-related interventions and the specific behavioural aspects relevant for a successful transition to cleaner, safer and healthier behaviours related to flame-based cooking devices among South African

indigent households. The essential aspects of BCD processes, mechanisms and frameworks are applied and evaluated.

The design and implementation of an entire BCD intervention exceed the scope of the study. The technical aspects of cooking appliances and fuels were excluded from the study. Coal-fired stoves are excluded because of their localised use on the Mpumalanga and Gauteng Highveld. The thesis intends to obtain insights that could be generalised to broader applications.

1.6   Research Focus

The research focus of this thesis is on the behavioural aspects related to flame-based cooking to provide evidence of success in cookstove-related interventions. The thesis seeks to confirm the benefits of behaviour centred design approaches in the design and implementation of improved cookstove dissemination efforts. The design of new appropriate behavioural interventions aims to increase the diffusion of clean cookstoves by affected households in South Africa and beyond.

1.7   Research Relevance

The thesis strengthens the case for behaviour-focused design approaches in general and a BCD approach when addressing inefficient cookstove-related practices among emerging and low-income communities. The thesis seeks to establish the relevance of BCD approaches as a necessary condition for the accelerated reduction of the use of unsafe and inefficient cookstoves at a scale sufficient to make inroads into the levels of poverty outlined in the SDGs. The scale and severity of the health and safety effects attributed to the flame-based cooking of more than three billion people require a large-scale and urgent response from academia, policymakers, governments, implementing organisations, governments and the donor community. The continued widespread use of inefficient cookstove-related behaviour among impoverished communities – with their associated adverse health effects – warrants the urgency of finding a solution to this persistent problem in South Africa. Previous studies have not discussed the application of behaviour-focused design strategies that aim to transform the culinary behaviour patterns related to the flame-based cooking appliances of South African households.

1.8   Limitations of the Study

The study is limited to a single case validated by implementing the BCD intervention at a pilot scale in two representative sample areas. The time constraints limited the replication of pilot implementations in other areas of South Africa. The detailed assessment of current stove designs found in the literature or the plethora of behavioural design research methods and techniques with the following aspects of the investigation were outside the scope.

1.9   Thesis Outline

This thesis is guided by a BCD research approach in the investigation of the main research aim, drawing on Van Aken (2004), Hevner *et al.* (2004), and Peppers (2006) as applied in BCD practice (Gautam, 2015; Aunger & Curtis, 2016; Aunger, White, Huberts, *et al.*, 2017; Greenland, 2017; Tidwell *et al.*, 2019a). The first part consists of a literature review structured into two sections: a review of the critical aspects of a BCD approach and an analysis of selected improved cookstove dissemination interventions (Chapter 2). The literature review is followed by an in-depth description of the research framework (Chapter 3). The research methodology (Chapter 4) describes the design and implementation of a BCD intervention in a representative South African context, preceded by an appraisal of the critical behavioural factors that influence the use of flame-based cookstoves. Chapter 5 presents the results of applying a BCD approach assessed during the case study. In Chapter 6, the thesis culminates with conclusions and discussions of the implications of the research findings accompanied by recommendations. A summarised overview of the critical case-based study design, delivery and evaluation is included at Appendix I.

1.9.1   Chapter outline

Chapter 1: Introduction

The introduction provides a broad overview of the research study. The problem statement reviews the main themes (i.e., how BCD-based interventions could lead to safe and clean cookstove-related culinary practices). The main research aims and objectives are outlined. The relevance is grounded on the proven knowledge of the mounting human cost associated with inefficient cookstoves and the inherent urgency of finding a viable solution. The scope and focus of the study are outlined, followed by an abridged thesis and chapter outlines, and concluded with the study limitations.

Chapter 2: Literature review

The second chapter reviews literature relevant for designing and evaluating behaviour centred interventions that influence human behaviour. The BCD approach is reviewed, followed by a summarised description of the pertinent behaviour-focused aspects. The chapter concludes with an analysis of flame-based cookstove-related initiatives in South Africa.

Chapter 3: Research design

The third chapter discusses the research design. First, the research paradigm is outlined. The ontological, epistemological and axiological perspectives are provided, culminating in a discussion of the case study-based research framework to facilitate the research. Descriptions of research methods and instruments are drawn from the reviewed repositories accessed for the study.

Chapter 4: Research methodology

The fourth chapter describes the research methodology for designing the pilot BCD intervention. The steps of the multiphase process are followed and documented iteratively, with the results of each step informing the next, resulting in a testable behavioural intervention. The intervention is evaluated with a pilot implementation in a representative study area in South Africa. Finally, the researcher triangulates the results of each phase of the methodology to find valid and reliable evidence for the necessity of a BCD approach in influencing the diffusion of improved cooking technologies.

Chapter 5: Results and discussion

The intermediate results in the design of the intervention are presented first. The resultant pilot intervention is described, and the results of its implementation are provided. The triangulation methodology outcomes are described, comparing the literature-based review, the research design framework and the results of the pilot study implementation. The triangulated results are accompanied by a discussion of the research results in achieving the main research aim – the necessity of BCD approaches in the dissemination of improved cooking technologies in South Africa.

Chapter 6: Conclusions and recommendations

The final chapter summarises results derived from the design of the intervention and the resultant analysis of pilot implementation in the target area. The results for each research objective are outlined, building an argument that answers the central research question of the thesis. The proven necessity of BCD approaches in achieving a significant dissemination of safe and energy-efficient cookstoves among indigent South African households is discussed. The thesis concludes with recommendations for implementing BCD strategies in South Africa and beyond.

2 LITERATURE REVIEW

This section reviews a BCD approach for potentially improving flame-based cookstove use in a South African context.

The literature review provides an introductory overview of the BCD approach of Aunger and Curtis (2016). A brief summary is provided of the critical aspects contributing to the success of the BCD approach in contextually relevant Water, Sanitation and Hygiene (WASH) applications. Reviews of mismatch theory, behaviour setting theory and reinforcement learning theory are complemented by a summary of the behavioural motivations theory applied in BCD practice. Critical aspects of the phase-based process of designing an intervention are summarised.

In addition, the leading behavioural approaches underpinning interventions attempting a shift in cookstove-related behaviour in practice are discussed. Aspects pertinent to designing behaviour centred approaches in cookstove interventions for under-resourced contexts are summarised. A review of the essential aspects for designing a behaviour centred intervention in a South African context is provided. A literature analysis of contextually appropriate improved cookstove interventions is conducted. The analysis concludes with a summary of the elements pertinent for a successful behaviour centred design intervention.

2.1 Selected Aspects of a BCD Approach for Designing Interventions

The incorporation of behaviour-focused approaches is considered instrumental when designing interventions to improve the health and safety of women and children affected by the use of flame-based cookstoves and fuels (Puzzolo *et al.*, 2013; Michie *et al.*, 2014; Davis *et al.*, 2015; Rosenthal *et al.*, 2018). According to Torondel *et al.* (2019), the pioneering BCD approach to WASH and complementary food hygiene interventions has achieved significant success in South Asia and SSA. While intentional BCD approaches, as proposed by Aunger and Curtis (2016), are absent in current cookstove initiatives, the application of behaviour-focused approaches can be found in numerous initiatives for influencing cookstove-related behaviour (Thandapani & Woodbridge, 2011; Gadgil, 2012; Kshirsagar & Kalamkar, 2014; Stanistreet *et al.*, 2015; Hallsworth, 2017; Jürisoo *et al.*, 2018). The BCD approach of Aunger and Curtis (2015a, 2016) uses a well-validated theoretical approach as the foundation for formulating a behavioural intervention facilitated by a range of behavioural theories, methods, techniques and instruments.

The approach as gleaned from literature proposes a phase-based design process, incorporating human-centred design methods into the design, implementation and evaluation of behavioural interventions (Aunger & Curtis, 2016; Tidwell *et al.*, 2019b).

2.1.1 The BCD Approach to Water, Sanitation and Hygiene

The phase-based approach to designing and implementing behavioural interventions emerged as a critical contributor to the success of WASH applications conducted since 2010 under the auspices of the Sanitation and Hygiene Applied Research For Equity (SHARE) consortium (Torondel *et al.*, 2019). The BCD approach arose from the need to achieve universal access to appropriate, sustainable and equitable sanitation and hygiene. The interventions primarily concentrated on disseminating handwashing with soap to lower the risk of respiratory and gastrointestinal diseases and preventable child deaths. The critical aspects of the BCD approach gleaned from the main WASH implementations are discussed in the following summarised interventions.

SuperAmma in India

The *SuperAmma* initiative in rural India is the first intervention employing the BCD approach in successfully disseminating the washing of hands with soap (Biran *et al.*, 2014). In partnership with a local creative agency, the intervention focused on the primary motivations of nurture and status informed by the formative research findings (Biran *et al.*, 2014). The campaign was developed through several iterations (Biran *et al.*, 2014). The emphasis on aesthetic features was vital in ensuring the campaign evoked aspirational feelings appropriate to the local context (Biran *et al.*, 2014). The campaign was delivered to several rural communities in India in six days, spread over 25 days (Biran *et al.*, 2014). The intervention was carried out by street theatre performers, effectively engaging the crowd and establishing confidence in the behaviour change efforts (Biran *et al.*, 2014). An entertaining motivational animation accompanied the live events (Biran *et al.*, 2014). The intervention concluded with an evaluation of the success of the intervention by measuring the length of time spent by the targeted population washing hands with soap before and after the intervention implementation (Biran *et al.*, 2014).

Safe Food Healthy Child campaign in Nepal

Applying the findings of the *SuperAmma* intervention, the *Safe Food Healthy Child* campaign in Nepal consisted of a comprehensive community-based intervention in a rural context to change attitudes linked to weaning food hygiene. The campaign used a fictional, idealised mother figure practising good hygiene to seek the participation of mothers in the local neighbourhood. The intervention sought to alter local food preparation sequences and change related factors in the surrounding social and physical culinary setting. The campaigns were conducted over three months by local female change agents. The women facilitated activities that included playing structured games accompanied by the facilitator narrating a story linking critical moments in the game to motives of status, affiliation, aroma, and nurture (Gautam *et al.*, 2017). The intervention concluded with an assessment of the changes in the performance of the five targeted hygiene-related behaviours at baseline and endline, assisted by an observational study (Gautam *et al.*, 2017).

Hygiene intervention to reduce weaning food contamination in Bangladesh

A further SHARE-funded intervention to reduce food contamination in rural Bangladesh applied the BCD approach (Islam *et al.*, 2013). The results demonstrated a significant decrease in food contamination in response to the intervention (Islam *et al.*, 2013). The structured assessment of the behavioural outcomes of the Bangladesh intervention was furthermore considered essential in addressing the significant gaps of knowledge connected to WASH behaviour change interventions (Islam *et al.*, 2013).

Hygienic food handling promotion intervention in the Gambia

A further adaptation of the Nepalese intervention was conducted in the Gambia to enhance the food-related hygiene behaviours of local mothers (Manjang *et al.*, 2018). The community-based intervention integrated the performing arts over four days. The campaign was facilitated by artists and behavioural communication specialists with experience in health promotion (Manjang *et al.*, 2018). The campaign materials from the Indian and Nepalese interventions were reproduced and reused essentially unchanged and successfully engaged the target audience (Manjang *et al.*, 2018). Home visits were added after six months to reinforce the targeted behaviours (Manjang *et al.*, 2018). The Gambia intervention assessed the change in people's attitudes around food safety and contamination at the community-level. The assessment included measuring the setting down of clean dishes on clean surfaces. In addition, levels of diarrhoea were assessed (Manjang *et al.*, 2018).

Safe Start Kenya

As part of the *Safe Start* initiative in Kenya, a BCD approach was employed to design and deliver behaviour change campaigns in a select group of informal urban settlements (Aseyo *et al.*, 2018). Direct observation of infant food preparation and feeding helped shape the design of the intervention (Aseyo *et al.*, 2018). The interventions in Kenya were carried out by local community health workers and volunteered with little success (Aseyo *et al.*, 2018). A critical failure was the lack of training in behaviour change communication techniques provided to unpaid volunteer healthcare workers (Aseyo *et al.*, 2018). In addition, no comprehensive intervention strategy was created during the intervention design process (Aseyo *et al.*, 2018).

San-Dem Project in Zambia

The *San-Dem* project developed an innovative behavioural intervention to raise demand for improved toilets in urban Zambia (Tidwell *et al.*, 2019b). First, a thorough formative literature-based assessment of the factors linked to locally available sanitation was conducted (Tidwell *et al.*, 2019b). The assessment identified motives of comfort, status, disgust, and fear as critical to improving cleanliness in the Zambian context. A motive mapping technique was employed where participants were shown visuals or text relating to the fifteen human motives suggested by Aunger and Curtis (2013) and asked to evaluate or rate them. The research team used a co-creative workshop with officials from Lusaka's administration and local sanitation experts to

develop initial campaign concepts (Tidwell *et al.*, 2019b). Guided by a creative brief, a reputable local creative agency designed the final intervention campaign (Tidwell *et al.*, 2019b).

Mikono Safi Handwashing Initiative in Tanzania

Mikono Safi, a handwashing initiative targeted selected schools in northeast Tanzania to lower helminth infections among schoolchildren, employed formative research and pilot interventions before designing a fully-fledged intervention (Okello *et al.*, 2019). Qualitative interviews with children indicated perceptions of handwashing closely related to nurturing motives, while the lack of handwashing linked to disgust motives (Okello *et al.*, 2019).

2.1.2   Theoretical foundations of the BCD approach

The theoretical foundations of the BCD approach offer a novel understanding of how psychological and environmental factors determine human behaviour, incorporating diverse theoretical perspectives on behaviour (Aunger & Curtis, 2016). Such theoretical perspectives span evolutionary, ecological and cognitive psychology, neuroscience, robotics, behavioural economics, social marketing and human-centred design (Aunger & Curtis, 2016). The BCD theoretical approach explores and formulates the behavioural determinants in a specific behaviour setting underpinned by the mismatch theory (Nesse & Williams, 1998; Eaton *et al.*, 2002; Curtis & Aunger, 2012; Giphart & van Vugt, 2018), a revised version of behaviour settings theory (Barker, 1968), the human motivations theory and reinforcement learning theory (Aunger & Curtis, 2015a; Giphart & van Vugt, 2018). Essential to the BCD approach is incorporating behavioural theories linked to the human body and brain (Aunger & Curtis, 2016). The field of neuroscience has established that the biophysical human body and brain have acquired – over a long evolutionary timespan – intertwined systems that determine human behaviour (Rolls, 1998; Daw *et al.*, 2006, 2011; Dayan *et al.*, 2006; Wunderlich *et al.*, 2012). The individual behavioural determinants are categorised in scientific literature as the reactive, motivated and executive behaviour control systems (Aunger & Curtis, 2015b).

Most human behaviour consists of automatic responses learnt through repeated behavioural sequences to form a habit (Neal *et al.*, 2006). The reactive mechanisms of the human brain produce near-instant responses to stimuli in a behaviour setting, often without the person being aware of them (Neal *et al.*, 2006). An example is ducking from a sudden threat (Aunger & Curtis, 2016). Behavioural sequences are formed as the body repeatedly becomes accustomed to exposure to a stimulus (Aunger & Curtis, 2016). The reactive behaviour continues even in the temporary absence of the stimulus (Everitt & Robbins, 2005). An example of facilitating the performance of a behavioural goal in an intervention is the creation of a habit by rewarding the repetition of a behavioural sequence until a regularly occurring routine is established in a stable behaviour setting (Aunger & Curtis, 2016).

The failure of many behavioural interventions is attributed to an excessive focus on conscious cognitive approaches (i.e., the planning of behaviour), despite evidence suggesting that this part of human behaviour is reserved only for particular and unusual situations (Wilson, 2004, 2011). The ability to consciously imagine alternative futures and plan a course of action is a crucial human ability (Wilson, 2004, 2011). Nevertheless, its importance is overstated due to the failure of an intervention to distinguish between the various mental determinants of human decision-making (Webb & Sheeran, 2006; Harkin *et al.*, 2016). Health psychologists now acknowledge the importance of subconscious decision-making processes (Sheeran *et al.*, 2013), making a distinction made between long and short-term determinants of behaviour in behavioural interventions (Sheeran *et al.*, 2013).

The overwhelming majority of human behaviours are linked to underlying motivations linked to the body and brain. In contrast, the minority behaviours we are consciously aware of are linked to the brain's executive control system (Aunger & Curtis, 2016). The main theoretical perspectives are described separately in the following three subsections.

Mismatch theory

The first component of the BCD approach of identifying the behavioural need or challenge is underpinned by mismatch theory, which is drawn from the field of evolutionary biology (Aunger & Curtis, 2016; Li *et al.*, 2018). Behaviour generates a pleasurable feeling by rewarding the dopamine-generating pathways of the brain, leading to a higher likelihood of a behaviour being repeated (Aunger & Curtis, 2016). A mismatched behaviour detrimental to human health occurs when the behaviour is reinforced through short-term rewards despite long-term adverse side effects (Byrnes *et al.*, 1999; Henderson, 2008). This mismatch to our ancestral environments occurs in all life – including humans (Nesse & Williams, 1998; Eaton *et al.*, 2002; Curtis & Aunger, 2012). In hunter-gatherer societies, this evolutionary reward system was beneficial for human flourishing, yet the rapidly changing environments led to unhealthy and dangerous consequences (Aunger & Curtis, 2016). Rapid changes in our material and socio-institutional environments (i.e., urbanisation) imply that established behavioural patterns result in unhealthy repercussions over the long term (Hall & Fong, 2007). Examples of mismatch include the preference for sweet energy-intensive foods that used to be rare but have become plentiful and cheap (Spinella, 2003; Giphart & van Vugt, 2018).

Behaviour setting theory

In framing the context of an intervention, applications of the BCD approach incorporate aspects of a simplified behaviour setting theory (Barker, 1968). Behaviour setting theory provides a powerful tool for conceptualising how behaviour is situated in a specific context (Goffman, 1959; Barker, 1968; Tharp *et al.*, 1988; Shove *et al.*, 2012). A framed behaviour setting, drawing on the choice architecture approach, reduces the need for cognitive load, requiring little conscious attention of participants (Sunstein & Thaler, 2008; Just & Wansink, 2009). A behaviour setting refers to local sequences and

things required to perform a behavioural routine (Barker, 1968). The objects, places and people interact in the behaviour setting to achieve a specific behavioural goal (i.e., a band playing music or someone preparing a meal). Behaviour setting theory is considered a highly accurate predictor of individual behaviour (Barker & Schoggen, 1973; Zimbardo, 2007; Meyer *et al.*, 2009; Rauthmann & Sherman, 2015). BCD practice frequently employs the theatrical metaphors used by behaviour setting theory (i.e., stages, roles and props) in designing a behavioural intervention (Aunger & Curtis, 2016). These metaphors describe the physical location and objects (i.e., the place and props required for the behaviour to be performed) and the roles of the participating people (Aunger & Curtis, 2016).

Reinforcement learning theory

The design of a BCD intervention is informed by the latest developments in reinforcement learning theory (Sutton & Barto, 1998; Botvinick *et al.*, 2009; Doll *et al.*, 2012; Niv *et al.*, 2012; DeWitt, 2014; Yoon, 2015). Reinforcement learning is the dominant theory in neuroscience, psychology, robotics and organisational management for explaining how feedback from interactions with the environment shapes our motivations and the resulting behaviour (Sutton & Barto, 1998). Reinforcement learning holds that changes in our immediate environment that unexpectedly signal levels of reward linked to the performance of a targeted behaviour will lead to a revaluation of the motivations for the targeted behaviour, in turn leading to the performance of a targeted behavioural sequence (Kaelbling *et al.*, 1996; Dolan *et al.*, 2012; Aunger & Curtis, 2015b). Daily behaviour consists mainly of repeating past behavioural actions, most performed subconsciously in response to perceptual inputs from our environment (Sutton & Barto, 1998). We receive a perceptual input at each point of interaction during a behavioural sequence (Aunger & Curtis, 2015a). We mostly subconsciously decide on a course of action leading to a behavioural response (Aunger & Curtis, 2016). The environmental effect of the behavioural response is again perceived by us (Aunger & Curtis, 2016). The perceived environmental effect is a reinforcement signal to our brain and body (Aunger & Curtis, 2016). A positive reinforcement triggers a particular behavioural sequence (i.e., eating tasty food soothes hunger) (Aunger & Curtis, 2016).

Behavioural motivations theory

Unique to the BCD approach is successfully incorporating the human motivations linked to a specific behavioural sequence (Aunger & Curtis, 2016). The motivations directing nearly all human behaviour are attributed to the psychological mechanisms arising primarily from evolutionary adaptations (Aunger & Curtis, 2008, 2013, 2015b; Kenrick *et al.*, 2010). By learning to survive, accumulate resources and develop reciprocal relationships over a long period, motivations for behaviour have become increasingly complex (Aunger & Curtis, 2016). The motivations depicted in Figure 2.1 are categorised in the scientific literature according to biophysical motivations, emotional motivations and motivations linked to learning (Aunger & Curtis, 2008).
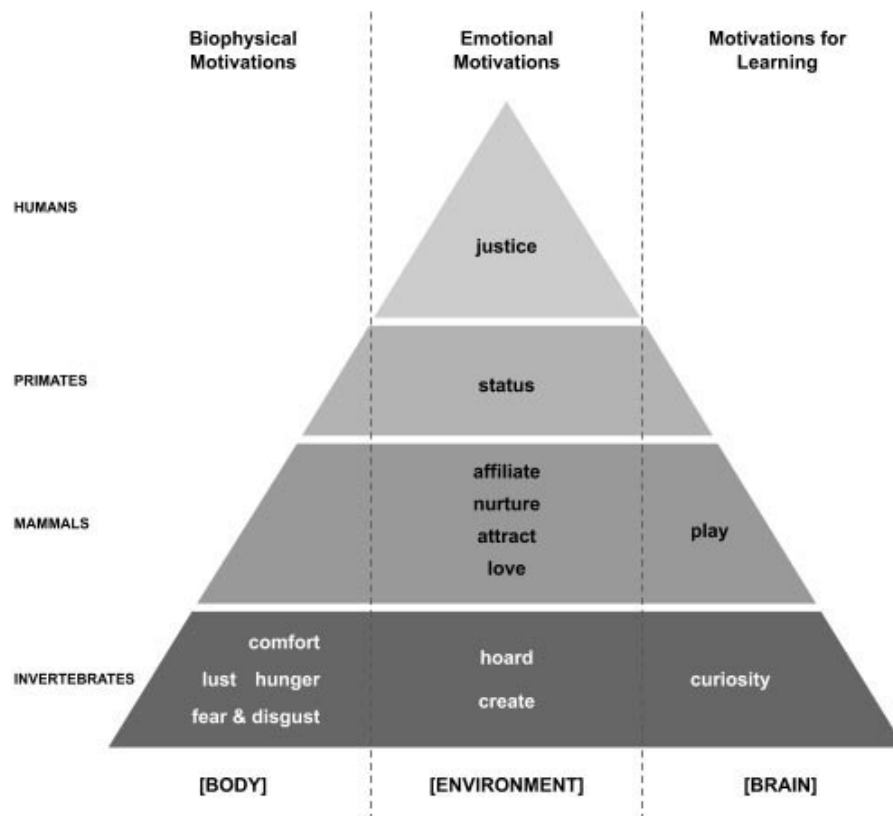
Figure 2.1:   Behavioural motivations (Aunger & Curtis, 2015a)

The biophysical motivations shared with other vertebrates and invertebrates are satisfied by passing resources from the environment into the body (e.g., food for hunger and heat for comfort) or avoiding the loss of internal resources (e.g., the disgust of rotting food or fear of fire) (Aunger & Curtis, 2008). The emotional motivations are predominantly triggered by the environmental setting, with affiliation, nurture, attraction and love shared with other mammals; status shared with other primates; and justice being exclusively human (Aunger & Curtis, 2016).

Lust in Figure 2.1 refers to the human motivation to reproduce genetically through sexual intercourse, shared with all vertebrates (Aunger & Curtis, 2016). This motivation is expressed through searching for and pursuing appropriate mates and consummating sexual union (Aunger & Curtis, 2016).

Comfort in Figure 2.1 encompasses maintaining the body's physiology in terms of temperature and moisture levels through behaviour (Aunger & Curtis, 2016). An example is seeking shade from the sun, warmth when it is cold and shelter during the night (Aunger & Curtis, 2016).

The hunger motive in Figure 2.1 refers to the seeking and consuming of resources such as nutrients, water and oxygen to optimise bodily functions (Aunger & Curtis, 2016).

The neurologically closely related motives of fear and disgust in Figure 2.1 organise behaviour that meets the need to minimise bodily damage from external threats (i.e., predators or accidents) or internal threats (i.e., parasites). A response to fear is expressed by meeting in groups or avoiding fires (Aunger

& Curtis, 2016). The disgust motive is expressed in avoiding sick people or spoiled food (Aunger & Curtis, 2016).

Attract in Figure 2.1 refers to the competition for high-quality mates shared by all vertebrates, expressed in humans by a drive to secure one-time copulation or long-term pair-bonds (Aunger & Curtis, 2016). The motivation is expressed through displays of sexual attractiveness (i.e., body adornment, painting or modification), displays of mating quality (i.e., sport and dancing) and risk-taking behaviour (Aunger & Curtis, 2016).

Create in Figure 2.1 refers to the motive to improve and maintain a habitat conducive to survival and reproduction (Aunger & Curtis, 2016). Human creativity is expressed in cooking, planting, weeding, irrigating, cleaning, tidying and repairing the immediate environment; building safe and dry dwellings; and creating artefacts that aid the diversion of energy towards survival and reproduction (Aunger & Curtis, 2016).

Nurture in Figure 2.1 refers to the human need for parental care of children who are born highly dependent, requiring provisioning, protection and education (Aunger & Curtis, 2016). Nurture encourages maternal and paternal feeding, cleaning and protective behaviour, and the provision of opportunities for play learning and attempts to influence the social world in favour of one's kin (Aunger & Curtis, 2016).

Status in Figure 2.1 considers the motivations for establishing and maintaining hierarchical social structures that provide individuals with privileged access to resources through alliances, deception, and other strategies (Aunger & Curtis, 2016). Status can be expressed through the motivations to optimise social positioning through flattering superiors, submitting to authority, drawing attention to achievements, and displaying wealth, ability and 'good taste' (Aunger & Curtis, 2016).

Love in Figure 2.1 refers to the motivation that causes individuals to seek, build and defend a pair-bond to meet the mammalian need for joint investment in offspring with an extended period of dependence on parents (Aunger & Curtis, 2016). Mothers must keep partners around to share the burden of rearing offspring (Aunger & Curtis, 2016). Examples include making costly gifts, offering tokens of commitment and jealousy-driven rivalry (Aunger & Curtis, 2016).

Affiliation in Figure 2.1 refers to maintaining communal relationships by humans participating in social activities, forming alliances and conforming to group norms (Aunger & Curtis, 2016). Affiliation is expressed through the display of cooperative intentions to engender trust by sharing resources or knowledge. It is linked to the search for experiences – often ritualised – to reinforce group cohesion (Aunger & Curtis, 2016).

The motivation to hoard in Figure 2.1 refers to scarce resources resulting in competition in humans (Aunger & Curtis, 2016). The motivation to produce surpluses is linked to hoarding behaviour,

expressed in the accumulation of physical resources, the performance of group activities to produce, the negotiation of territorial rights, or guarding resources against theft (Aunger & Curtis, 2016).

Justice in Figure 2.1 refers to the uniquely human forms of social control and punishment, enabling large-scale, genetically unrelated, cooperating communities (Aunger & Curtis, 2016). The justice motive causes humans to enjoy punishing anti-social behaviour (Aunger & Curtis, 2016). Feelings of shame and guilt appear to regulate the transgression of social norms and provide incentives to repair damaged social relationships, with individuals self-regulating behaviour in socially adept groups when the justice motive is present (Aunger & Curtis, 2016).

The curiosity motive in Figure 2.1 is linked to a range of behaviours that improve human proficiency in meeting human needs, reducing uncertainty related to environmental threats and opportunities (Aunger & Curtis, 2016). This results in brain structures that can create and update information and identify gaps in knowledge (Aunger & Curtis, 2016). Curiosity is engaged when we have sufficient energy stores and no pressing emergencies, driving experimentation and implementing new ideas (Aunger & Curtis, 2016).

Finally, the play motive in Figure 2.1 concerns the acquisition of embodied skills and knowledge through the repeated enactment of a particular sequence of behaviours stored as procedural memories (Aunger & Curtis, 2016). Play is expressed in the simulation of activities that include nurturing babies, fighting, hunting or courting without the usually associated risks (Aunger & Curtis, 2016).

2.1.3 BCD intervention design process

An iterative phase-based intervention design process to achieve sustained changes in culinary behaviour is recommended instead of large-scale rollouts of untested stove interventions without sufficient preparation and contextualisation (Johnson *et al.*, 2015; Lambe & Senyagwa, 2015; Jürisoo *et al.*, 2018). The BCD intervention design process traces its origins to Simon (1969). It moves through the widening and narrowing of the design scope through activities clustered around interrelated phases, similar to the ubiquitous double diamond process developed by the British Design Council (2005) and the IDEO (2015) human-centred design process. The flexible and transparent design process allows the integration of a wide variety of contextually appropriate behavioural methods and techniques, contributing to an increasing body of evidence of innovative and sustainable behaviour change interventions (Aunger & Curtis, 2016). The BCD intervention design process can be adjusted to the specific size and focus of an intervention, ranging from the level of the individual to broader institutional or community interventions, while maintaining a single-minded focus on behaviour in a specific physical, social, biological and temporal context (Aunger & Curtis, 2016).

The BCD process depicted in 2.2 places the behavioural framework at the centre with the steps in the design process for designing an intervention around the outside (Aunger & Curtis, 2016).
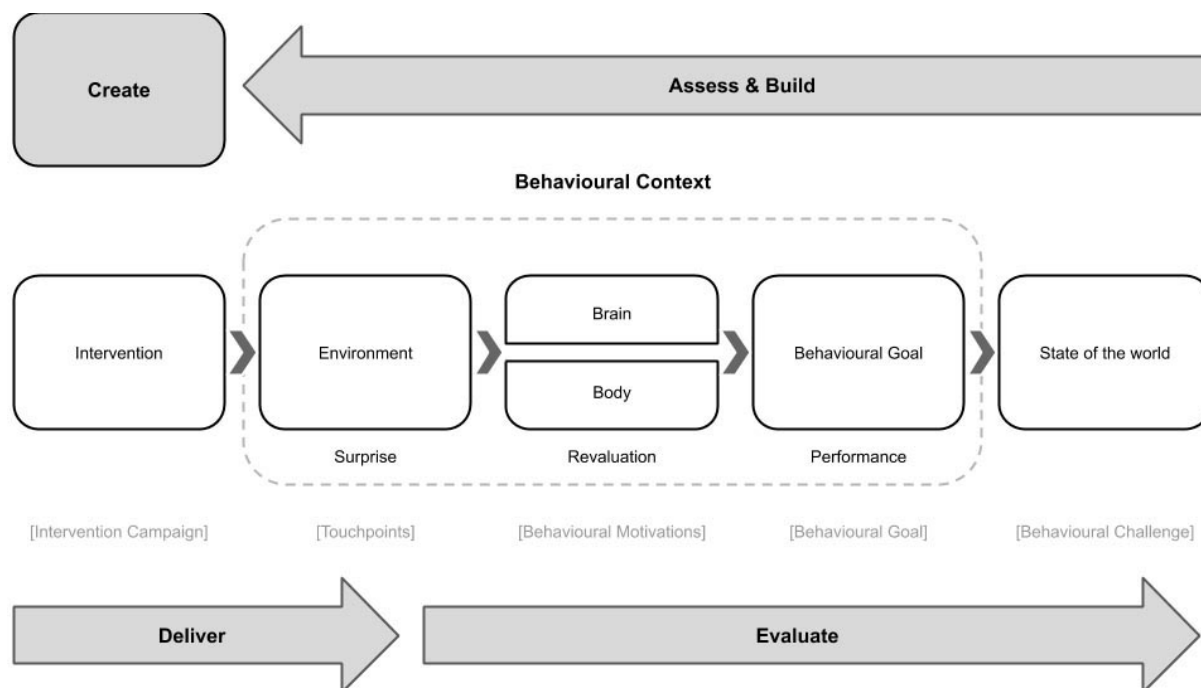
Figure 2.2: Behaviour Centred Design (BCD) process (Aunger & Curtis, 2016)

The five steps of the BCD process are described through the monikers of *Assess, Build, Create, Deliver* and *Evaluate* (Aunger & Curtis, 2016). The *Assess* step proceeds with a formative assessment and review of the behavioural challenges and the likely behavioural determining factors (Aunger & Curtis, 2016). In the *Build* step, research is conducted to identify and stratify the group affected by the behavioural challenge and explore the behavioural challenge in the specific context (Aunger & Curtis, 2016). A framework is formulated for a specific behavioural setting to guide the design of an intervention (Aunger & Curtis, 2016). During the *Create* step, an intervention is iteratively developed, often with the help of creative professionals (Aunger & Curtis, 2016). In the *Deliver* step, a feasible and viable intervention is implemented and shared with the targeted population (Aunger & Curtis, 2016). The framework concludes with the *Evaluate* step, extensively appraising the outcomes and process of an intervention in a structured manner (Aunger & Curtis, 2016).

2.1.4   Formative assessment of the behavioural challenge

An assessment of the behavioural challenge under investigation is described as the first step, which provides the basis for exploring a representative behavioural context, identifying the main behaviour goal, and formulating a proposed set of motivations to facilitate the creation of an intervention in the next step (Aunger & Curtis, 2016).

The formative assessment commences with gathering knowledge and estimating the scope of the problem under investigation based on the best available – yet incomplete – evidence (Curtis *et al.*, 2011) (i.e., Behavioural Challenge in 2.2). Attention is paid to what is known about the factors related to the behavioural need and defining which behavioural aspects need to change (Curtis *et al.*, 2011). Central

to the assessment of the behavioural challenges are the intertwined material and socio-institutional factors that powerfully shape human behaviour, influencing the distribution of wealth, income, knowledge and competencies in society (Welzer, 2011; Aunger & Curtis, 2016). The material environment comprises the biological and physical objects and infrastructure present in the behavioural context (Aunger & Curtis, 2016). The local objects can include the type of dwelling, products, tools and other resources (i.e., kitchen, fireplace, cookstoves, chimneys, cooking ingredients and LP gas cylinders). The material infrastructure includes the physical systems and structures that indirectly influence behaviour (i.e., geographic factors that include the electric infrastructure and gas supply networks) (Aunger & Curtis, 2016; Rosenthal *et al.*, 2018). The socio-institutional environment includes the multiplicity of social, economic, demographic and political factors affecting the specific behavioural challenge (Aunger & Curtis, 2016; Matin, 2016). Socio-institutional factors can include the affordability of goods and services, the availability of financial instruments, or the level of urbanisation (Aunger & Curtis, 2016). A discriminatory institutional environment related to gender, age and race can entrench a behavioural sequence in a behaviour setting (Aunger & Curtis, 2016; Tidwell *et al.*, 2019a). External governance or administrative institutions applied through policies or regulations frequently influence behaviour (Aunger & Curtis, 2016; Matin, 2016). For example, the availability of educational institutions is often linked to changes in behaviour (Aunger & Curtis, 2016). The assessment methods applied in practice are characterised predominantly by reviews of relevant literature to identify the critical behavioural factors (Aunger & Curtis, 2016).

2.1.5 Clear identification and inclusion of the targeted population

The targeted population is described as the group of people that the behavioural intervention intends to serve. Identifying the targeted population affected by the behavioural challenge is critical (Aunger & Curtis, 2015a). Working closely with the targeted groups in designing an intervention is essential (Engl *et al.*, 2019). The lack of involvement by local representatives of the targeted population is frequently flagged as a reason for failure (Engl *et al.*, 2019).

The behavioural challenge could be affected by various determinants as all people are not motivated in the same way to change their behaviour. Any behavioural intervention needs to understand the different causes of the problem affecting the people it seeks to address. A segmentation method is frequently applied to accurately identify the targeted population affected by the behavioural challenge and assist in uncovering behavioural determinants for each distinct group of people an intervention intends to serve (Aunger & Curtis, 2015a).

2.1.6 Exploration of the behavioural context

The *Build* process first proceeds with exploring the behavioural context easing the framing of a behavioural goal in a specific behaviour setting (Aunger & Curtis, 2016). Understanding the linkages between the material and socio-institutional aspects in the representative behavioural setting is essential

for a BCD intervention to succeed (Manzini, 2006; Shove & Walker, 2010; Leeuwis & Aarts, 2011; Welzer, 2011; Nazemi, 2014; Devisscher *et al.*, 2016).

The exploration of the BCD approach prioritises research methods and instruments that engage with actual behaviour in a representative behavioural context (Aunger & Curtis, 2015a, 2016). The flexible, iterative application of mainly qualitative research methods and tools is recommended (Aunger & Curtis, 2015a, 2016). The methods and instruments for data collection and analysis are selected to provide reliable and valid insights in a limited period, drawing on ethnography, design research and design thinking (Aunger & Curtis, 2015a, 2016). Expert advice is consulted if relevant literature is unavailable (Aunger & Curtis, 2015a, 2016). Contextualised observational studies, discussions, questionnaires and interviews are often used to confirm behaviour observations (Aunger & Curtis, 2015a, 2016).

2.1.7 Framing of essential behavioural components for an intervention

The *Build* step culminates in synthesising a framework integrating a specific, clearly defined behavioural goal, providing the foundation for designing an intervention (Aunger & Curtis, 2015a, 2016). The framework incorporates key behavioural components as discussed below, including a description of the linkages between the behavioural goal and the motivations for guiding an intervention (Aunger & Curtis, 2015a, 2016). In addition, the contextually relevant linkages between the environment and the motivations in the setting are summarised (Aunger & Curtis, 2015a, 2016).

Setting a clear behavioural goal

Aunger and Curtis (2016) propose setting a clear behavioural goal that can achieve an unexpected level of surprise in a behaviour setting, prompting the revaluation of motivations linked to the goal by the targeted population and, in turn, achieving the performance of the goal. To ensure the performance of the behavioural goal, the benefit must be surprisingly rewarding (Aunger & Curtis, 2015a, 2016). The reward can be expressed as a financial benefit, the absence of a better alternative, or the ease associated with performing the behaviour (Aunger & Curtis, 2015a, 2016). The behavioural goal's performance can be reinforced by including regulatory barriers (i.e., regulated smoke-free zones in low-status settings) (Fichtenberg & Glantz, 2002; Paluck & Shepherd, 2012; Doyle, 2016).

Behavioural motivations

The pertinent motivations related to the behavioural goal are included in the framework (Aunger & Curtis, 2015a, 2016). The activities during the *Build* step explore the linkages between the behavioural goal under investigation and the intertwined biophysical and psychological motivations related to the targeted group of beneficiaries in a specific setting (Aunger & Curtis, 2015a, 2016). The framework includes a synthesised description of possible motivations in a targeted setting to disrupt the current behavioural pattern that has been identified as problematic (Aunger & Curtis, 2016; White *et al.*, 2016).

The resulting insights on the motivations in the behavioural setting can provide a novel understanding of how to disrupt the current behavioural pattern that has been identified as problematic (Aunger & Curtis, 2015a, 2016). While the motivations linked to a societal problem may be well documented, identifying the specific motivation that could positively influence the behavioural goal is often tricky (Aunger & Curtis, 2015a, 2016). During the design of a BCD intervention, a range of possible contextually appropriate motivations that could cause revaluation are iteratively selected (Green & Myerson, 2004). The motivations are drawn from the domains described in Section 2.1.2. For example, eating food can assuage the hunger motivation; cleanliness can be linked to disgust and sex to lust; storing food or fuel satisfies the hoarding motivation, and a demonstration of good manners can be linked to the affiliation motivation (Biran *et al.*, 2014; Curtis, 2014).

2.1.8 Iterative design of an intervention

Central to the BCD design process is the creative development of an intervention (i.e., the *Create* step in 2.2). A creative team or established change agency frequently develops an intervention in response to a creative brief guided by the proposed behavioural framework (Aunger & Curtis, 2015a, 2016). Such an intervention is formulated, comprising a description that proposes intervention elements for a specific behavioural context formulated around a series of critical touchpoints linked to motivations, which can facilitate the performance of the specific behavioural goal (Aunger & Curtis, 2015a, 2016). Many methods and instruments are accommodated to facilitate an iterative process, oscillating between creative and reflective activities (Aunger & Curtis, 2015a, 2016). Multiple iterations narrow the untested ideas to more promising proposed conceptual avenues (Aunger & Curtis, 2015a, 2016). The continued analysis and synthesis of assumptions during the design process winnow the ideas that emerge from the creative activities, with emerging ideas holding untested assumptions of behaviour change either being discarded or developed further (Aunger & Curtis, 2015a, 2016). The creative activities progressively produce increasingly tangible and complex concepts for an intervention. In contrast, the reflective activities become less abstract, with empirical instruments employed to assess the emerging intervention prototypes, easing the choice of a testable intervention concept (Aunger & Curtis, 2015a, 2016). The creation of an intervention culminates in the intervention mapping around the following critical intervention elements discussed below, spanning an intervention concept, a series of touchpoints, the channels of communication, the intervention materials and the support infrastructure required for a proposed intervention (Aunger & Curtis, 2015a, 2016).

Intervention concepts facilitating targeted sequences and touchpoints

An intervention concept consisting of a singular or series of conceptual narratives is developed by a creative team depending on available funding in response to a creative brief (Aunger & Curtis, 2015a, 2016). An intervention concept can be defined as the structured conceptual narrative associated with the particular behaviour setting, differentiating it from other existing settings that resonate with the

motivations of the targeted population (Aaker, 2007; Alexandris *et al.*, 2008; Aunger & Curtis, 2015a). During the *Create* step, the concept is developed to facilitate interactions around a series of touchpoints, channels of communication, and intervention materials guided by the proposed behavioural framework (Aunger & Curtis, 2015a, 2016). A branded conceptual narrative for the specific setting should reflect the intended relationship with the intended final beneficiary, the targeted behavioural sequence and the motivations related to the behavioural goal (Aunger & Curtis, 2015a, 2016). The intervention concept should reflect and support an intervention's sequence of interactions and touchpoints (Aunger & Curtis, 2015a, 2016). Aunger and Curtis (2015a) recommend the engagement of professional agencies, with the intervention designers analysing the emerging ideas and assisting in synthesising a final conceptual narrative through a series of creative proposals. The behavioural framework should guide them in the intervention's ability to surprise the targeted beneficiaries, leading to a revaluation of touchpoint-linked motivations and disruption in the performance of a behavioural sequence in the targeted setting. The emerging creative proposals are balanced against the likely desirability, feasibility and viability of the proposed concept (Aunger & Curtis, 2015a)

Behavioural sequences

Behavioural sequences are frequently employed in designing BCD interventions (Biran *et al.*, 2014; Greenland *et al.*, 2016; Gautam *et al.*, 2017). Using the definition of Norton and Pine (2013), a behavioural sequence describes the series of interactions and touchpoints of beneficiaries in an intervention. The concept of sequences, frequently also referred to as journeys, is currently used in a wide variety of design fields and for different kinds of analysis (Fowkes, 2007; Jenkinson, 2007; Zomerdijk & Voss, 2009; Spies, 2012; Nichifor *et al.*, 2021). When designing interventions, the sequences are centred around the targeted beneficiaries to achieve the desired articulated behavioural goal (Aunger & Curtis, 2015a, 2016). The sequence is analysed to ascertain the series of touchpoints linked to motivations for adopting the overriding behavioural goal from the perspective of the final beneficiary (Aunger & Curtis, 2015a, 2016). A timely analysis of the sequence during intervention design allows a rapid improvement in the accuracy and dosage of a sequence and selected touchpoints (Aunger & Curtis, 2015a, 2016). The methods tools used for the analysis are applied, and the different needs and techniques proposed for analysing the sequences vary according to the type of intervention (Aunger & Curtis, 2015a, 2016). These can include structured observations and in-depth interviews (Aunger & Curtis, 2015a, 2016).

Touchpoints

The iterative development of an intervention relies heavily on the concept of touchpoints drawn from the field of service design (Brazelton *et al.*, 1997; Lockwood, 2009; Zomerdijk & Voss, 2009; Aunger & Curtis, 2016). The touchpoints linked to the relevant motivations guide exposure of a representative segment of the targeted population to an intervention in a specific behaviour setting (Lockwood, 2009).

In design literature and practice, touchpoints describe the points of contact or interaction between people in an intervention (Clatworthy, 2011). The touchpoints include non-physical interactions in a targeted setting. Analogue or digital communication channels facilitate exposure to the touchpoints.

Successful interactions with a set of touchpoints result in the revaluation of motivations resulting in the performance of a specific behavioural goal (Stein & Ramaseshan, 2015; Ziliani & Ieva, 2018). The motivations are linked to the emerging set of touchpoints in the setting. The motivations that could generate a marked surprising response at the point of interaction during the intervention are selected, guided by the level of perceived reward to bridge temporal and spatial gaps in the behaviour setting (Aunger & Curtis, 2015a, 2016).

The touchpoints are selected by proportional intensity and frequency of interactions by people during the intervention, balanced against the cost and effectiveness of each interaction (Aunger & Curtis, 2015a, 2016). To achieve surprise, the touchpoint of interaction in an intervention seeks to expose the participants to a memorable experience that stands out to achieve a significant revaluation of the underlying motivation (Aunger & Curtis, 2015a, 2016). The human brain is designed to react and respond to unexpected interactions in a behavioural setting that could hold a reward or threat (Mnih *et al.*, 2015; Niv *et al.*, 2015). A disruptive touchpoint in the behavioural setting can, for instance, attempt to target the status motivation of the targeted beneficiaries, assisted by intervention materials and reinforced by a support infrastructure (Aunger & Curtis, 2015a, 2016).

Communication channels

The communication channels to mediate behaviour refers to digital and analogue media facilitating the interactions and touchpoints in an intervention (i.e., digital, personal or mass media, or in a specific physical location). Channels facilitating tailored interpersonal communication ease the intensity and duration of exposure and allow specific population segments to be targeted (Aunger & Curtis, 2015a, 2016). The communication channels can comprise analogue and digital channels for communicating tailored messages to small groups or broadcasting to a larger group of people, emphasising analogue emotional demonstrations in BCD practice (Scott *et al.*, 2007). The physical demonstration of a targeted cookstove is recommended as the primary behavioural communication channel (Aunger & Curtis, 2015a, 2016). Most interventions in under-resourced settings rely on emotional demonstrations (i.e., emo-demos) accompanied by graphic visualisations (Curtis & Biran, 2001; Sigler *et al.*, 2015).

Intervention materials and support infrastructure

Incorporating locally available intervention materials and providing local support infrastructure are recommended to facilitate the sustained performance of the behavioural goal beyond the lifetime of an intervention (Aunger & Curtis, 2015a, 2016).

The selection of intervention materials refers to the physical stage, props and support infrastructure required for the intervention activities to be performed in an intervention (Aunger & Curtis, 2015a, 2016). The intervention materials are selected to facilitate the intervention in realistic circumstances for the targeted population (Aunger & Curtis, 2015a, 2016). The stage and props are selected to semiotically embody the intervention concept, disseminating and reinforcing the behavioural goal (Boujut & Blanco, 2003; Westerlund, 2009; Carlile *et al.*, 2013). In addition to the physical props for performing the behavioural sequences, the materials frequently include the design of training guides, protocols, television advertisements, radio spots and social media campaigns (Aunger & Curtis, 2015a, 2016).

A support infrastructure including the final beneficiaries is recommended in designing and implementing appropriate, scalable and sustainable interventions (IDEO, 2011; Ambole *et al.*, 2012; Dorst *et al.*, 2014; Gordon & Burns, 2014). Sangiorgi (2011) and Lønvik (2016) view participatory agency in the design process as an essential catalyst in facilitating behavioural change and securing lasting intangible outcomes of improved health and wellbeing. Including training for the local change agent is advised to ensure a consistent intervention (Aunger & Curtis, 2015a, 2016). While the contribution of change agents is acknowledged, Lévesque (2006) warns against an overreliance on an external support infrastructure of professional change agents in an unfamiliar context, following a universal behavioural approach in a complex local environment. A localised distributed infrastructure is recommended (Lévesque, 2006; Pel & Bauler, 2014; Pel *et al.*, 2017).

2.1.9 Implementation of a feasible and viable intervention

The delivery of a BCD intervention (i.e., *Deliver* in 2.2) involves implementing a proposed BCD intervention in a real-world environment (Aunger & Curtis, 2015a, 2016). An implementation is guided by a proposed intervention to reach the targeted population (Aunger & Curtis, 2015a, 2016). Constrained by the cost and level of engagement during an intervention, implementations can take the form of one-on-one demonstrations or large community events, facilitated by change agents and assisted by outdoor, mass or social media (Carroll *et al.*, 2007; Hoffmann *et al.*, 2014). The implementation includes training facilitators and producing materials and support infrastructures to target a specific setting (Scott *et al.*, 2007). The implementation is monitored to assess the success of engagement with the selected touchpoints (Aunger & Curtis, 2015a, 2016). The evaluations primarily focus on whether the behavioural goal and challenge have shifted (Aunger & Curtis, 2015a, 2016). Due to resource constraints in most implementations, small-scale tests and continued action learning methods are recommended before full-scale implementations (Aunger & Curtis, 2015a, 2016).

2.1.10 Evaluation of the intervention design processes and outcomes

Including appropriate research methods and instruments is paramount for a reliable assessment of the design and implementation of a behavioural intervention (Aunger & Curtis, 2015a, 2016). The final key aspect of a BCD intervention involves assessing the BCD intervention process and outcome (i.e.,

Evaluate in 2.2). Collected evidence of the process and outcome is evaluated to determine which aspects were successful (Aunger & Curtis, 2015a, 2016). Ideally, the sustainability of the behaviour change over the longer term should be measured (Aunger & Curtis, 2015a, 2016).

Relevant aspects of the implementation are evaluated to test for dynamic changes in the main behavioural challenge associated with the BCD intervention (Rajaraman *et al.*, 2014). A credible assessment of behavioural interventions requires the inclusion of behavioural theories and behaviour change models (Aunger & Curtis, 2015a, 2016).

However, the measurement of improvements can be complicated, expensive and frequently unnecessary if the relationship between the behavioural goal and behavioural challenge is already well established (Michie *et al.*, 2009; Van Achterberg *et al.*, 2011; French *et al.*, 2014). The BCD literature provides a comprehensive set of analytical methodologies for increasing the validity and reproducibility of a BCD implementation (Aunger & Curtis, 2015a; Aunger, White, Greenland, *et al.*, 2017). These methods can include observations of behaviour and discrete evaluations of actual behavioural outcomes (Aunger, 2003; Klesges *et al.*, 2004; Baumeister *et al.*, 2007; Contzen *et al.*, 2015). The critical aspects of behaviour are assessed by evaluating the role of selected aspects of the cascading cause–effect linkages in the performance of a behavioural sequence (Saunders *et al.*, 2005; Peters *et al.*, 2015).

2.2 Aspects of BCD in South African Cookstove-Related Interventions

Despite many efforts to alleviate the adverse health and safety effects related to flame-based cookstove use among energy-poor South Africans, rigorous statistical confirmation of successful interventions is rare to non-existent (Makonese *et al.*, 2012; Kimemia *et al.*, 2014; Kimemia & Van Niekerk, 2017; Makonese & Bradnum, 2018). Furthermore, no successful cookstove-related intervention underpinned by a coherent behavioural approach can be found in South Africa (Barnes, 2014; Langerman *et al.*, 2015; Brown *et al.*, 2017; Kimemia & Van Niekerk, 2017). Initiatives to disseminate clean and safe fuels and stoves among energy-poor households in South Africa remain small, localised and largely ineffective (Kimemia & Annegarn, 2016; Pailman *et al.*, 2018). A limited number of localised South African studies have included behavioural approaches for assessing how households are affected by the harmful effects of flame-based cooking appliances (Barnes, 2011, 2014; Barnes *et al.*, 2015)

Designing an intervention to influence behaviour related to flame-based cooking appliances requires an approach that extends beyond the individual cookstove user, exchanging their existing cooking appliance for an improved alternative (Anenberg *et al.*, 2013; Lambe & Senyagwa, 2015). Iterative design processes incorporating hybrid behavioural approaches are considered instrumental when designing an intervention appropriate for disseminating improved cookstoves in an under-resourced context (Lambe & Senyagwa, 2015).

This section first provides a brief review of the critical aspects of a successful behaviour-focused cookstove dissemination intervention spanning the inclusion of branded intervention concepts, the delineation of targeted cookstove-related sequences, the incorporation of appropriate communication channels to mediate the targeted culinary behaviours guided by the motivational touchpoints linked to the diffusion of an improved cookstove.

To gauge the role of the varying aspects of BCD approaches in increasing the diffusion of improved flame-based cookstove appliances in an under-resourced South African context, a cross-case literature analysis of contextually relevant interventions is then conducted.

2.2.1 Critical aspects of behaviour-focused cookstove dissemination interventions

For an improved cookstove to achieve widespread diffusion, an intervention requires a personal and memorable conceptual narrative structure accommodating cookstove-related behavioural sequences, aided by emotional demonstrations with locally available and affordable cleaner-burning stove alternatives, supported by a local infrastructure to facilitate agents of change (Barnes *et al.*, 1994; Anenberg *et al.*, 2013; Goodwin *et al.*, 2015).

Clear identification and inclusion of the targeted population

Successful design-led interventions and the majority of successful improved cookstove initiatives in under-resourced contexts share the identification of the segment of the population affected by specific challenges under investigation. The most effective interventions are characterised by the active participation of local beneficiaries (i.e., women cooks) in the intervention design and dissemination process. This confirms the assertion of Prahalad (2009) and many others regarding the necessity for the involvement of the final beneficiaries in the design of interventions. Partnerships with community representatives are recommended, with local change agents facilitating the design of an increasing number of clean cooking interventions (Troncoso *et al.*, 2011; Barstow *et al.*, 2014; Goodwin *et al.*, 2015; Namagembe *et al.*, 2015). Incorporating the agency of local community leaders and social workers in a behavioural intervention makes it more likely that the cooks' personal, social and economic needs and expectations will be met (Namagembe *et al.*, 2015). Local change agents have local practice-based knowledge and carry the trust of the targeted communities (Goodwin *et al.*, 2015; Niedderer *et al.*, 2017). Credible participation acknowledges the final beneficiaries as experts in how their scarce resources and time can best be invested in cooking a meal with a cleaner cooking appliance while attempting to meet a myriad of needs or pursuing other opportunities (Namagembe *et al.*, 2015).

Exploration of the behavioural context

A preliminary assessment of the array of behavioural factors related to the specific behavioural challenge has been highlighted as essential (Lambe & Senyagwa, 2015; Lambe *et al.*, 2018). Recognisable field research of the behavioural factors related to improved flame-based appliances in

clean cooking interventions is sparse and inconsistent in the design of interventions (Goodwin *et al.*, 2015). The vast majority of cookstove-related interventions fail to accommodate the cookstove-related behaviours of the impoverished communities they are intended to serve (Von Braun *et al.*, 2010; Goodwin *et al.*, 2015). The lack of accommodation is shared in a South African context (Barnes, 2014; Rhodes *et al.*, 2014; Abdelnour, 2015). The behavioural focus on the targeted health considerations alone rarely suffices as the motivation for households to adopt and use clean, safe and efficient cookstoves and fuels (Rosenthal, 2015). A successful intervention needs to understand and focus on what impoverished households using unimproved cookstoves value in addition to their immediate health and safety considerations (Xu *et al.*, 2003; Thurber *et al.*, 2013; Golden *et al.*, 2015; Rosenthal, 2015). The necessity of engagement with local motivations appears foundational (Akintan, 2014; Barnes, 2014; Simon *et al.*, 2014; Soini & Coe, 2014; Akintan *et al.*, 2018). The lack of focus on local culinary behaviours and underlying motivations is especially evident in failed initiatives, with novel cookstove designs promising improved health parachuted into communities accompanied by ill-conceived and superficial behavioural awareness interventions (Xu *et al.*, 2003; Thurber *et al.*, 2013; Golden *et al.*, 2015; Rosenthal, 2015).

Framing of essential behavioural components for an intervention

The use of specific behavioural frameworks underpinned by a recognisable theoretical approach is rare in cookstove-related interventions (Johnson *et al.*, 2015; Rosenthal *et al.*, 2017). The limited use of researched and tested guiding behavioural frameworks in cookstove-related dissemination efforts is a major deficiency (Johnson *et al.*, 2015; Rosenthal *et al.*, 2017). Behavioural frameworks are found in social marketing and dissemination of innovation approaches (Pine *et al.*, 2011; Goodwin *et al.*, 2015). Most interventions are framed around explaining the implementation process without explaining how the behavioural change process will occur (Goodwin *et al.*, 2015).

Setting a clear behavioural goal

The importance of understanding cookstove-related behaviour is frequently highlighted, yet modelling a behavioural framework with an explicit targeting of a specific behavioural goal is rare (Lambe & Senyagwa, 2015; Lambe *et al.*, 2018). A lack of a clear behavioural goal is identified as a critical factor in the failure of dissemination efforts in the past (Hanna *et al.*, 2012). The lack of focus can be attributed to the number and complexity of motivations linked to under-resourced households (Lambe *et al.*, 2018). Most successful cookstove dissemination interventions link the behavioural goal to include locally available and affordable cookstoves and fuels as the essential material props and infrastructure for daily cooking needs (Goodwin *et al.*, 2015; Johnson *et al.*, 2015). The cooking appliance's affordability, ease of use and expected performance are paramount in the dissemination efforts (Karekezi *et al.*, 2012).

Creation of clearly conceptualised and branded interventions

A BCD intervention must communicate a coherent conceptual narrative to motivate a shift in behaviour (Aunger & Curtis, 2015a, 2016). Common among successful improved cookstove dissemination interventions is a coherent branded conceptual narrative across multiple settings of sensory engagement, with the beneficiary being consistent with the underlying interrelated infrastructures, artefacts, behavioural sequences and supporting community infrastructure (Evans *et al.*, 2017). A coordinated and branded communication campaign can link the improved cookstove-related behaviour's psychological and emotional appeal with prospective beneficiaries' values (Saad, 2011; Beltramo *et al.*, 2015b). The strategic use of a branded conceptual narrative structure as part of an intervention can establish and reinforce relationships and a sense of ownership between the beneficiaries and the introduced cookstoves in a complex ecosystem (Goodwin *et al.*, 2015). The importance of storied narratives cognisant of long-held cultural traditions, norms and habits in designing behavioural interventions is frequently highlighted in the literature (Ramirez *et al.*, 2014; Rhodes *et al.*, 2014; Armenis, 2020; McCarron *et al.*, 2020). The uniquely human ability to organise, record and transmit culinary knowledge, experience and skills through the narration of stories has allowed the reliable transmission of culinary sequences over time (Bruner, 1990; Koehler *et al.*, 2018; Armenis, 2020). The way we cook has been transmitted through narratives and rituals from one generation to the next (Wrangham, 2009; Carmody *et al.*, 2016; Høgh-Olesen, 2019; McAdams, 2019). The narratives follow recognisable patterns, lending themselves to further dissemination (Wrangham, 2009). Therefore, the culinary sequences are easier to commit to memory and assist in how we relate with one another (Wrangham, 2009). The transmitted narratives and rituals have served and still serve to differentiate between individuals and large groups over time, borne out over a wide variety of human diets, eating habits and culinary traditions (Wrangham, 2009). A branded conceptual narrative for an intervention in an African context must be cognisant of both written and unwritten narrative traditions (Finnegan, 2012; Reitsma *et al.*, 2013). However, oral African culinary narratives are complex, hard to record and present (Finnegan, 2012). The localised oral transmission of cooking sequences for foraging, cooking and eating in small social groups has evolved into a complex material and socio-institutional environment (Wrangham, 2009; Carmody *et al.*, 2016; McAdams, 2019). The accuracy and stability of dissemination are secured by interweaving the culinary sequence with myths, taboos and beliefs, reflected and reinforced by the surrounding environment (Wrangham, 2009; Carmody *et al.*, 2016; McAdams, 2019); and intertwined with the development and use of the various cookstoves and fuels in each local setting (Puzzolo *et al.*, 2013; Ramirez *et al.*, 2014; Akintan *et al.*, 2018; Hasan *et al.*, 2019). The wide variance of culinary behaviour across Africa implies that an intervention should avoid prescriptive abstractions, relying instead on local facilitators to iteratively develop and adapt the conceptual narrative to each intervention (Finnegan, 2012; Reitsma *et al.*, 2013; Akintan *et al.*, 2018).

Physical demonstration of cookstove-related behavioural sequences

However, a coordinated and branded intervention cannot save a flawed intervention when the suggested cooking appliance does not meet the behavioural challenge (Hanna *et al.*, 2012; Namagembe *et al.*, 2015; Shafer, 2019). To disseminate an improved cookstove, an intervention needs to inculcate the culinary behavioural sequences steeped in local narratives to have a lasting influence on the physical and economic well-being of the targeted impoverished communities (Osseo-Asare, 2005; Sesan, 2012; Kinyanjui, 2014). Interventions incorporating the demonstration of culinary sequences with local change agents cooking a meal familiar to the targeted population are frequently suggested (Person *et al.*, 2012; Jürisoo *et al.*, 2018). Traditional cooking sequences with existing cookstoves are deeply intertwined with local culinary factors (Osseo-Asare, 2005; Sesan, 2012; Rhodes *et al.*, 2014). The taste of meals cooked over flame-based appliances is frequently preferred over alternative preparation methods (Akpalu *et al.*, 2011). This can be attributed to the sustained transmission of culinary behaviour dependent on physical, performative sequences interwoven with rich, complex narratives (Osseo-Asare, 2005; Haaland, 2006; Wrangham, 2009; Shove *et al.*, 2012; Lackner, 2014; Urmee & Gyamfi, 2014). These complex narratives enable accurate retention and recall ensuring the continued intergenerational transmission of culinary behaviours (Ogede, 1999; Osseo-Asare, 2005; Shove *et al.*, 2012; Dunbar, 2014).

Communication channels to mediate cookstove-related behaviours

Successful cookstove dissemination interventions mediate the advantages of adopting a targeted cookstove through analogue and, in an increasing measure, digital communication channels. Traditional analogue communication channels in health-related behavioural interventions, as suggested by van der Kroon *et al.* (2014) and Shankar *et al.* (2015), are considered unreliable as drivers of diffusion, failing in most cookstove-related interventions (Puzzolo *et al.*, 2013; World Bank, 2014b; Clark *et al.*, 2015). By contrast, physical demonstrations as analogue communication channels have succeeded in similar under-resourced contexts (Gautam, 2015; Greenland *et al.*, 2016). The repeated exposure of people to a cooking sequence is intended to achieve the diffusion of the improved cooking appliance (Colombetti *et al.*, 1996; Konidaris & Barto, 2006; Shankar *et al.*, 2014). Analogue communication channels are more robust in activating members of under-resourced communities as agents of change since the communities are geographically and socially close because of strong reciprocal peer-to-peer relationships between individuals (Shankar *et al.*, 2014; Clark *et al.*, 2015; Goodwin *et al.*, 2015; Rosenbaum *et al.*, 2015). Culinary behavioural sequences in Africa are predominantly mediated through performative physical demonstrations reinforced by verbal storytelling drawing on oral culture (Finnegan, 2012; Reitsma *et al.*, 2013). The inclusion of a metaphorical dramatisation that includes bodily interaction can add emotion through physical and vocal expressions and facilitate the repeated performance of a targeted culinary sequence (Surridge *et al.*, 2005; Reitsma *et al.*, 2013). The demonstrations used include one-on-one contact by change agents or peers, community events,

counselling sessions, outdoor or indoor live demonstrations, training workshops, community groupings (i.e., societies, guilds or clubs) and social media suited to peer-to-peer communication (i.e., WhatsApp) (Reitsma *et al.*, 2013; Goodwin, 2015; Goodwin *et al.*, 2015; Namagembe *et al.*, 2015). In addition, the mass media channels comprising radio, television, print media, billboards, the internet and mass-based social media (i.e., Facebook) are increasingly employed (Lilje & Mosler, 2018).

Motivations for using improved cookstoves

The linking of the interventions to the underlying motivations for using a selected improved cooking device is critical in achieving and reinforcing the targeted behavioural goal linked to the surrounding ecosystem of cookstoves, fuels, and other ancillary elements in a local behaviour setting (Goodwin *et al.*, 2015; Lambe & Senyagwa, 2015). Recent cookstove interventions incorporating aspects of behavioural approaches have attributed a measure of success to targeting economic motivations combined with some form of social support (Goodwin *et al.*, 2015). Beyond economic considerations, the motivations for revaluing specific flame-based cooking sequences are frequently associated with regulating family arrangements or expression of status (Goodwin *et al.*, 2015). A flexible conceptual narrative capable of accommodating multiple motivations and engaging with the beneficiary is vital (Goodwin *et al.*, 2015; Lambe & Senyagwa, 2015). The individual motivations to adopt an improved cookstove are predominantly based on factors unrelated to improvements in long-term respiratory health (Goodwin *et al.*, 2015; Lambe & Senyagwa, 2015). The motivations for adopting an improved stove to interact with the external material and social environment are discussed below.

Structured assessment of intervention outcomes

A valid criticism of numerous failed interventions in under-resourced contexts is the lack of reliable, standardised methods of analysis and verification of the intervention outcomes (Marcus, 2011; Honig *et al.*, 2014). The structured description and analysis of improved cookstove interventions' behavioural processes and outcomes are frequently identified as a critical deficiency (Vogel, 2012; Johnson *et al.*, 2015; Rosenthal *et al.*, 2017). Relevant aspects of the implementation are evaluated to test for dynamic changes in the main behavioural challenge associated with the BCD intervention (Rajaraman *et al.*, 2014). The documentation of the practice-based approaches underpinned by behavioural theories is critical in the larger improved cookstove sector (Vogel, 2012; Johnson *et al.*, 2015; Rosenthal *et al.*, 2017). The incorporation of participatory and iterative methods incorporating the Base of the Pyramid (BoP) approach pioneered by Prahalad (2009) are frequently applied in contexts to meet the expectations of impoverished households according to their local needs (Ambole *et al.*, 2012).

2.2.2 Comparative literature analysis of improved cookstove-related interventions

A systematic literature-based search on improved cookstoves yielded over 2 000 records. These records were screened down to 143 projects, mainly in SSA, that had achieved some success with behaviour centred processes, methods and instruments. This subset of interventions was scanned for the most

prominent selected behavioural aspects. Six interventions were selected. Each intervention approach is summarised in tabular format, allowing for systematic conclusions.

The following case studies of interventions were selected for review. They were chosen due to the (often unintentional) use of BCD approaches, methods and instruments in implementations with varying degrees of success. The South African Electricity Rollout Initiatives are reviewed, followed by the *Basa Njengo Magogo* initiative, the KayaGAS stove project, the Wits Behaviour Change study and the BREADrev Bread Baking Initiative, selected as the South African case studies. As no large-scale, successful implementation of a South African cookstove-related intervention, the Kenyan *Ceramic Jiko* project was included because of its success and its commonalities with key characteristics of South African indigent households.

The case studies are discussed, and a comparative cross-case literature analysis is then applied (Section 2.2.9).

2.2.3 South African regulatory and policy interventions

In South Africa, interventions to eradicate the detrimental effects of flame-based cookstoves have been primarily institutional initiatives of the national government, focused on the electrification of urban and rural low-income households (Figure 2.3) (Howells *et al.*, 2006) and policies, regulatory standards and subsidies that relate to the use of inefficient flame-based cooking appliances and fuels (Lloyd, 2009; Tsikata & Sebitosi, 2010). These interventions are fraught with inconsistencies with no clear focus on using unimproved flame-based appliances (Quass, 1953; Barnes *et al.*, 2009; Makonese & Bradnum, 2018). Mostly, the South African government's energy and health interventions have not considered the cooking needs of low-income households (Qase, 2000; Mohlakoana & Annecke, 2009; Fig, 2010). The dangers associated with flame-based cookstoves and fuels have not been a traditional priority for households or the government, with no coherent response beyond instituting a small free basic electricity supply (Bekker *et al.*, 2008; Winkler & Marquand, 2009; SA Government, 2013). No major impetus has been given to the issues surrounding respiratory health and safety related to indoor air pollution (Barnes *et al.*, 2009). Furthermore, the interventions focused on providing financial incentives or disincentives have been marred by poor execution (Chang *et al.*, 2011; Wlokas, 2011).

Figure 2.3:   National electrification of informal South African households (Eskom, 2012)

Madubansi and Shackleton (2007), Stats SA (2017) and many others have confirmed that interventions to shift use to electric stoves have been slow in impoverished urban areas and unchanged in rural areas. Cooking and heating with flame-based appliances remain unchanged among impoverished South Africans, despite the increasing scarcity of wood in the local environment and the large-scale electrification rollout (Stats SA, 2017). Reasons given vary from cultural inertia to the cost of electricity (Sebitosi & Pillay, 2008; Kimemia & Annegarn, 2011; Kimemia, 2013). The failure of a shift to electric cooking is further attributed to the unreliability of the electricity supply attributed to a growing number of illegal makeshift electrical connections, fear of electrocution, dramatic increases in the relative cost of electricity, and precarious levels of household income (Kimemia & Annegarn, 2012; Tait, 2015). In addition, the failure has been compounded by an ongoing period of rolling blackouts with electric demand outstripping diminishing supply attributed to institutional failure and widespread corruption on the part of South Africa's state-owned electricity provider (Inglesi & Pouris, 2010; Shabangu, 2021). Reversals to previous patterns of flame-based cookstove use have been reported in several areas (Tait, 2015, 2017; Lusinga & de Groot, 2019).

The South African interventions have focused on providing an electricity support infrastructure for South African households (Tait, 2015). The initiatives include the National Electrification Programme, which has as its goal the connection of all South African households to the national grid and the Free Basic Electricity Programme (FBE), which provides all connected households with a free basic minimum amount of electricity (Howells *et al.*, 2006; Tait, 2015). The preference for electrification in alleviating energy poverty was expressed in the restructuring and development programme (RDP) (Bekker *et al.*, 2008). This focus on household electricity provision has led to the increasing use of electricity for lighting yet has had a limited influence on cooking stove preferences (Bekker *et al.*, 2008). The fuel-choice patterns of low-income electrified and unelectrified households do not differ significantly, with fuel stacking being prevalent (Van der Kroon *et al.*, 2013). Households view electricity as an additional option for high-end energy applications, with flame-based fuels remaining

dominant for heating and cooking (Bekker *et al.*, 2008). An additional factor contributing to the limited success of electrification is the limitation on implementations in households with legal tenure, which excludes more than 30% of urban households.

While subsidies are a popular short-term policy tool, they are politically difficult to remove over the long term (Mumtaz & Hussain, 2013). By 2019, illegal connections and non-payment by households across South Africa were estimated by Eskom to be approximately R3 billion, with Soweto approximately R18 billion in arrears and 10% of residents paying for electricity (Eskom, 2019).

Since 2006, the institutional interventions by the DoE have primarily focused on providing financial incentives or disincentives to change cookstove-related behaviour (McKenzie, 2011). The policy interventions target all sectors of society, particularly those without access to electricity (McKenzie, 2011). The DoE has introduced a basket of free basic energy carriers, implying the subsidised promotion of various energy carriers and cooking stove technologies (DME, 2006; Mohlakoana & Annecke, 2009; Kriel, 2010). The interventions undertaken in the 2007 Free Basic Alternative Energy (FBAE) policy focus on providing subsidised access to cleaner fuels and appliances (McKenzie, 2011). The FBAE policy envisages the increased provision of LPG to low-income households in particular (McKenzie, 2011). Since 2010, the DoE has steadily transferred the subsidy on paraffin fuel to LPG to encourage greater use of LPG in place of electricity and delay the need to develop new electricity generation capacity (McKenzie, 2011). Reducing the cost of appliances, access to retailers, cylinder costs, and bulk product availability are all factors intended to form part of the LPG strategy (McKenzie, 2011). The financial viability of the subsidised provision of electricity is increasingly questionable, with the total amount paid in subsidies aimed at poverty alleviation in 2012 estimated at more than R8.4 billion. R6.6 billion was allocated to FBE and R1.9 billion to the FBAE (PMG, 2013).

No explicit behavioural approach is articulated in South African policy initiatives, with interventions to improve the safety of cooking appliances focused on regulating the availability of improved flame-based cooking appliances (Tait *et al.*, 2012). The legislated standards fall under the ambit of several organisations (Tait *et al.*, 2012). The South African Bureau of Standards (SABS) provides voluntary standards for the design of cooking stoves (Tait *et al.*, 2012). In addition, the National Regulatory of Compulsory Specifications (NRCS), acting on behalf of the Department of Trade and Industry (DTI), is tasked with the regulation of paraffin cooking stoves and heaters (Tait *et al.*, 2012). Despite regulations and voluntary industry standards, enforcement has been ineffectual, with NRCS agents unable to check for compliance (Tait *et al.*, 2012). The Department of Energy (DoE) and NERSA are responsible for regulating the primary energy carriers of electricity, paraffin or LPG (Marquard, 2007). Biomass and fuelwood use has received limited attention within the DoE's policy framework, with no effective regulations pertaining to biomass or coal-based cooking stoves currently under development (DME, 2006; Madubansi & Shackleton, 2007).

Formative assessment of the behavioural challenge

The government-led initiatives relied on regulatory policy instruments with no explicit behavioural theory or challenges articulated. The entire South African population without access to electricity was selected as the targeted population, specifically indigent black households.

Behavioural contextualisation and focus

No contextualisation of the behavioural challenge was found. No mention of a theory of change was found in the unsuccessful interventions. The main goal appears to focus on economic policy, not behavioural. The goal focused heavily on regulation and fuel subsidies.

Intervention design and implementation

The national policy-based interventions combined the rollout of electricity connections, a free basic electricity component, and switching subsidies from paraffin to LPG over the last 20 years. The regulatory and policy-driven activities by the different spheres of government and related agencies focus primarily on providing electricity from the state-owned electricity utility. Limited and diffuse regulation of cooking fuels and appliances followed. While Eskom branding was incorporated, a cogent conceptual narrative was not present. Participation by the final beneficiaries in the design of the intervention was limited. The interventions relied on television, radio and print communication channels facilitated by Eskom, the state-owned electricity utility and the government bureaucracy at the national, provincial and local levels. The materials for the interventions relied on the physical provision of electric connections, supplemented by a belated communication strategy incorporating printed materials. The support infrastructure relied on regulatory methods and financial subsidies buttressed by unsuccessful attempts to remove dangerous appliances by legislating safety standards.

Structured assessment of intervention process and outcomes

No behaviour-focused analysis of the intervention results is found. Behavioural research methods and outcomes are not reported since this programme has no specific behavioural goals. The only proxy measure for assessing success was the wide-scale provision of electric connections and subsidies for paraffin and, recently, LPG gas.

2.2.4 *Basa Njengo Magogo* fire lighting initiative

One of the most notable programmes to promote clean and safe cookstove behaviours in South Africa was the *basa njengo magogo* alternative fire lighting routine for coal-fired self-constructed stoves, as depicted in Figure 2.4. Initiated in 1994, by the then Department of Minerals and Energy (DME), the Low-Smoke Fuels Programme formulated an Integrated Household Clean Energy Strategy that proposed the design of better-insulated housing, the provision of improved flame-based stoves, lower emission fuels (paraffin, LPG and low-smoke coal) and the dissemination of a low-smoke top-down ignition behavioural intervention for coal fires (i.e., Basa Njengo Magogo) (Qase, 2000). Changing how

people have been making fires for generations is difficult (Van Niekerk, 2006). During the 1980s, the National Association for Clean Air, distributing pamphlets using the *Scotch Fire* rubric, unsuccessfully promoted the top-down ignition methodology. The method was sourced from a 19th-century Victorian household guide containing plagiarised and unattributed household hints and recipes (Surridge *et al.*, 2005; Hughes, 2013). The alternative top-down ignition method when using the local hand-made metal barrel braziers (i.e., *imbaula* stoves) can reduce HAP by 80% and fuel consumption by 50%, requiring no additional resources (e.g., time, money, stoves or fuels) (Nuwarinda, 2010; Kühn, 2016).

Figure 2.4: *Basa njengo magogo* **outdoor visual communication media (Surridge *et al.*, 2005)**

Towards the end of 1997, SASOL, a South African synthetic gas and liquid fuel-from-coal producer, commissioned the NOVA Institute to design and test a behaviour change intervention with the project goal of reducing air pollution in eMbalenhle, a township near their plant in Secunda (Van Niekerk, 2006). The initial research phase identified the main *behavioural goal* of investigating the possibility of changing the method of lighting an imbaula with the top-down lighting method (Van Niekerk, 2006). Stakeholders were canvassed until a joint agreement on the nature of the problem emerged (Van Niekerk, 2006). A set of components was formulated to guide the intervention design process (Van Niekerk, 2006). The programme applied participatory design methods, in stakeholder workshops and field studies (Van Niekerk, 2006). As part of the communication strategy, the brand name and moniker *basa njengo magogo* was chosen, originating from Mrs Nebelungu Mashinini, an elderly grandmother from the eMbalenhle community who had participated in the design of the intervention concept, meaning 'to start a fire like a grandmother' (Van Niekerk, 2006). Mrs Mashinini of Embalenhle assisted during the participatory sessions to adapt and hone the behavioural pattern for local conditions in the eMbalenhle community (Van Niekerk, 2006).

A pilot implementation proceeded with trained field workers demonstrating the method in homes and public spaces by verbally describing the steps and benefits, as depicted in Figure 2.5 (Van Niekerk, 2006). The adapted behavioural pattern of lighting the fire proved to be the breakthrough in community acceptance. Over 1 000 households adopted the behaviour by 2000, accompanied by a reduction in particulate emissions of 78% (Van Niekerk, 2006). Further pilot implementations in Zamdela, Sasolburg and Orange Farm yielded similar results (Van Niekerk, 2006). However, prolonged change

in the ignition method was limited to between 40 and 50% for unknown reasons (Van Niekerk, 2006). A full-scale national implementation has been requested from NOVA and partners (Van Niekerk, 2006). It appears, however, to have stalled, with the national government switching emphasis to electrification in their approach to reducing energy poverty (Matinga *et al.*, 2014).

Figure 2.5: *Basa njengo magogo* **coal stove lighting demonstration (Surridge *et al.*, 2005)**

The following overview of the *basa njengo magogo* initiative summarises the critical aspects, covering the behavioural theoretical approaches, the main behavioural focus, the segment of the population targeted by the intervention, a description of the branded conceptual narrative, a characterisation of the intervention, the level and type of participation, the communication channels, employed in the initiative, the selected intervention materials and support infrastructure found in the initiative and the methods and techniques employed to assess the success of changing behaviour.

Formative assessment of the behavioural challenge

The main behavioural challenge was to reduce HAP emanating from self-constructed wood and coal stoves on the coalfields of Mpumalanga in South Africa. Indigent households using self-constructed, coal-fired cooking appliances living in proximity to the coalfields of the Mpumalanga province in South Africa were selected as the primary affected segment of the population.

Behavioural contextualisation and focus

A hybrid behavioural theory of change approach was employed, drawing from the user experience (UX) design and marketing research field. The main behavioural goal was to replace the traditional method of lighting a fire with the top-down lighting method, by communicating the increased ease of lighting a top-down fire and the reduced levels of smoke emitted while cooking.

Intervention design and implementation

The intervention consisted of low-intensity social marketing campaigns facilitating local physical public demonstrations of the top-down lighting method with self-constructed imbaula stoves, showing the reduction in the smoke emitted. A coherent conceptual brand narrative was developed and built around the co-creator of the behavioural routine central to the initiative. An intensive participatory

intervention design process was followed with the community. The top-down lighting method was iterated together with a local resident, which gave the project its name.

In addition to the physical demonstrations of the top-down lighting method, the communication channels included locally trained change agents accompanied by printed posters and billboards.

Self-constructed imbaula stoves and locally sourced coal were used. A lack of a support infrastructure ensuring ongoing participation appears to have been instrumental in the initiative's demise. The lack of infrastructure to sustain the initiative was attributed to the lack of financial support from local governments.

Structured assessment of intervention process and outcomes

A structured research methodology was applied and evaluated. The Max-Neef theory of human needs was applied with customised assessment research methods and instruments drawing on UX design and marketing research.

2.2.5 KayaGAS LPG project

Established in 2006, KayaGAS aimed to displace paraffin as the primary energy carrier among the urban poor in South Africa (Mohlakoana & Annecke, 2009; Tatham, 2013b). The programme was able to service homes with LPG and stoves at a price competitive with paraffin fuel and stoves in the low-income targeted market of Cape Town (Tatham, 2013a).

Exploratory research by KayaGAS found that users were less concerned with the well-documented appalling health and safety concerns associated with the use of paraffin and more with the problem of soot-covered pots; food tainted with the taste of paraffin; discoloured walls inside the dwelling; and the smell of paraffin on clothing (indicating a lower social status) (Tatham, 2013b). The behavioural barriers for switching to LPG-based stoves were identified (Tatham, 2013b). The single most significant market barrier identified among the customer base was a fear of using gas because of the potential hazard of a cylinder explosion (Tatham, 2013b). Furthermore, there was a perception that cooking on LPG stoves was expensive relative to using paraffin stoves and comparable electrical appliances (Tatham, 2013b). This was due to institutional barriers limiting the supply of LP gas and cylinders to informal settlements (Tatham, 2013b).

KayaGAS developed its own stove and gas distribution networks, thus enabling supply directly from the manufacturer and refilling depots to spaza shops (Figure 2.6) at prices competitive with existing paraffin stoves (Tatham, 2013b). KayaGAS is engaged in legal proceedings to amend the municipal regulations for distributing LPG cylinders to accommodate small-scale sellers in regulations designed for large-scale commercial sellers (GNESD, 2014).

Figure 2.6:   KayaGAS container-based gas cylinder distribution point (GNESD, 2014)

A change agent-based model was adopted to ensure a reliable supply and adherence to safety standards (Tatham, 2013b). A community-based dissemination intervention was used with the change agents consisting of local women residents living in the targeted areas demonstrating the use of LPG on a door-to-door basis (Tatham, 2013a). In addition, promotional days with cooking competitions accompanied by scripted discussions were held to inform people about the merits and safety of gas (GNESD, 2014).

The aspects of the KayaGAS gleaned from the case study critical to its success are discussed below. Negligible structured assessment of the intervention process was found.

Formative assessment of the behavioural challenge

The primary behavioural challenge was focused on acquiring LPG stoves and fuels, displacing paraffin and electric hob stoves as the preferred cooking option. KayaGAS's behavioural focus closely resembled the intervention strategies pursued in Southeast Asia.

The targeted population comprised urban low-income households in Cape Town. Local paraffin agents, retailers, municipal officials and regulators were intentionally engaged as stakeholders.

Behavioural contextualisation and focus

The market research and marketing campaign components presented a hybrid behavioural theory of change, similar to social marketing approaches.

Intervention design and implementation

The intervention consisted of physical demonstrations of the use and handling of LPG stoves and cylinders compared with paraffin stoves, facilitated by change agents and retailers living in the local community. A professional agency was engaged to design a cogent conceptual brand narrative. Limited participation was incorporated into the intervention design phase. However, there was active local participation during the implementation phase.

The communication channels consisted of local stove demonstrations by change agents and localised, branded, converted shipping containers repurposed as cylinder distribution points and printed outdoor media.

The demonstrations were facilitated by a 5-kg single LPG hob and cylinder combination. A support infrastructure of local capacity-building workshops and small-scale LPG cylinder distribution networks was established. The long-awaited regulatory changes required to enable the local legal storage and use of LPG fuels in South Africa are a significant deficit in the support infrastructure.

2.2.6 Wits behaviour change study (North West Province, South Africa) (2004–2005)

The rural South African behaviour change study conducted by Brendon Barnes under the auspices of the University of the Witwatersrand set out to assess the effectiveness of low-cost behaviour change techniques in reducing particulate air pollution emanating from unimproved flame-based cookstoves (Barnes *et al.*, 2009, 2011). The year-long study aimed to determine which behaviour change techniques could be linked to improved indoor air quality levels (Barnes *et al.*, 2009). In contrast to previous technology-focused interventions, the study provided initial indications that a behavioural intervention can reduce exposure to HAP (Barnes *et al.*, 2009, 2011).

Figure 2.7: **Focus groups and structured interviews conducted in the behavioural context (Barnes *et al.*, 2009)**

The critical aspects gleaned from the case study are discussed in greater detail in the following section.

Formative assessment of the behavioural challenge

The main behavioural challenge centred around the dangers of stove emissions in the targeted households. The study set out to gain community support for the activities. The targeted population consisted of primary caregivers for children under five years and indigent rural households in the North West Province of South Africa.

Behavioural contextualisation and focus

The behavioural approach employed a community counselling model and associated behaviour change techniques similar to Bandura's concept of mastery modelling. The behavioural context related to the recommended improved cookstoves is identified, and analysed as depicted in Figure 2.7. The main behavioural goal was centred around motivations for cooking outdoors, improving household ventilation and decreasing the proximity of children to the cooking area.

Intervention design and implementation

The intervention was focused on behaviours with a single stove and fuel. The intervention proceeded with an introductory meeting outlining the main dangers of stove emissions. In addition, there was a structured community-based education session on health Information to increase local capacity in disseminating health information. No coordinated branded narrative appeared to be present. The participation of respondents was intentionally integrated into the process at the outset. Regular consultative meetings were held for feedback on the research process after the study. The communication channels included face-to-face meetings, community meetings and presentations in the homes of the targeted primary caregivers.

Particulate monitoring equipment was installed in selected households to gauge the success of the intervention. A support infrastructure of training materials and courses was provided for a limited period.

Structured assessment of intervention process and outcomes

The behaviour change study outputs were assessed by measuring the changes in household stove emissions. Focus group sessions were held in homes with follow-up visits to identify possible motivations. The limited success of the project in changing behaviour at scale and capacitating local organisations was attributed to the limited scope and budget of the university-based research study.

2.2.7 The Kenya Ceramic Jiko project

The Jiko stove intervention has become the template for numerous improved stove initiatives worldwide (Karekezi, 2002; Bazilian *et al.*, 2012). However, most attempts at replication have met with failure (Bazilian *et al.*, 2012). The cumulative effect of an iterative design process is best exemplified by the charcoal-saving Kenya Ceramic Jiko (KCJ) stove dissemination project (Karekezi & Majoro, 2002; Dunford, 2012; Tigabu *et al.*, 2015). The success of the KCJ projected in Kenya is attributed, in part, to the attention paid to the participation of the local community in the design and dissemination process, the agency of its designer and the patient support of donors in the initial project phase (Hyman *et al.*, 1987; Njenga *et al.*, 2014). By 2002, the KCJ initiative had achieved a penetration rate of approximately 50%. The firewood-based version languished at around 5% penetration (Silk *et al.*, 2012). This poor performance has been attributed to the communal lack of incentives to save fuelwood except where it

was already scarce (Silk *et al.*, 2012). In addition to the basic design of the KCJ stove depicted in Figure 2.8, the product range has widened to include ovens and griddles; charcoal ovens are reputed to be 70% more cost-efficient than their gas or electricity counterparts (Dunford, 2012; Littlewood & Holt, 2013).

Figure 2.8:   Locally produced and distributed Jiko cookstoves (Dunford, 2012)

Pioneered by the late Dr Maxwell Miringu Kinyanjui as part of a wide range of sustainability initiatives promoting reforestation and efficient charcoal production in Kenya, the design process approximated a circular approach illustrated by the seed-to-ash philosophy still present in the family-owned stove manufacturing company (Dunford, 2012; Littlewood & Holt, 2013). After prototyping various designs of efficient cooking stoves, Dr Kinyanjui initiated the widespread local marketing, production and sale of the cookstoves (Karekezi & Majoro, 2002; Tigabu *et al.*, 2015). Iterative improvements to the stove design continued after its launch in 1982 in a co-creative manner, increasing its usability, affordability and efficiency (Dunford, 2012). Households with relatively higher living standards were initially targeted, with the status motive as a behavioural technique (Barnes *et al.*, 1994). The stove designs were not patented, with copying the design encouraged to aid speedy dissemination (Dunford, 2012). Local groups and individuals were trained as part of the manufacturing and dissemination process, leaving institutional knowledge and a thriving stove industry as a legacy (Chavangi, 1995; Karekezi, 2002). The critical aspects of the KCJ project gleaned from the case study are discussed below.

Formative assessment of the behavioural challenge

The initial behavioural challenge was the rapid deforestation linked to firewood as the primary cooking fuel in Kenya (Dunford, 2012; Goodwin *et al.*, 2015). Initially, the targeted population was newly urbanised, impoverished Kenyan households (Dunford, 2012). The initiatives were aimed at all stakeholders within the biomass cookstove sector, including the stove users, manufacturers and distributors, and men and women (Goodwin *et al.*, 2015).

Behavioural contextualisation and focus

While the initial stages of the Kenyan interventions incorporated few explicit behavioural approaches, recent rural interventions have examined the motivational drivers of cookstove use, drawing on cognitive psychology and behavioural economics and integrated them into the Clean Cooking Interventions Framework (Goodwin *et al.*, 2015). The main behavioural goal sought to achieve correct and consistent use of an appropriately designed, locally produced stove by impoverished Kenyan households. The goal was achieved by demonstrating the benefits of clean cookstoves and supporting the acquisition of clean cookstoves. The design of a local support infrastructure ensured the reliable dissemination of cooking appliances (Goodwin *et al.*, 2015).

Intervention design and implementation

Interventions were comprehensive, comprising stove demonstrations, promotion and awareness campaigns, training workshops, and setting regulatory standards for biomass stoves. A coherent intervention concept was developed around the *Jiko* concept derived from the Kenyan Swahili phrase *jiko okoa,* meaning a cookstove that saves charcoal in food preparation. Participation was observed in multiple aspects of the intervention. The long period from the project's beginnings to the first successful changes in cookstove use was attributed to the patient involvement of local beneficiaries in the design process. The communication channels included local public community demonstrations, radio spots and flyers, posters and leaflets. The physical object was a charcoal stove with a replaceable internal ceramic liner housed in a sturdy metal exterior. The support infrastructure spanned training workshops, stove manufacturing programmes and financial support for small-scale manufacturers. Recent interventions have included baking demonstrations with improved biomass ovens (Figure 2.9).

Figure 2.9:   the intervention concept of a baking course demonstrating to people how to bake with a Jiko improved biomass oven (Heggie & Miles, 2012)

In-depth preliminary research and market research accompanied the initiative. Intentional behaviour change methods and theories were not present for most of the existence of the intervention.

2.2.8 BREADrev bread baking interventions

The BREADrev Bread Baking Initiative in South Africa was founded in 2012 by Jeremy Barty, a former professional baker with 25 years of experience and owner of the South African behaviour change agency MC4C (Barty, 2008, 2017). The bread baking interventions apply a behavioural framework developed in 2004 for individual and corporate change projects and adapted for the emotional demonstrations in local physical settings to facilitate lasting behavioural changes (Barty, 2008; Jackman, 2013; LeadSA, 2016; Barty, 2017). In partnership with local NGOs and universities, the first mobile bread baking intervention was held in Nkanini, Khayelitsha, in October 2013, imparting baking and necessary business skills (Barty, 2017; Zgambo *et al.*, 2018). The participants were trained in how to bake bread with a portable wood-fired rocket oven, culminating in the establishment of three small-scale bread baking businesses (Barty, 2008, 2017). One of the three small-scale bakeries is still in existence (Barty, 2017).

The dissemination of improved bread baking rocket ovens has been suggested as a viable adjunct to electric ovens in reducing emissions, reducing food insecurity and increasing employment in under-resourced SSA settings (De Chastonay *et al.*, 2012; Manhiça *et al.*, 2012; Adria *et al.*, 2013; Mayer-Trasch *et al.*, 2013; Peters & Sievert, 2016; Aneke, 2017). Biomass-fuelled ovens are a critical component in commercial bakeries in SSA outside of South Africa (Kabuleta, 2008; Manhiça *et al.*, 2012; Scott, 2012; Adria *et al.*, 2013; Aneke, 2017). In Zimbabwe alone, over 1,200 bakeries are estimated to consume over 218 000 tonnes of fuelwood annually (Nyabeze *et al.*, 1996; Saunyama, 2020). While traditional forms of bread baking over an open fire can still be observed in isolated rural areas of the Eastern Cape, KwaZulu-Natal, and the North-eastern Free State (Nkhabutlane, 2014), large-scale electric industrial bread production predominates in South Africa (Van der Walt, 2016). The small-scale cooking and baking enterprises in South Africa's informal settlements predominantly rely on unimproved wood-fuelled appliances (Kimemia & Annegarn, 2013). However, the staple food in the communities has shifted from traditional maize porridge to industrial bread (Steyn, 2011). Several small-scale bread baking interventions have been attempted in South Africa in recent years without much success (Erasmus & Cownie, 2002; Strydom, 2005; Botha *et al.*, 2007; DEVNET, 2014; Govender *et al.*, 2015). Common to them is the use of expensive electric-powered ovens and seemingly unsustainable business models with an overreliance on external donor funding (Erasmus & Cownie, 2002; DEVNET, 2014; Govender *et al.*, 2015).

Because bread is displacing traditional staple foods, a key advantage of the BREADrev approach is the ability of the locally baked bread to compete against the incumbent industrial bread in terms of both

price and quality (Barty, 2017). The baking activities draw on artisanal bread baking practices, relying on locally available materials, and reducing the need for electricity, expensive equipment or ingredients (Barty, 2017; Zgambo *et al.*, 2018). The BREADrev Bread Baking Initiative in South Africa is a practice-based behaviour change intervention to establish small-scale bakeries powered by improved wood-fuelled rocket ovens among under-resourced communities and disseminate the knowledge to ordinary South Africans about how to bake bread in portable wood-fired rocket ovens (Jackman, 2013; LeadSA, 2016; Barty, 2017).

The critical aspects of the BREADrev Bread Baking Initiative are highlighted below.

Formative assessment of the behavioural challenge

The main behavioural challenges are poor nutrition and high unemployment levels in South Africa. The targeted population comprises indigent South African households. The first implementations targeted representative households in Enkanini, Khayelitsha, a burgeoning South African township to the west of the Cape Town metropolitan area in the Western Cape. The area is characterised by high levels of unemployment and poor nutrition.

Behavioural contextualisation and focus

The main behavioural goal of the bread baking interventions is to assist indigent households in South Africa in baking their own bread with improved flame-based ovens, thereby increasing economic activity and improving nutrition. The hybrid behavioural theoretical approach underpinning the intervention engages participants on both a psychological and a contextual level in facilitating behavioural change, explicitly providing a sense of self-efficacy and personal agency for the participating individuals and their families. The practice-based change process reduces resistance to change in the local behaviour by assisting participants in identifying their personal needs and desires, followed by a practical set of actions.

Intervention design and implementation

An iterative design process facilitates the development of each intervention. Guided by a basic bread baking routine, local entrepreneurs from the community learn how to bake bread with wood-fired rocket ovens and establish small-scale bakeries with minimal capital inputs and low overheads. The bread baking activities facilitate personal communication between participants, providing individual assistance where required. A coherent conceptual brand narrative was developed around the baking of bread. Beneficiary participation is vital to the intervention design and development, with the pace and direction determined by their input. The local community is actively encouraged to participate.

The communication channels consist of local bread baking demonstrations by change agents centred around an improved flame-based oven. The bakeries are visually branded. Digital social media is used to disseminate baking and business advice.

The intervention materials include a medium portable wood-fired rocket oven, basic equipment and baking ingredients for the duration of the intervention. The rocket ovens can bake 128 loaves using 5 kg of wood. The smallest wood-fired rocket oven can bake four loaves at a time, whereas the largest can bake up to 48 loaves. The large double shelf oven is constructed from locally available 3-mm mild steel, refractory shelving, ceramic tile shards and sand used as insulation. A novel innovation is the enlarged burn chamber, which allows more prominent pieces of wood, thereby saving time and resources. While the ovens are deemed popular, the cost of the rocket ovens is still considered a significant barrier because it is high relative to the available local income levels. The local support infrastructure includes ongoing mentorship and technical assistance to ensure the small bakeries are sustainable and viable. Support infrastructure is established for each intervention to raise additional donor funds from local sponsors and businesses for the rocket oven.

Structured assessment of implementation process and outcomes

A limited research analysis is present for reinforcing the behavioural objectives of the intervention and incorporating findings in amended future interventions.

2.2.9　Comparative analysis

A comparative analysis of the above case studies revealed BCD aspects in improved cookstove initiatives for the South African context (Table 2.1). Most of the aspects were applied unintentionally. The KCJ and KayaGAS interventions demonstrated most aspects of a successful BCD implementation. The *basa njengo magogo* intervention most closely resembled a behaviour centred intervention. Although small in comparison, the Tree is Life Trust Initiative demonstrated the importance of participatory aspects in the success of a community-centred intervention.

Table 2.1:   Aspects of behavioural design approaches in successful stove projects

Cases under Review	Kenyan Stove Initiative (1982 – ongoing)	KayaGAS (2006 – ongoing)	Basa Njengo Magogo Fire Lighting Initiative (2009 – 2010)	South African Electricity-Focused Interventions (2007 – 2011)	Wits Behaviour Change Study (North West, South Africa) (2004 – 2005)	BREADrev Rocket Oven Bread Baking Initiatives
Type of Behavioural Approach	Limited hybrid behavioural approach with a reliance on cognitive psychology and behavioural economics	A hybrid behavioural approach is present, with a social marketing approach prominent.	Hybrid behavioural approach Max-Neef theory combined with social marketing methods & tools.	No explicit behavioural approach is present.	Social science community counselling model and associated behaviour change techniques	Aspects of individual and contextual behavioural approaches are present.
Formative Assessment of the Behavioural Challenge	Strong formative research underpinned the initiative facilitated by the University of Nairobi.	Extensive research was undertaken drawing on case experience in India and Indonesia.	Formative market research was undertaken in preparation of the project development.	The formative research appeared to be economic and social, not behavioural.	Thorough behavioural research followed up by Focus group sessions and follow-up visits.	Limited formative assessment is present.
Behavioural Contextualisation and Focus	All Kenyan stakeholders comprising stove users are included In-depth grounded research by local stake-holders in Kenyan context. The behavioural goal is to achieve correct and consistent stove use and manufacture	Urban localised SA low-income households in the urban areas Limited exploratory primary research. The behavioural goal is to achieve the acquisition of LPG stoves and fuels,	Indigent localised SA households using coal stoves close to coalfields. Exploratory research included focus groups and field studies. The main behavioural goal is to reduce household air pollution from wood and coal stoves.	Indigent SA black households. without electricity, Limited exploration of the behavioural context. No behavioural goal was identified.	Indigent localised rural SA households. Exploration included house-hold observations, field studies &focus groups. The behavioural goal was to improve household ventilation and decrease the proximity of children to the cooking area.	Indigent localised SA households. Limited exploratory research. The main behavioural focus is to assist indigent entrepreneurs and reduce food insecurity.
Intervention Design and Implementation	A coherent branded intervention facilitated local community stove demonstrations, awareness campaigns and practice-based training workshops with financial support for small-scale manufacturers.	Local physical LPG stove demonstrations facilitated by change agents and retailers living in the local community, supported by local cylinder distribution points and printed outdoor media.	Co-created intervention concept facilitating physical demonstrations of improved coal stove lighting method by local change agents supported by posters and billboards.	Regulatory interventions and financial subsidies, supplemented by a belated communication strategy incorporating countrywide television, radio and print campaigns.	Primarily conceived of as a research field study and not an intervention.	Change agent's coherent concept of local bread-baking demonstrations centred around an improved flame-based oven.
Evaluation of Intervention Design Processes and Outcomes	While methods were initially not present, the project implementations are extensively documented.	Limited assessment of the outcomes was present, restricted to financial success and applied.	Structured analysis of outcomes was present, applied and evaluated.	No research or analysis of the behavioural outcomes was found.	Structured measurement of changes in household stove emissions.	A limited analysis is present to reinforce the behavioural aspects of the intervention and amend future interventions.

The assessment of the BCD aspects applied in successful stove dissemination initiatives, as reflected in Table 2.1, led to the following conclusions:

- Hybrid behavioural aspects supported by the BCD approach were employed to understand the factors associated with changing a targeted behavioural sequence appropriate for a local context.

- While most projects seemed to perform a basic form of exploratory or formative research of the cookstove-related behavioural challenge (primarily qualitative), the research served a secondary function in the interventions. The Jiko project stands out as the exception for the level and depth of research undertaken throughout the project's lifespan.

- In most cases, a form of segmentation was present to identify the affected group. The formative research undertaken in both the KayaGAS and Jiko projects includes the clear identification and stratification of the targeted population, providing a formative understanding of the final group of beneficiaries in the interventions.

- A robust exploration of the behavioural context is present, drawing from available data sources. Before specifying a specific behavioural goal, common to all case studies was the prerequisite of an in-depth understanding of the behavioural setting.

- Despite the difficulties in obtaining reliable information, a clear behavioural framework is articulated beyond the objective of cookstove dissemination. Three projects – *Basa Njengo Magogo*, KayaGAS and KCJ – gave a clear notion of the behavioural goal, coherent with the preceding formative research of behavioural aspects. A prerequisite for framing the behavioural goal for intervention is an affordable, available and reliable cooking appliance and larger support infrastructure, including fuel supply.

- The use of an iterative intervention design process was present in all the projects, albeit often unintentional and incomplete. The KCJ project stands out for its iterative process of designing a series of sustained interventions. Participatory design methods that seek to include all stakeholders are indicated as essential. The acknowledgement and integration of informal community networks were considered vital to all and attributed to the success of the KCJ initiative. Interventions in South Africa incorporating physical demonstrations of cookstove use have shown a measure of success. The BREADrev intervention is highlighted in the successful incorporation of emotional demonstrations of a specific behavioural sequence.

- In conclusion, even if unintentional, aspects of a BCD approach significantly contributed to the success of the selected projects.

2.3 Chapter Summary

The consensus in the literature is that most improved cookstove interventions in South Africa over the last thirty years have failed. The following critical aspects are highlighted as critical in the phase-based design of a BCD intervention for potentially improving flame-based cookstove use in a South African context. Improved cookstove initiatives largely follow hybrid behavioural approaches spanning cognitive psychology, behavioural economics, and social marketing. The theoretical underpinnings of the BCD approach provide support and direction for understanding the behavioural factors for intervention in contexts similar to South Africa. A formative assessment of the behavioural challenge related to unimproved cookstoves is frequently present in the reviewed initiatives yet serves a secondary role in adopting a specific cookstove technology. Successful design-led interventions and the majority of successful improved cookstoves initiatives in under-resourced contexts share the clear identification of the affected segment of the population. An in-depth exploration of the local behavioural context is foundational in formulating a BCD intervention. Framing the prospective behavioural components provides a powerful heuristic tool to synthesise the pertinent behavioural aspects found in the formative assessment of the behavioural challenge under investigation into a coherent theory of change for an intervention. An iterative participatory design process is recommended to design a cookstove-related intervention. Constrained by the cost and level of engagement during an intervention, implementations can take the form of one-on-one demonstrations or community events facilitated by change agents and assisted by outdoor, mass or social media. The implementation is assessed to gauge the success of engagement with the selected criteria articulated in the intervention. The sustainability of the behaviour change over the longer term should be measured. Including appropriate research methods and instruments is of paramount importance for the reliable assessment of the development and implementation of behavioural interventions.

3   RESEARCH DESIGN

This chapter presents the research design for assessing a BCD approach to the design and implementation of a behaviour-focused cookstove dissemination intervention.

The research design visually depicted in Figure 3.1 proceeds with a review of the transdisciplinary paradigmatic orientation and philosophical interpretation of the ontological, epistemological and axiological aspects. A summary of the research approach is provided. The phase-based case study research framework is then presented (Figure 3.2). The research focus is articulated to guide the exploration of the research objectives during the phase-based research process (Figure 3.3). The framework summarises the choice of research methodology for collecting and analysing data during the research study. The specific time horizon is set constrained by the aforementioned research focus. The scope of supported research methods and techniques is given with descriptions of essential methods emerging from the literature review.
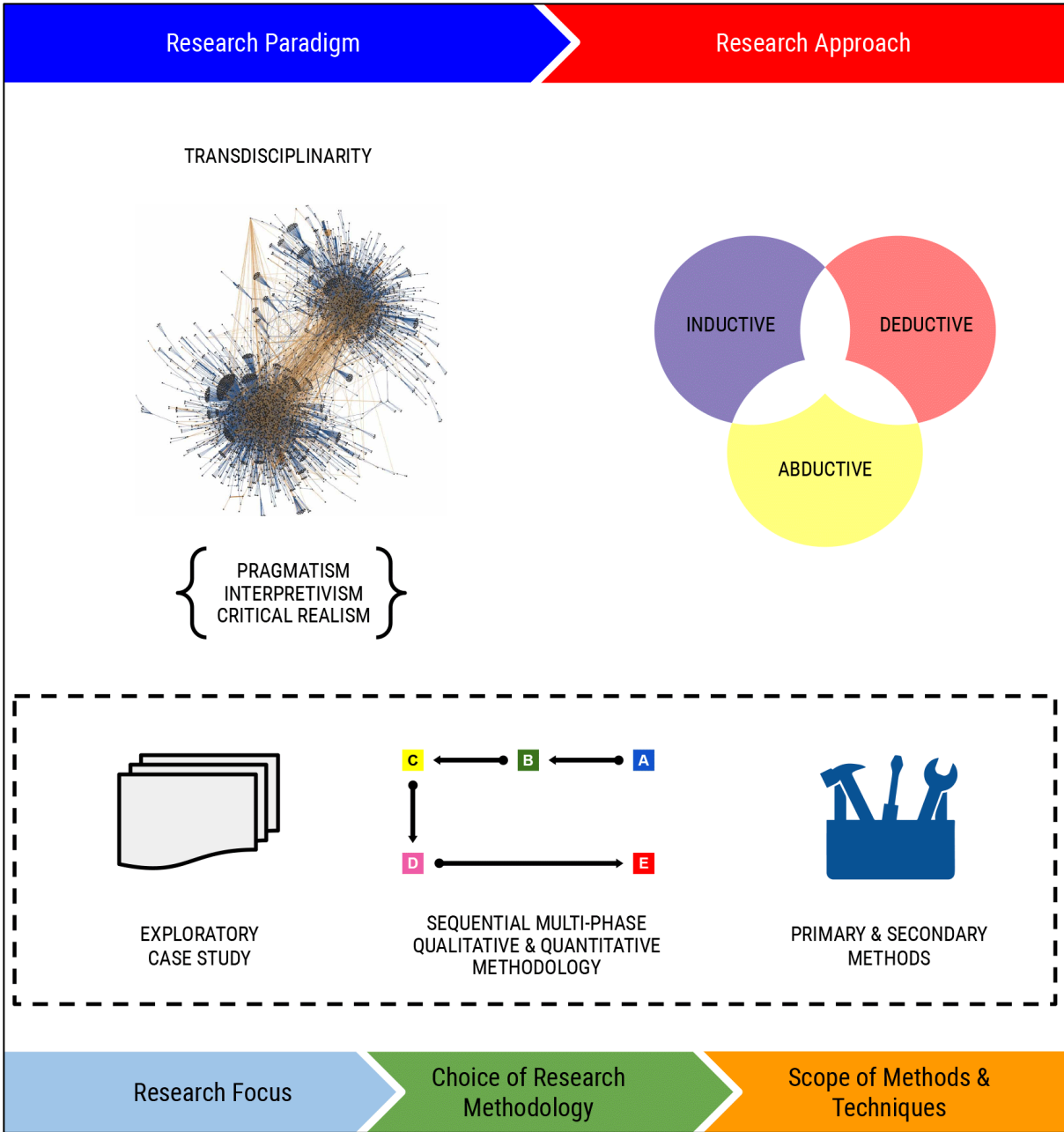
Figure 3.1:   Research design visualisation (adapted from Saunders *et al.*, 2009)

3.1   Research Paradigm and Philosophy

The research design is situated in a transdisciplinary research paradigm to transcend the complexity of problems and numerous interconnected perspectives related to the research aim and objectives (Burns *et al.*, 2006; Darbellay *et al.*, 2008; Cockell *et al.*, 2011; Welzer & Sommer, 2014; Erlhoff, 2015; Irwin *et al.*, 2015; Manzini & Coad, 2015; Strömberg *et al.*, 2015; Niedderer *et al.*, 2017). A transdisciplinary paradigm accommodates the hybridisation of knowledge characterising a BCD approach drawing on design theory and the behavioural sciences (Darbellay *et al.*, 2008; Cockell *et al.*, 2011). The pragmatic accumulation of knowledge in a transdisciplinary paradigm necessarily implies that the research focus could shift in direction during the research process. The changes in research focus that may occur during

the process of accumulating knowledge require a pragmatic research methodology (Darbellay *et al.*, 2008). A phase-based methodology as emphasised in BCD theory and practice allows the researcher to pragmatically apply appropriate methods and techniques during the research process as recommended by Darbellay *et al.* (2008) and Dalsgaard (2014).

3.1.1 Research philosophy

The research is situated in a pragmatic realist philosophy, as suggested by Love (2000), Dalsgaard (2014) and Bruno Latour in Salinas (2016). The research philosophy supports a pragmatic objective view of the nature of reality (i.e., pragmatic realist ontology) and an interpretive way of understanding the nature of reality (i.e., interpretivist epistemology) guided by an emancipatory set of guiding values (i.e., emancipatory axiology).

Pragmatic realism is interpreted as a pragmatic philosophy for guiding a BCD approach. The philosophical stance guides the critical analysis of the nature of complex phenomena operating in the biophysical and socio-institutional fields while probing the relationships and processes that govern them (Dickens, 2003; Hodgkinson & Starkey, 2012). Critical realism philosophy pragmatically assumes that there is a real world. We behave and act as though it is real, frequently explaining phenomena by their apparent underlying causes (Sayer, 2004; Easton, 2010). In this regard, design philosophies are distinct from the sciences and humanities, articulating theoretical and practice-based design research approaches. Common in the philosophical positions is a reliance on assumptions that are adjudicated pragmatically in terms of human perceptions and assumptions that then provide explanations for the phenomena (Dilnot, 1999; Jonas, 2007; Krippendorff, 2007; Breslin & Buchanan, 2008; Erlhoff, 2015; Herlo *et al.*, 2017). A pragmatic realist philosophical stance allows the researcher to avoid metaphysical debates about the nature of truth and reality and focus instead on understanding the concrete real problems under investigation (Patton, 2015).

Research ontology

A pragmatic realist ontology underpins the present research study to address a complex behavioural design problem spanning several disciplines that must accommodate divergent views on the nature of reality held by relevant individuals and communities of interest and practice (Creswell, 2007; Iivari & Venable, 2009; Robson, 2011). The pragmatic investigation in this study focuses on practical experience with an agnostic approach toward theory, focusing on practical processes, implications and outcomes, avoiding nebulous discussions on the nature of knowledge and truth (Teddlie & Tashakkori, 2009).

Research epistemology

The study adopts a pragmatic interpretivist epistemological stance due to the complexity of the phenomena under investigation, as suggested by Fukuuchi, Yang and Dalladay-Simpson (2009), and

Saunders, Lewis and Thornhill (2009). An interpretivist epistemological stance is taken to understand the nature and purpose of phenomena under investigation by studying real-world situations as they unfold. Conceptual models and frameworks are built based on the analysis of qualitative data and reflection by the researcher on the emerging insights. A pragmatic stance, as suggested by BCD research and practice, provides the researcher the ability of straddling the tension of subjective interpretations and positivist objective evaluations on the validity and reliability of a design research study, allowing a pragmatic level of flexibility in the research choices made between qualitative and quantitative research methods and techniques during the research process (Saunders *et al.*, 2009). The stance is necessary to accommodate an exploratory research focus, which could lead to non-generalisable findings beyond the scope of this thesis (Saunders *et al.*, 2009). A transdisciplinary research philosophy supports a pragmatic epistemological stance that is not purely methodologically driven, accommodating mixed research methods (Gibbs, 2015).

Research axiology

An emancipatory axiological philosophy informs the research design as proposed by Gibbs (2015) and Puri (2004). The value of the research is informed by the emancipation of the local community in an ethical process, which is integral to a lasting change in a specific behavioural challenge (Georges & Goldsmith, 2010). BCD employs deliberate methods and techniques to influence the behaviour of people. A transparent, ethical approach demonstrating an interest in the personal lives and concerns of beneficiaries is imperative when designing an intervention seeking to influence their behaviour (Verbeek, 2017; Mills, 2020). The difference between positive influence in a consensual manner and manipulation is a narrow line. The unethical deployment of behavioural design approaches to deceive people and coerce behaviour is well documented. Past interventions have included a long history of nefarious persuasion campaigns linked to the consumption of tobacco (Longfellow, 2002; Murphree, 2015) and political propaganda (Voigtländer & Voth, 2015). Current persuasion campaigns utilise large-scale psychographic profiling aided by data sourced from social media (Bakir, 2020), manufacture the consent by policymaking and regulatory means (Goldstein & Findley, 1996; Petticrew *et al.*, 2020), and conduct sophisticated marketing campaigns for a wide array of goods and services that prey on human frailties (Drumwright & Williams, 2013).

Designing for a transformative change in the behaviour of a community, specifically, the diffusion of clean cooking technologies is aligned with the present researcher's ethics and values. From the perspective of the present researcher, it is considered the designer's responsibility to positively contribute to the community's economic, social, cultural and environmental sustainability (i.e., society, businesses and other stakeholders). Specifically, in this case, this refers to the health and wellbeing of individuals and society as a whole. While codes and guides can help facilitate an ethical approach, a truly ethical approach requires an ethical and moral imagination (Werhane, 1998; Benatar, 2005; Moberg & Caldwell, 2007; Kiragu & Warrington, 2013). Balsamo (2017) places this ethical

responsibility on the designer. When designing in a South African context, the designer needs to guard against the prejudicial effect of the patterns of behaviour of South Africans (Barnes, 2010).

3.2   Research Approach

The research approach combines aspects of deductive, inductive and abductive approaches to generate knowledge in line with the main research aims and objectives. The research approach informs the exploratory phase-based case study framework with both theoretical and practice-based components as suggested by Aunger and Curtis (2016). The research approach incorporates aspects of abductive, inductive, and deductive approaches to frame, develop, and deliver a behaviour-focused intervention drawing on the design and behavioural science fields (Aunger & Curtis, 2014, 2015a, 2016; Cash *et al.*, 2022).

3.2.1   Deductive research approach

A deductive approach underpins the identification of critical aspects in designing a South African behaviour-focused cookstove intervention by drawing on the review of theory and applications in practice. Aspects of deductive approaches are applied in examining the validity of the available assumptions and theories; and setting the research objectives and goals to be assessed during the research process of the case study (Aunger & Curtis, 2008; Gulati & Puranam, 2009).

3.2.2   Inductive research approach

An inductive approach is employed for the exploratory formative research phase to provide a deeper understanding of emergent aspects of the societal problem, assist in generalising the research findings, and formulate theoretical insights emerging from the secondary research. The inductive research approach is underpinned by an interpretivist epistemology reflecting the researcher's subjective observations of the information collected with qualitative methods (Kelle, 2006; Suri, 2006; Ambole *et al.*, 2012; Aunger & Curtis, 2016). The inductive approach guides the synthesis of frameworks to guide the unfolding intervention design process (Trochim & Donnelly, 2006). Inductive approaches are used to analyse and synthesise insights emerging from the patterns and themes and incorporate them into the research process (Trochim & Donnelly, 2006).

The inductive approach extends to describe the emerging conceptual approximations of solutions drawing on a pragmatic interpretivist realist philosophy to categorise between the subjective perception of phenomena and material empirically verifiable phenomena (Newell & Simon, 1972; Rittel & Webber, 1974; Laverty, 2003; Coyne, 2005; Kafle, 2011; Zia, 2018). The phenomena can include the subjective views, judgments, perceptions and emotions of the cookstove users, stakeholders or researchers. The subjective insights and perceptions are expected to be gathered through qualitative research methods (i.e., interviews and observational studies) (Creswell & Miller, 2000). An inductive

approach is employed to evaluate the sequentially collected findings of the development and implementation of a BCD intervention. Inductive inferences are made from the study's systematic combination of collected and analysed data.

3.2.3   Abductive research approach

An abductive research approach in addition to deductive and inductive approaches of inquiry is employed in the development of a behaviour-focused intervention strategy. The abductive approach is included to accommodate the creation of concepts and frameworks that do not yet exist as recommended by Erlhoff (2015) and Jones *et al.* (2016). Abductive research approaches are frequently used to navigate gaps in the exploratory or iterative phases in design approaches similar to the BCD research approach (Jonas, 2007; Kolko, 2010). Cross (2007) and Gibbs (2015) suggest incorporating abductive research approaches in creative, intuitive processes to enable transdisciplinary inquiry and to overcome often incomplete and conflicting data. An abductive approach facilitating iterative methods is employed in the design of a BCD intervention. The approach is employed to encourage unencumbered disciplinary thought, to increase the feasibility of finding an elegant synthesis navigating the epistemic relations to discipline-specific ontologies, and to record unusual findings incorporated in the emerging BCD intervention (Jonas, 2007; Kolko, 2010).

3.3   Phase-Based Case Study Research Framework

An exploratory phase-based research framework is formulated to attain the main research objectives as depicted in Figure 3.2. The development and assessment of a BCD intervention for the diffusion of clean cookstoves in representative South African contexts requires a distinct research framework as reviewed in Section 2.1.3. The ontological, epistemological and axiological research philosophy described above suggests a phase-based case study framework as appropriate for addressing the aim and objectives. An exploratory case study focus is recommended in accommodating deductive, inductive and abductive research approaches (Yin, 2017).
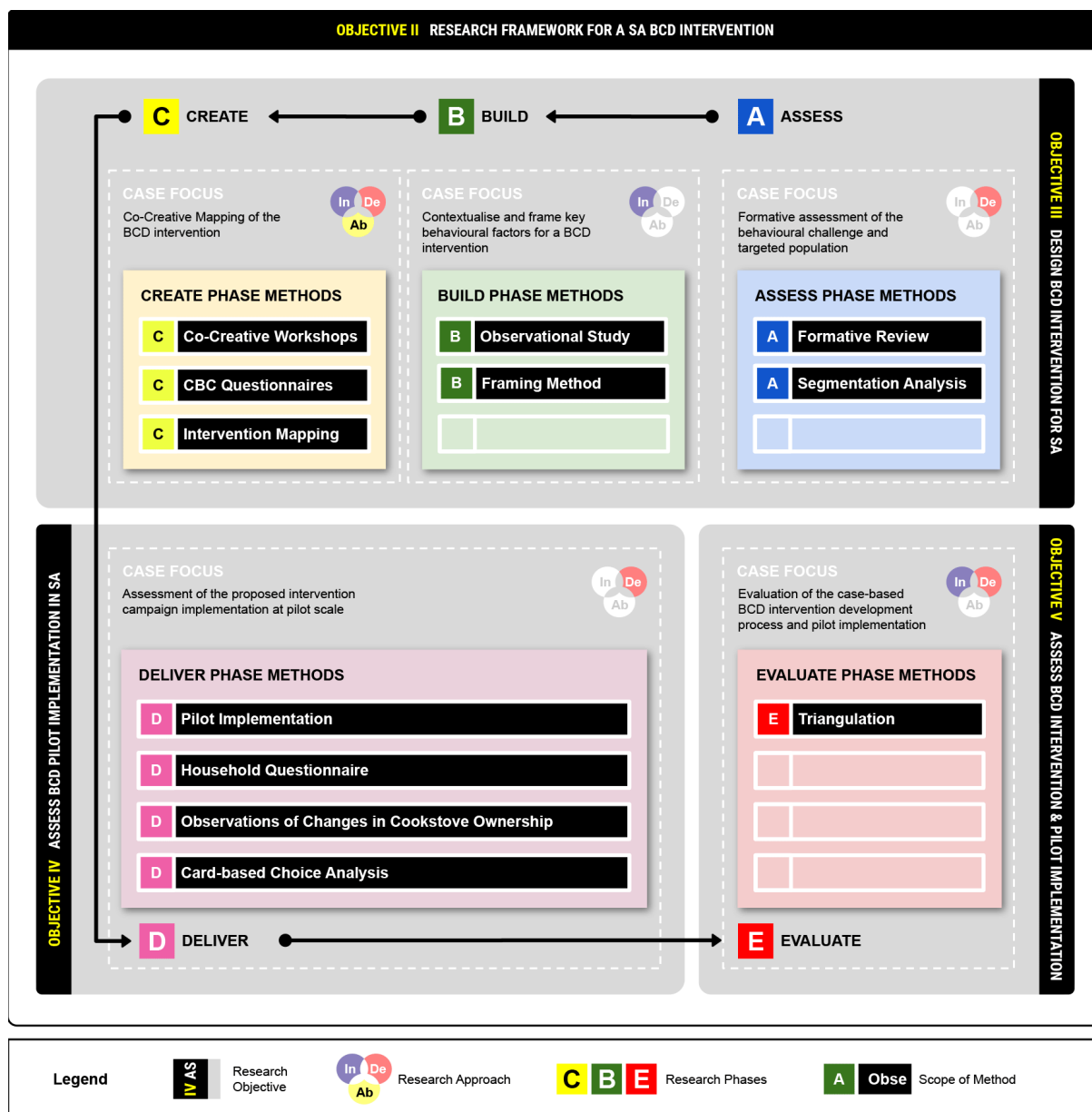
Figure 3.2: **Phase-based case study research framework**

A pragmatic phase-based research framework can reduce the complexity of identifying a problem and finding a solution (Findeli *et al.*, 2008; Ambole *et al.*, 2012; Aunger & Curtis, 2016). Pragmatic frameworks similar to the BCD approach have successfully been applied in a South African (Brown & Wyatt, 2010; Ambole, 2016) and SSA context (Aunger *et al.*, 2010; Greenland *et al.*, 2016), exploring complex problems transcending different professional disciplines while attempting to solve specific problems in an empathetic manner. The framework supports pertinent theoretical and practice-based methods and techniques depending on the research focus during each phase of the case study as recommended by design research literature (Simon, 1969; Fogg, 2009; Francis *et al.*, 2009; Michie *et al.*, 2011; Sangiorgi, 2011; Castillo *et al.*, 2012; Kelders *et al.*, 2012; Welzer & Sommer, 2014; Erlhoff, 2015; Aunger & Curtis, 2016; Niedderer *et al.*, 2016; Tromp & Hekkert, 2016; Cash *et al.*, 2017).

3.3.1 Exploratory research focus

An exploratory case study-based research focus guides the process of knowledge acquisition facilitated by the articulated main research aims and objectives. An exploratory case study can accommodate expected changes in the phenomena under investigation (Yin, 2009; Bell *et al.*, 2018; Creswell & Creswell, 2018). The focus accommodates the complexity of the phenomena expected to be encountered in practice and adjust the research objective during the study as emerging findings direct the research in more valid directions. A phase-based research focus structurally guides the case study methodology accommodating the deductive, inductive and abductive aspects of the research approach in responding to the results and themes emerging from the real-world practice, cognisant of the limited time available (Goupy, 1993; Saunders *et al.*, 2009; Creswell, 2014; Gravetter & Forzano, 2018). The exploratory case study provides the ability of navigating the ostensible gaps in the area of knowledge under investigation within relatively short time horizons (Gravetter & Forzano, 2018).

Descriptive aspects are included in the preliminary phases of the case study. The descriptive focus accommodates a plethora of survey methods, which include literature-based reviews and observations of behaviour (Gravetter & Forzano, 2018). A pilot study is supported during the latter phases of the study, as suggested in the reviewed BCD approach in Section 2.1 and discussed in the following outline of the research methodology.

3.3.2 Choice of research methodology

A phase-based case study research methodology is chosen to facilitate an exploratory research focus investigating the effect a BCD intervention can achieve in the diffusion of improved flame-based cookstoves on a sample scale (Aunger & Curtis, 2015a; Aunger, White, Greenland, *et al.*, 2017; Aunger, White, Huberts, *et al.*, 2017; Niedderer *et al.*, 2017; Yin, 2017). The case study research methodology is chosen, consistent with a transdisciplinary pragmatic research paradigm, accommodating deductive, inductive and abductive research approaches and with an exploratory research focus, accommodating the use of quantitative and qualitative research methods as recommended by Easton (2010) and Yin (2017).

The case study methodology accommodates the flexible adaptation of research approaches throughout the phase-based research process (Aunger & Curtis, 2014, 2015a, 2016). The methodology is clustered around the research phases depicted in Figure 3.3, informed by the critical elements of the BCD approach of Aunger and Curtis (2016) reviewed in Section 2.1.

The phase-based process is oriented towards solving the designated research objectives with appropriate data collection methods, processes and techniques guided by the BCD practice and theory that emerged from the literature review.
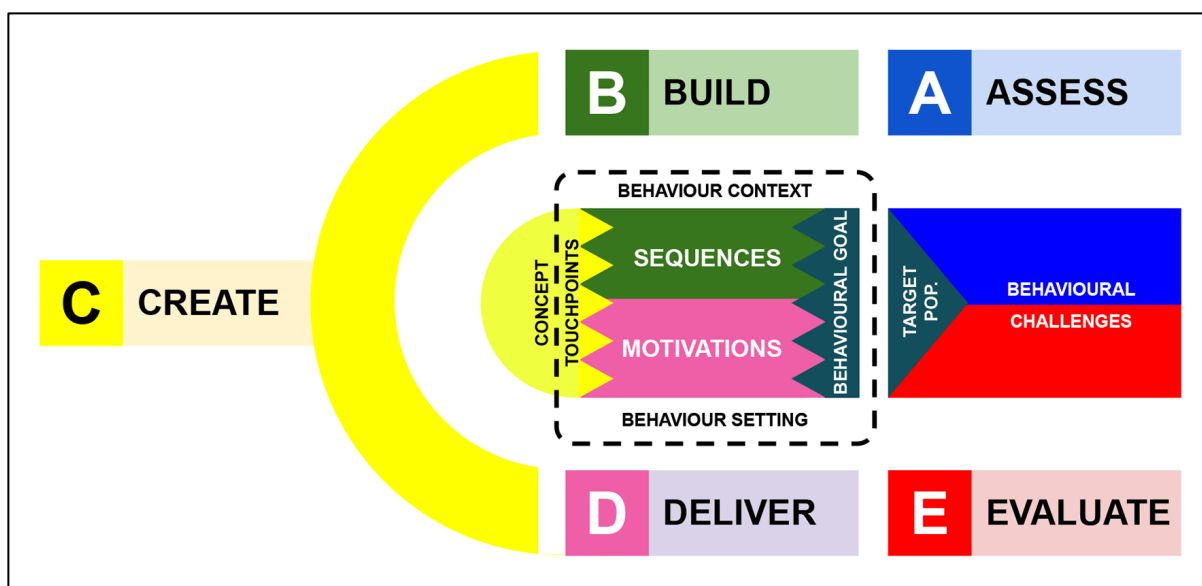
Figure 3.3: **Phase-based BCD process (adapted from Section 2.1.3)**

As depicted in Figure 3.2 and Figure 3.3, the first phase proceeds with a formative assessment of the behavioural challenges related to using flame-based cooking appliances in a South African context in preparation for the second phase. The formative assessment is complemented by the identification the targeted population.

The second phase explores the behavioural factors of the targeted population in a representative setting. The second phase concludes with the formulation of a behavioural framework synthesising the insights emerging from the review of gathered information and exploration of the behavioural context.

The focus of the third phase entails creating the critical elements of an intervention strategy. Central to the process of analysis and synthesis is developing a select group of touchpoints guided by the motivations proposed in the preceding behavioural framework.

The fourth phase of the research framework concerns the pilot implementation and analysis of the intervention. The evaluation spans the success of the implementation in generating surprise at interactions with the touchpoints, the revaluation of motivations and the performance of behavioural goals.

The final phase evaluates the results that emerge during the preparation (i.e., ASSESS), exploration (i.e., BUILD), creation (i.e., CREATE) and implementation (i.e., EVALUATE) of the BCD intervention process to strengthen the design and evaluation of behaviour-focused on improved cookstove dissemination on a larger scale.

3.3.3   Qualitative and quantitative multi-phase aspects

Due to the diverse nature of data to be collected during the multi-phase case study, the methodology supports the administration of qualitative, quantitative methods (Yin, 2009; Bell *et al.*, 2018; Creswell

& Creswell, 2018). The qualitative and quantitative multi-phase research methodology is facilitated by the following unit of analysis, the researcher's stance in the study and suggested time horizon.

Qualitative methodological aspects

Qualitative methods are accommodated to explore insights throughout the phase-based study from the researcher's perspective (Creswell & Creswell, 2018). As suggested by Mouton (2001) and Creswell (2014), qualitative research methods are most appropriate when exploring and understanding the meaning that individuals and the broader surrounding community attach to various patterns of behaviour. The qualitative research methods are used in a deductive, value-bound inquiry, to understand the specific phenomena under investigation.

Quantitative methodological aspects

Quantitative methods are supported to gather and analyse data towards the later phases of the case study (Bell *et al.*, 2018; Creswell & Creswell, 2018). Quantitative data analysis is used to evaluate BCD intervention results on a descriptive level to reflect the reliability and validity of the results. The quantitative research methods were supported to analyse data collected during the case study. Mathematical and statistical analytical methods are applied to derive realist, objectivist or inductive insights in the case study, depending on the specific research focus. Supported quantitative methods include surveys, formal questionnaires and statistical analyses, whereas qualitative methods include interviews and ethnographic analyses as research instruments.

Unit of analysis

The unit of analysis in the case study was the design and application of a BCD intervention implemented at a pilot scale among a representative sample drawn from two sites in South Africa. The unit of analysis for the research included the procedures of the BCD intervention design process, the research methods, drawing on appropriate behavioural design theory and the practice reviewed in Chapter 2.

Researcher's stance

In the case study methodology, the researcher took the roles of the initiator of the project, co-facilitator at critical junctures, participant and observer. The stance provided a holistic view of the case study and each of the methods and instruments applied. This active participation provides an insight into a rich array of subtleties, which may have been more challenging to observe from a distance. The research design allowed the researcher's role to change from observer to facilitator during the research process while guiding the participatory activities in the decision-making process. The involvement of research participants implies the need for building trust and partnerships, requiring conscious preparation due to the socio-cultural differences and constraints of projects situated in under-resourced contexts.

The choice of time horizon, specifying the duration and number of recurring intervals during the study, is a crucial attribute in determining the limits and scope of the research methodology (Creswell, 1998; Saunders *et al.*, 2009). A cross-sectional time horizon was applied, directing the study of phenomena during the research process limited to a specific period. The cross-sectional horizon selected for the research, including data analysis, took place during approximately the same period. In contrast, data collection occurred at specific times within the different phases of the research.

3.3.4 Scope of methods for data collection and analysis

The scope of research methods employed during the phase-based case study methodology for data collection and analysis is delimited to effectively gather observations of behaviour, interviews with people, questions about the phenomena under investigation, or standardised experiments to assess the success of an intervention. Mouton (2001) suggests various data collection methods (e.g., observation studies, self-reporting, and interviews). The researcher selected the data collection methods according to their ubiquity and success across multiple disciplines to address the complex relationships in contexts similar to those expected in the under-resourced context of the South African study area. The research methods chosen for each specific design activity or collection of activities unfolding in each of the phases of the framework were drawn from research methods and instruments described in the literature review. A detailed description of the methods used during each phase of the research methodology is presented in the relevant sections of their procedural application. To provide a comparative baseline the researcher gave preference to methods and instruments drawn from the BCD protocol toolset described in the relevant literature (Aunger, White, Huberts, *et al.*, 2017). Additional research methods were drawn from the background review of the research methods applied in the broader design- and cookstove-related practice appropriate for a South African under-resourced context and included for consideration. An explicit classification scheme of all possible BCD research methods was considered inappropriate to near impossible due to the inherent complexity of predicting the myriad of actions an intervention design process could take and the multiplicity of methods available.

Formative literature-based reviews

The thesis literature review is supplemented by the conduct of supplementary contextually relevant preparatory research during the multiphase case study. As recommended by Aunger and Curtis (2016), secondary research methods are employed, including the review, collation, or synthesis of existing literature-based sources of data to identify behavioural challenges related to flame-based cooking appliances in South Africa.

Population segmentation method

To provide a more nuanced and differentiated understanding of the targeted population and their underlying needs, a segmentation of the population into smaller homogeneous segments is considered foundational to successful interventions in general (Söderlund *et al.*, 1999; Schewe & Meredith, 2004; Brochado & Martins, 2008; Wedel & Kamakura, 2012; Aunger & Curtis, 2015a; Higgs, 2015) and recommended in BCD literature and practice in particular (Aunger, White, Greenland, *et al.*, 2017; Verplanken, 2018). In South African practice, the reliable segmentation of a population relies on a combination of the living standard measure (LSM) instrument and its successor, the socio-economic measurement (SEM) instrument (Haupt, 2006; Brochado & Martins, 2008; Beer, 2015; Langschmidt, 2017; Frontline, 2018).

Observational study method

An observational study method was accommodated to develop a broad understanding of the behavioural context related to representative under-resourced South African households using flame-based cooking appliances—as described and applied by Hutchinson (2003), Kuniavsky (2003), Kelle (2006), Suri (2006) and Aunger and Curtis (2016). The observational study methods appropriate for inclusion span integrated qualitative, ethnographic research techniques with the researcher acting as a passive observer (nonparticipant observations or immersions) (Kumar & Phrommathed, 2005). The recommended observational techniques include questionnaire-based interviews, immersions, video recordings and photos, with note-taking as the instrument of data collection adding in-context observation.

Framing analysis method

A framing analysis method is frequently employed to propose a guiding framework for the design of an intervention comprising contextually related behavioural factors drawing on primary and secondary data (Aunger & Curtis, 2015a; Kar & Zerriffi, 2018). A framing analysis method provides the ability to analyse the behavioural factors that influence how people live in a specific context (Goffman, 1974; Tversky & Kahneman, 1981; Carnahan *et al.*, 2019). The framing of the emerging qualitative data sets out to understand the critical behavioural factors linked to the proposed behavioural challenges, motivations and goals for intervention.

Co-creative workshop method

The framework facilitates the application of co-creative workshop-based methods to develop a BCD intervention as suggested by BCD practice (Aunger, White, Greenland, *et al.*, 2017; De Buck *et al.*, 2017). Co-creative workshop-based methods have been applied across a wide array of design disciplines in support of descriptive, explanatory and theoretical research objectives (Stienstra & Hoonhout, 2003; Wensveen & Matthews, 2015; Van Lettow *et al.*, 2016), including in BCD interventions (Aunger & Curtis, 2016; Aunger, White, Greenland, *et al.*, 2017). Co-creative workshop-based methods are

recommended for assisting in the inclusive, participatory development of the proposed intervention, including the iteration of intervention activities, sequences and touchpoints (Mor *et al.*, 2012; Lockton *et al.*, 2013; Kwon, 2016). Data collection during the workshop activities can include observational studies and exit interviews.

Intervention mapping method

An intervention mapping method is recommended to synthesise collected data for an intervention. (Lim *et al.*, 2008; Bartholomew Eldredge *et al.*, 2016; Kok *et al.*, 2016; Fernandez *et al.*, 2019). Intervention mapping provides a systematic process for developing, implementing, and evaluating interventions (Bartholomew Eldredge *et al.*, 2016; Fernandez *et al.*, 2019). The mapping in a BCD approach includes the synthesis of behavioural sequences, motivations and touchpoints for a targeted setting (Aunger & Curtis, 2015a). Intervention mapping applications have accompanied community-based co-creative research methods in practice (Fernandez *et al.*, 2019).

Card-based choice analysis method

The collection and analysis of data emerging from a phase-based process can be facilitated by card-based choice analysis methods (Lockton *et al.*, 2010). A card-based choice (CBC) questionnaire presented in the form of illustrated cards depicting prompts reflecting attributes is recommended (Segelström, 2010; Dziegielewski, 2011). Card-based choice experiments visually depicting hypothetical stove attributes as printed cards allow the reliable collection of choices and avoid potential confusion and fatigue in a South African context (Maré & Annegarn, 2017).

Pilot implementation method

To evaluate the proposed process of designing a BCD intervention and assessing the behavioural outputs and outcomes, the framework facilitates the implementation of the intervention on a pilot scale (Platt *et al.*, 1993; Yin, 2017; Šimek & Šperka, 2019). The testable prototyping of an intervention at such a scale is supported (Yin, 2017). The case study-based pilot implementation provides the ability to generate knowledge of the phenomena for the distinct areas of study covered. BCD practice suggests the administration of tailored household surveys and structured observations of changes in behaviour before, during and after implementation (Aunger & Curtis, 2016; Greenland *et al.*, 2016; White *et al.*, 2016). The assessment of changes in behaviour can be augmented by statistical analyses of the collected data, with discrete choice experiments, stated preference surveys and willingness to pay instruments frequently applied, accommodating methods such as statistical analysis of variance (ANOVA) (Hensher *et al.*, 2005; Takama *et al.*, 2012).

Triangulation method

Triangulation is recommended to evaluate phenomena resulting from the case study research process, its emerging findings and outcomes; provide plausible explanations for the findings and provide the

basis for generating new knowledge (Stappers, 2007; Aunger, White, Huberts, *et al.*, 2017); The triangulation is furthermore expected to strengthen the validity and reliability of the diverse types of data (Mathison, 1988; Flick, 2004; Freeman *et al.*, 2007; Denzin, 2012; Denzin & Lincoln, 2017). Triangulation has proved reliable as a monitoring and evaluation instrument in interventions, corroborating the final research results and increasing their reliability and validity, strengthening conclusions about said results and leveraging their reliable, sustained scalability (Freeman *et al.*, 2007; Stojanovic *et al.*, 2013). A triangulation can accommodate the multiple research methods and instruments applied, extending analysis and interpretation beyond the granular investigation of the specific phenomena under investigation to a high-level view of the research results.

3.4   Chapter Summary

A multiphase case study-based research framework is proposed combining sequential and concurrent research and design approaches in addressing the research objectives. The phase-based research framework facilitates an exploratory case study methodology, applying qualitative and quantitative methods in a systematic research process. The research design combines deductive, inductive and abductive research approaches to systematically collect and analyse the primary and secondary data, culminating in disseminating the results. The study employs a deductive approach to assess a behaviour-focused intervention's emerging aspects in a representative South African community and deduce whether a proposed BCD intervention has been successful. An inductive approach is employed in exploring and describing behavioural challenges related to the low adoption of improved flame-based cookstoves and establishing a preliminary categorisation of selected aspects of the behavioural context under investigation. An abductive approach is employed during the co-creative phase. The research framework supports the application of mixed quantitative and qualitative methods, depending on the changing research foci during the research phases. The phase-based process facilitates the collection and analysis of data before, during and after the iterative design of the intervention. A triangulation is included to increase the validity of the research results.

4   RESEARCH METHODOLOGY

A case study-based research methodology was applied to assess the efficacy of a BCD approach in positively influencing flame-based cooking technologies among impoverished South Africans (Yin, 2009; Bell *et al.*, 2018; Creswell & Creswell, 2018) The phase-based case study accommodates an adaptive methodology adjustable to various applications combining multiple research methods and instruments, as depicted in Figure 4.1. The primary data collection process took place from February to December 2017. The emerging intervention was developed, implemented and assessed at a pilot scale in the Dunoon and Mamelodi study areas. The case study-based methodology proceeds along the phases described in the research design framework (Chapter 3).

The case study proceeds with a formative assessment of the behavioural challenge faced by impoverished South African households related to flame-based cookstove use is first provided (ASSESS phase in Figure 4.1). The summarised assessment spans the origins of culinary behavioural factors; the health hazards associated with flame-based appliances in South Africa; the critical behavioural factors related to the external environment; concluding with a description of the key cooking props and infrastructure in a South African context, namely the range of available flame-based cookstoves and related fuels. The case study continues with a segmentation to identify the targeted population, guided by the formative literature-based assessment of the behavioural challenges in Section 4.1 of the ASSESS phase depicted in Figure 4.1.

An observational study follows the segmentation to explore the critical behavioural aspects in a South African context (BUILD phase in Figure 4.1). The main results of the segmentation and observational study are distilled within a behavioural framework articulating a behavioural goal and a set of contextualised motivations that could be linked to the critical points of interaction during an intervention (BUILD phase in Figure 4.1). Critical aspects of a testable intervention are developed using a co-creative workshop method (CREATE phase in Figure 4.1) guided by the behavioural framework. The case study then proceeds to pilot implementation in two representative sample areas to assess selected aspects of the intervention assisted by a stated preference (SP) analysis (DELIVER phase in Figure 4.1). The case study concludes with a triangulation method that crosscuts selected aspects of the BCD intervention process and outcomes (EVALUATE phase in Figure 4.1) to predict the results of a full-scale implementation of a BCD intervention in South Africa.
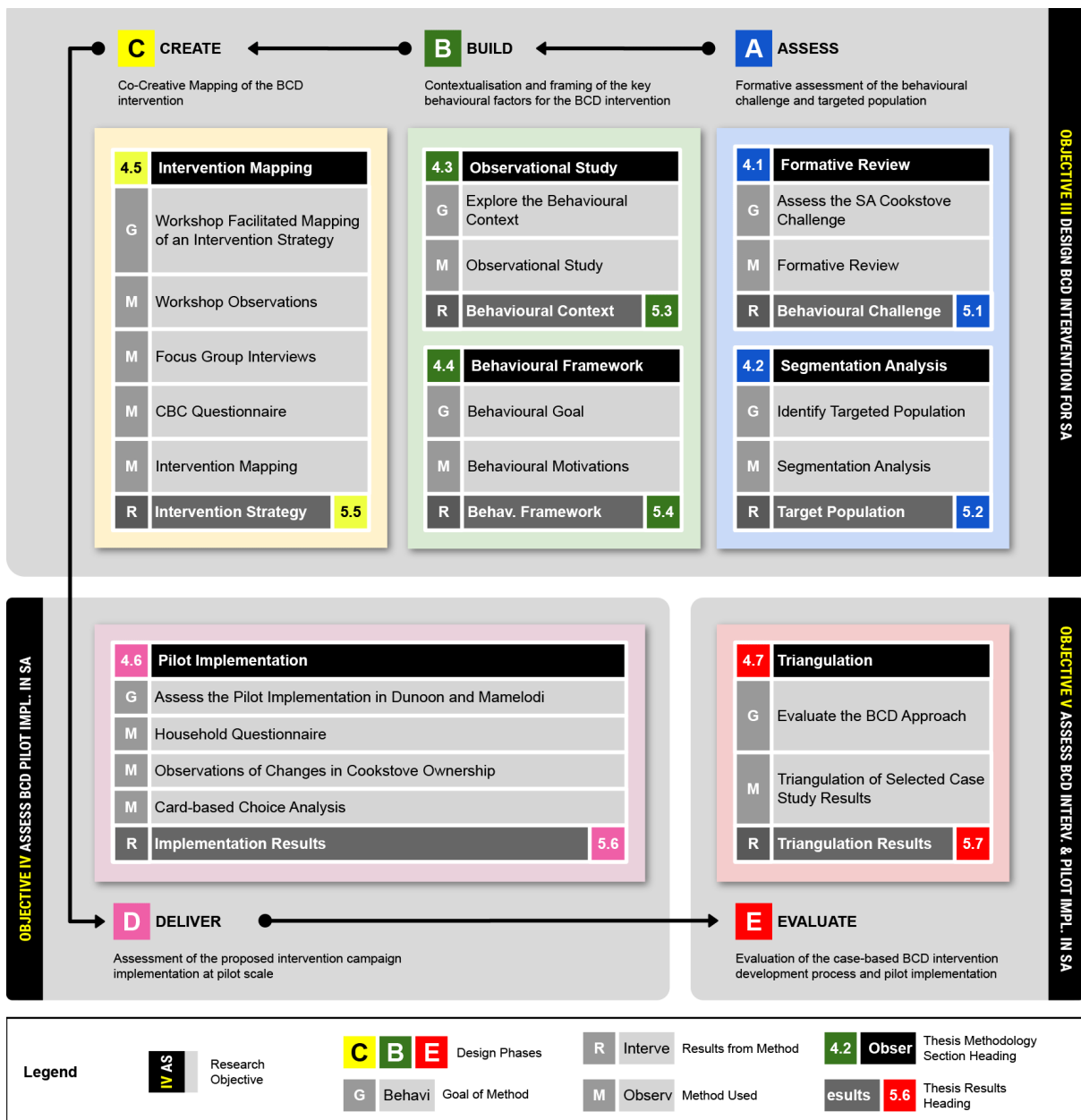
Figure 4.1:   **Multi-phase research methodology**

Methods and instruments for data collection and analysis

The data collection methods and instruments were selected based on their relevance within each particular context as the research methodology unfurled, building on the emerging results and mutually reinforcing a comprehensive body of evidence supporting the influence of a BCD intervention on achieving the main research aim. The methods and instruments were applied to answer the main research objectives in the following chronological order:

- A segmentation analysis method was applied to determine the targeted population based on secondary data sourced using the Socio-Economic Measure (SEM) instrument.

- An observational study was conducted to explore the behavioural context in two representative sample areas – incorporating immersions, short household questionnaires, stove use questionnaires and household observations of existing stove use.

- A framing method was applied to formulate a behavioural framework comprising blending the contextually pertinent aspects of the main challenge into a behavioural goal and related enabling or disabling motivations for an intervention. The framing method draws on the primary and secondary evidence from the literature review, the segmentation and the observational study.

- A co-creative workshop method was employed to orchestrate selected intervention sequences and touchpoints linked to the motivations proposed by the behavioural framework and facilitated by a proposed intervention concept. The workshop observations and structured interviews guided by a series of card-based choice (CBC) questionnaires were synthesised with an intervention mapping method, culminating in a testable intervention.

- A SP survey methodology was administered in two sample areas to assess a pilot implementation. It incorporated structured observations of stove ownership patterns to assess the achievement of the behavioural goal and a card-based questionnaire to assess the reach and accuracy of exposure to selected touchpoints for influencing targeted motivations.

- A triangulation method was used to appraise the results of the multiphase BCD approach that spanned the design and pilot implementation of an intervention and identify critical aspects responsible for its success or failure.

Sample area selection

The case study was set in two sample areas of South Africa. The sample area of Dunoon and Mamelodi were purposively selected as a sample frame for the target population, drawing on the 2016 South African household survey data (Stats SA, 2017). The living standards of these areas are covered predominantly by groups *SEM1* to *SEM4* (SAARF, 2014; BRC, 2017), given their population distribution, levels of economic and social development, and geographic location, which exhibit both rural and urban characteristics associated with South Africans vulnerable to the hazards of flame-based cooking appliances.

Data collection was conducted predominantly in the study areas of Dunoon. Mamelodi was added for the pilot implementation phase. The observational study was conducted in the study areas of Dunoon.. As part of the intervention design, the co-creative workshops took place predominantly in Fish Hoek Dunoon. Dunoon and Mamelodi sample areas served to assess the intervention pilot implementation with baseline and endline studies conducted in both. The locations of the two study areas in the Western Cape and Gauteng provinces are indicated in Figure 4.2.

Figure 4.2: Map of South Africa indicating locations of the Dunoon and Mamelodi sample areas (Municipal Demarcation Board, 2011)

Dunoon Sample Area

The Dunoon sample area is a small township on the northern outskirts of Cape Town in the Western Cape region of South Africa. Dunoon is situated between a light industrial area to the south and agricultural land to the north and west, adjacent to the N7 national highway (Figure 4.3). Established in 1996, Dunoon consists of informal dwellings made of corrugated iron and self-constructed brick and mortar houses. Narrow roads characterise Dunoon, with dwellings often extending onto the verges. Dunoon is served by municipal electricity and water connections. Sanitation is provided in the form of chemical toilets. A large influx of backyard tenants has increased levels of illegal water and electricity connections. Health services are limited to a recently established temporary clinic. In 2011, the population of Dunoon was estimated at 29 268 and consisted of 10 722 households living in an area of less than one square kilometre (Stats SA, 2013). IsiXhosa is the first language of 64.74% of the predominantly young Black African population. According to Stats SA (2012), the income levels of 80% of the Dunoon residents fall within the two lower *SEM* bands. Over 56% of residents are reported to be unemployed. The income for 75% of households is less than R3 200 per month (Stats SA, 2012). Energy carriers for cooking are predominantly a combination of electricity, paraffin and wood (Stats SA, 2012). Dunoon regularly experiences large-scale conflagrations. Since 2015 thousands of residents have lost all their belongings in fires, primarily attributed to flame-based cooking candles used for lighting during regular electricity blackouts (Luhanga, 2017).

Figure 4.3:   Location of Dunoon study area (33°49'3.61" 18°32'30.71")

The Dunoon sub-sample area (also referred to as Doornbach, Kwa-5 and Sibabalwe) is a new informal settlement on the north-western side of Dunoon (Figure 4.4). The Dunoon local ward councillor actively serves the sub-sample area. In most cases, the dwellings are made from corrugated iron and are serviced with prepaid electricity and water. However, the rapid growth of the area and the high population density have limited the provision of services, and physical access is limited to narrow, untarred pathways with no formal roads. In 2011, the population of Sibabalwe was estimated at 5 033 and consisted of 2 622 households living in an area of 700 square metres (Stats SA, 2013).

Figure 4.4: Location of Dunoon Sub-Sample Area (33°48'36.65"S 18°32'15.19"E)

Mamelodi Sample Area

The selected Mamelodi sample area for the pilot implementation is a large urban settlement in Tshwane, Gauteng Province (Figure 4.5). Situated on the eastern outskirts of the administrative capital of South Africa, Mamelodi covers a total area of 45 km^2 and has a population of close to half a million (Stats SA, 2013). Mamelodi households live in informal dwellings made of sheet metal (shacks and backyard shacks), RDP houses constructed from cement bricks and well-built brick houses (Ligthelm, 2012; Mashigo, 2012; Cant *et al.*, 2013). In 2011, the population of Mamelodi was estimated at 334 577 and comprised 110 703 households (Stats SA, 2013). Sepedi is the first language of 51% of the predominantly young Black African population. The income levels of an estimated 30% of Mamelodi residents fall within the lower two *SEM* bands, with only 4.3% of the residents living above the poverty line (Orton, 2010; Mashigo, 2012). Unemployment is over 50%, with most households dependent on

social grants. Households use on multiple energy carriers for cooking (Paulsen *et al.*, 2010). Over 73% of households were observed using both paraffin and electricity for cooking in 2011 (Stats SA, 2012).
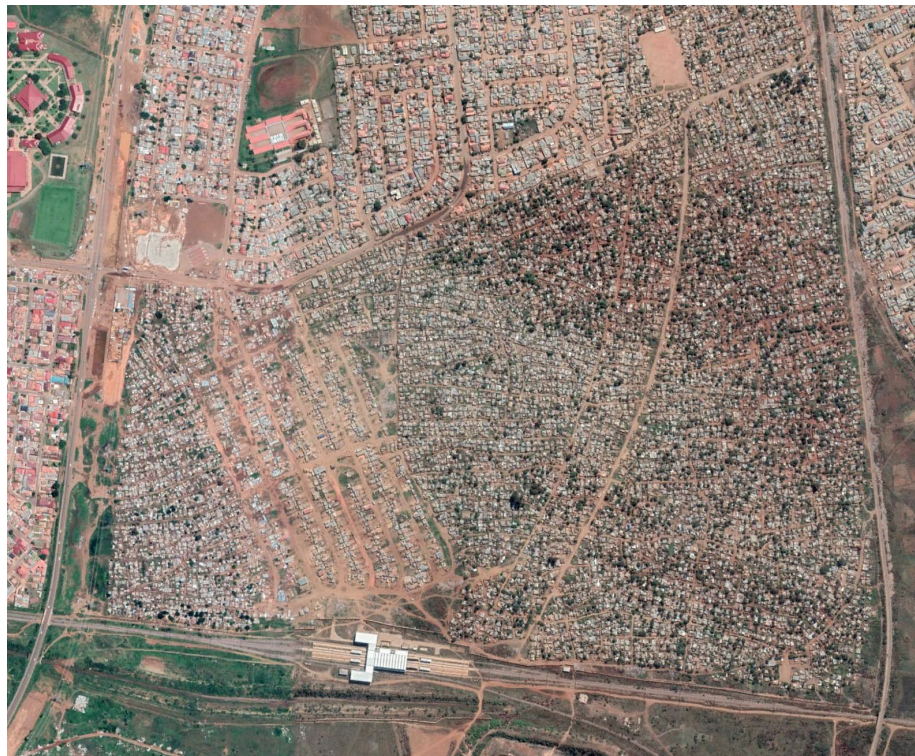
Figure 4.5:   Location of Mamelodi study area (25°42'37.76"S, 28°24'40.36"E)

The Phumolong informal settlement is located in the southeast of Mamelodi on the outskirts of Tshwane (Figure 4.6) and was selected as the sub-sample area for the pilot implementation. Phumolong (Sotho for "place of rest") is located between two converging railway tracks and is occupied entirely by informal dwellings with negligible institutional services available. The elected ward councillor was the recommended point of contact. The services in Phumolong include a maze of illegal water and electricity connections. Over 98% In 2011, the population of Phumolong was estimated at 30 763 and consisted of 13 262 households living in an area of 1.76 km^2 (Stats SA, 2013).

Figure 4.6:   Location of Phumolong informal settlement (25°43'40.79" 28°24'8.70")

Sample participant selection

The study participants were selected based on the relevant phase in the case study-based framework methodology. The participants were selected to determine the circumstances that could cause changes in behaviour related to flame-based cooking appliances rather than simply studying actual patterns of cookstove use in a specific geographic location. The participants were selected from the Dunoon sample area, with participants sampled from the Mamelodi sample area added for the second arm of the pilot implementation. The sample households were selected to represent low incomes, limited access to credit and inhabitants of dwellings constructed from a mixture of corrugated iron sheets, mud and brick, analogous to a representative South African segment.

A qualitative purposive sampling method was used to select the study participants for the observational study and the co-creative workshops. The results of the segmentation guided the selection of the observational study sample. Local community experts and municipal officials assisted in selecting the Dunoon study sample. The participants selected for the co-creative workshops were sampled from the Dunoon sample area and assisted by the Dunoon council community representative. Five workshop participants were selected from a larger sampling frame of ten in consultation with the workshop facilitator and the local community assistant in Dunoon.

A stratified sampling method was employed for the pilot implementation phase. The sample population was divided into smaller subgroups, with participants from the communities exposed to the interventions identified, selected and recruited according to segmentation and observational results, primarily through consultation with local community representatives and experts.

Researcher role

The researcher actively participated as an assistant facilitator and non-participant observer in the co-creative workshop sessions, collecting data that included informal communications (notes and audio recordings, WhatsApp messages, emails and presentations).

Case study limitations

The data collection was limited to the two South African sample areas. To overcome limited generalisability to the larger representative South African population, an SP method was administered at baseline and endline, culminating in the triangulation of the research study findings. Structured interviews and observations were furthermore conducted with all the participant groups integrated into the data collection process to mitigate the possible loss of data points that may have gone undocumented during the SP method.

Ethical considerations

The nature and purpose of the research were explained to the participants, both orally and in writing, seven days before their involvement in the case study. It was pointed out that participation was voluntary, and the confidentiality of identity and responses was guaranteed. Participating households were informed that their replies would be treated statistically and not as correct or incorrect, that their anonymity was fully guaranteed and that their identities would only be revealed if further interviews were required. There was no payment for participation. Approval for the nature and conduct of the research was obtained from the Cape Peninsula University of Technology Ethics Committee.

4.1 Formative Assessment of the Behavioural Challenge Associated with Flame-Based Cookstoves in South Africa

This section reviews the behavioural challenge associated with using flame-based cookstoves in South Africa, including a review of the historical, material and socio-institutional factors that influence the cooking sequences and motivations linked to interactions of the cooks with the unimproved flame-based appliances.[2] The cookstove-related behavioural challenges have received little attention in past South African cookstove-related interventions (Tait, 2017). Culinary behaviour is far more critical in facilitating a transition to improved cooking appliances than previously thought, regardless of the availability and affordability of cleaner cookstoves, fuels or income levels (Johnson & Takama, 2012). Culinary motivations employing fire are deeply ingrained in human behaviour, regulated by material and socio-institutional factors (Carmody *et al.*, 2016). The complexity of culinary behaviours is a significant obstacle in facilitating a transition from inefficient cooking technologies (Pachauri & Spreng, 2011; Bardouille *et al.*, 2012; De Jongh & Streeter, 2013). A multiplicity of factors influence

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[2] The formative assessment is limited to literature published up to and including the period when the case study was conducted.

the culinary choice of meals prepared by the women, who cook nearly all household meals (Viljoen *et al.*, 2010). Female cooks across multiple regions employ various culinary sequences to meet their needs and aspirations (Lambe *et al.*, 2018). The majority of improved cooking interventions in SSA are characterised by a standardised improved stove design introduced to a resource-poor populace of more than one billion people speaking over 2 000 languages (Pilcher, 2016; Quinn *et al.*, 2016). The interventions fail to consider that cookstove-related behaviours are situated in complex culinary settings influenced by several interrelated factors (Lambe *et al.*, 2018).

Despite the dramatic changes in the culinary history of South Africa, the widespread use of flame-based cooking appliances persists among South African black households (Kimemia & van Niekerk, 2017). Many factors determine flame-based cooking appliances in an under-resourced South African context (Barnes, 2011, 2014; Lambe & Senyagwa, 2015; Matin, 2016). Culinary behaviour is furthermore used to communicate social mores and values beyond meeting the biological necessity of preparing food (Matinga *et al.*, 2014; Akintan *et al.*, 2018). Cooking with fire contributes to the development of identity, motives of affiliation and social hierarchies, which are linked to the expression of hedonic pleasure, status, gender, age and ethnicity (Schrempp, 2011; Matinga *et al.*, 2014; Goodwin *et al.*, 2015; Evans *et al.*, 2017). Chikweche and Fletcher (2012) argue that a candidate for improved flame-based cookstoves must add tangible economic value. The build quality, durability, affordability and serviceability required of a stove design are influenced by a broad range of divergent needs, desires and expectations linked to the cook's socio-economic environment (Parment, 2008). Instead of designing highly engineered devices – shared with many of the past candidate stoves employed in cookstove-related interventions – the choice of a stove must be cognisant of the constraining lack of resources that influence the culinary behaviour of impoverished communities (Prahalad, 2009). Observed stacking of stoves and fuels has been reported in South Africa (Van der Kroon *et al.*, 2014). The proximity to South African urban environments has significantly changed the cookstove-related socio-economic environment in unexpected ways (Steyn, 2011; GNESD, 2014; Tait, 2015). However, the burden of cooking continues to fall on primarily black women caregivers in rural and urban areas (Barnes *et al.*, 2009; Knox *et al.*, 2017; Matinga *et al.*, 2018).

The following brief literature-based assessment of the behavioural challenge under investigation proceeds with a brief discussion of the hazards related to using inefficient flame-based cooking appliances in South Africa, followed by an overview of the flame-based cooking appliances used by indigent South African households. A brief historical and cultural contextualisation of flame-based cooking in South Africa is provided, including a summary of the origins of cooking with fire in South Africa and a brief chronological summary of South African culinary behaviour spanning the colonial era, the era of apartheid and the current post-apartheid era. The contextualisation then continues with a brief discussion of the profound complexity of critical behavioural factors related to the material and socio-institutional environment in South Africa as gleaned from the literature. The review of the

behavioural challenge concludes with a review of the individual motivations related to flame-based cooking in a South African context.

4.1.1 Health hazards associated with flame-based cookstove use in South Africa

The use of poorly constructed, inefficient and dangerous flame-based cookstoves by energy-impoverished South African households is a key contributor to the problems of respiratory illness, shack fires and burn-related injuries (Kimemia & van Niekerk, 2017) and is also linked to high levels of food insecurity (FAO, IFAD & WFP, 2013). The widespread use of inefficient paraffin and solid-fuel flame stoves in South Africa with their associated adverse health effects continues unabated despite a large-scale electrification programme in South Africa (Van der Kroon *et al.*, 2013; Matinga *et al.*, 2014; Tait, 2015). The severe health hazards associated with inefficient flame-based cooking appliances deepen the poverty levels among affected communities in South Africa (Kimemia *et al.*, 2014; Kimemia & van Niekerk, 2017). The health hazards associated with flame-based cooking in individual households are attributed to the overcrowded living arrangements, poorly designed and manufactured appliances and weakening family and social support structures, with the brunt falling on women cooks and their children (Kimemia *et al.*, 2014; Kimemia & van Niekerk, 2017). The destruction and loss of life associated with fires, burns, poisoning, respiratory illness and food insecurity caused by poorly constructed flame-based appliances are described in more detail in the following subsections (Kimemia *et al.*, 2014; Kimemia & van Niekerk, 2017).

Shack fires

The use of poorly constructed flame-based appliances in often overcrowded South African informal settlements is directly linked to 21% of fire-related injuries, with paraffin stoves accounting for 71% of the injuries (Steenkamp *et al.*, 2002; Maritz *et al.*, 2012). The destructive force of fires in informal settlements is demonstrated by over 3000 shack fires reported every year (Birkinshaw, 2008; Walls *et al.*, 2018). Shack fires kill and seriously injure thousands annually, entrenching a cycle of poverty (Kimemia *et al.*, 2018). Beyond morbidity and mortality, the conflagrations dramatically reduce the quality of life of the affected community (Kimemia *et al.*, 2018). The lives of affected households are disrupted due to the loss of life, income, personal possessions and documents that are difficult and expensive to replace (Kimemia *et al.*, 2018). The loss of shelter, including relatively expensive appliances, clothing and furniture, is particularly destructive to vulnerable households (Kimemia *et al.*, 2018). The physical and psychological dislocation further disrupts the maintenance of traditions and rituals, linked to a loss of tangible cultural heritage beyond monetary loss (Kimemia *et al.*, 2018). Recovery from a conflagration can take years for the affected household (Birkinshaw, 2008; Chance, 2015).

Burn injuries

Burn injuries in SSA are identified as a significant health care problem, with the number of deaths due to burns in South Africa being one of the highest in the world (Albertyn *et al.*, 2014; Allorto *et al.*, 2018; Kimemia *et al.*, 2018; Botman *et al.*, 2019). Using flame-based cookstoves and candles is considered the leading cause of burn injuries among impoverished households in informal settlements (Kimemia & van Niekerk, 2017; Van Niekerk *et al.*, 2022). Burns are frequently caused by conflagrations, which are mainly associated with the wick-type stove design and fuel contamination (i.e., petrol mixtures); mechanical instability of the stove during use due to large pot sizes and uneven surfaces; and pot combinations, which may cause scalding and food burns (Kimemia & van Niekerk, 2017; Kimemia *et al.*, 2018). Flame-based cooking appliances are directly linked to young children falling into fires and accidentally knocking over hot boiling pots (Kimemia & van Niekerk, 2017). Beyond poorly constructed combustion stoves, cramped cooking spaces and flammable fuels mainly affect women and young children (Kimemia & van Niekerk, 2017). Burn injuries leave disabling and deep psychological and social scars (Kimemia & van Niekerk, 2017). Young children are particularly vulnerable, with burn mortality the highest among babies and toddlers (Kimemia & van Niekerk, 2017).

Paraffin ingestion

The use of paraffin as cooking and lighting fuel is linked to the poisoning of young children due to them ingesting paraffin (Matzopoulos & Carolissen, 2006; Balme & Stephen, 2017; Matzopoulos *et al.*, 2017). Poisoning by paraffin ingestion is the most common cause of acute unintentional poisoning in South African black children younger than 14 years (Malangu *et al.*, 2005; Matzopoulos & Carolissen, 2006; Balme *et al.*, 2012; Matzopoulos *et al.*, 2017). The levels of childhood poisoning due to paraffin ingestion are estimated at 20% of all cases, with an estimated 40 000 to 60 000 cases per year (Balme & Stephen, 2017). High levels of mortality are further attributed to late diagnosis, with children being referred to the hospital a day or two after ingestion (Matzopoulos & Carolissen, 2006). Paraffin-induced pneumonia occurs in 12%–40% of cases admitted to hospital (Matzopoulos & Carolissen, 2006; Matzopoulos *et al.*, 2017). Children often mistake paraffin for water or soft drinks, with as little as 10 mL being required to lead to coma or death (Matzopoulos & Carolissen, 2006; Bader-Un-Nisa & Channa, 2010). Common complications include damage to the airways, lungs and gastrointestinal system, leading to central nervous system impairment, fever, heart disease and abnormally elevated white blood cell levels (Matzopoulos & Carolissen, 2006).

Household air pollution

HAP resulting from inefficient flame-based cooking affects numerous South African households (Winkler *et al.*, 2007; Tsikata & Sebitosi, 2010; Matinga *et al.*, 2014). The levels of HAP in South Africa and the associated health effects, particularly the effect of airborne particulate matter associated with flame-based cooking, heating and lighting, have been underrepresented. Thus, its effect on health

is underreported (Language *et al.*, 2016; Shezi & Wright, 2018). The World Health Organization (WHO) estimated that, in South Africa, more than 1 000 people die annually from HAP exposure—and 450 of those deaths are children (WHO, 2009). Despite the adverse effects, the effects of dangerous emissions emanating from inefficient combustion have largely been neglected in South African energy planning and policy discussions (Winkler *et al.*, 2007; Sebitosi & Pillay, 2008; Tsikata & Sebitosi, 2010; Matinga *et al.*, 2014).

Food insecurity

The relationship between inefficient cooking appliances and food insecurity is increasingly critical (Brouwer *et al.*, 1997; Bogdanski, 2012; FAO, IFAD & WFP, 2013; Sola *et al.*, 2016). An estimated 26% of South African households are food insecure, while 28% are at risk (Walsh & van Rooyen, 2015). Cooking with flame-based cookstoves is linked with food insecurity and poor nutrition, keeping impoverished South African households trapped in a self-reinforcing cycle of poverty (Azariadis & Stachurski, 2005; Barrett, 2008). Preference is given to cheaper, lower-quality foods to acquire cooking fuels (Brouwer *et al.*, 1997; FAO, IFAD & WFP, 2013; Sola *et al.*, 2016). The daily dietary choices and cooking practices of energy-poor households lead to diverting low household income and time to cheaper and inefficient flame-based cookstoves and fuels (Sola *et al.*, 2016), ensuring palatable meals are cooked (Bogdanski, 2012). The FAO, IFAD and WFP (2013) reported truncated preparation times and less nutritious meals when the use of improved cooking technologies and fuels is limited.

4.1.2 South African historical and cultural context related to cooking with fire

The origins and significance of flame-based cooking in South Africa are diverse, contradictory, and poorly understood (Coetzee, 1987; Gokee & Logan, 2014). The culinary routines of South African energy-poor black African households related to flame-based cooking appliances are characterised by a hybrid collection of African, European and Asian influences in domestic and commercial cooking activities, with a clear shift away from traditional culinary routines (Coetzee, 1987; Steyn, 2011; Gokee & Logan, 2014). The local flame-based culinary routines unfolded uniquely, evolving into distinct regional variants that still retain a shared African material and socio-institutional legacy (Osseo-Asare, 2005; Haaland, 2006, 2007; Viljoen *et al.*, 2010; Steyn, 2011; Chastanet *et al.*, 2014; Trefry *et al.*, 2014). The cooking routines emerged from multiple geographical locations diverging and converging throughout the subcontinent, assimilating technologies, traditions and practices over a long period without a single political or hegemonic military influence (Osseo-Asare, 2005; Haaland, 2006; Sellick, 2010).

The universal and exclusively human behaviour of cooking with fire has been transmitted from generation to generation over millennia, formed out of an array of biogenetic preconditions, psycho-social capacities and socio-institutional settings (Wrangham, 2009, 2017; Smith *et al.*, 2015; Carmody *et al.*, 2016; Planer, 2018). The earliest evidence of humans living and cooking with fire and tools in a

fixed indoor location is dated 3 million years ago in the Wonderwerk Cave site in South Africa (Shaar *et al.*, 2021). An increasing body of scientific literature attributes the human qualities of individual agency, attention to detail and a patient disposition to the repeated multi-generational performance and eventual transmission of culinary behavioural patterns, including the eventual biogenetic transmission of human traits (Wrangham, 2009; Carmody *et al.*, 2016). Cooking with fire has had a far-reaching effect on the development of our human brains and bodies over time (Wrangham, 2009, 2017; Smith *et al.*, 2015; Tigabu *et al.*, 2015; Carmody *et al.*, 2016). Cooking with fire satisfies the human body's and brain's biophysical needs (Carmody *et al.*, 2016). Cooking has expanded the variety, quality and quantity of our nutritional intake and changed the human body to the extent that is increasingly attributed to us becoming human, as part of an extended interplay of biological, psychological and social factors in human history (Wrangham, 2009, 2017; Smith *et al.*, 2015; Tigabu *et al.*, 2015; Carmody *et al.*, 2016).

The indoor use of fire in South African caves is estimated to be over a million years ago (Haaland, 2006; Shaar *et al.*, 2021). The earliest South African evidence of cookstove use in shallow-basin rock hearths is dated 72 000 years ago (Haaland, 2006; Oestmo, 2013; Esteban *et al.*, 2018). Cooking over a fire in clay pots approximately 10 000 years ago made previously inedible foods digestible and palatable, leading to changes in the biophysical factors related to diet and nutrition (Haaland, 2006). An estimated 8 000 years ago (Haaland, 2006), the typical African culinary routine of cooking porridge, stews and beer in pots over a fire was firmly established (i.e., porridge/pot culinary routines), and spread across the continent at least 6 000 years ago (Haaland, 2006). The flexibility of cooking with pots expanded the range of food resources and preparation techniques, allowing a nomadic lifestyle with the rapid dissemination of a porridge/pot culinary routine (Haaland, 2006). The flexibility and capacity for innovation in African cooking began with the fusion approximately 5 000 years ago in Nubia between the porridge/pot culinary tradition of SSA (Haaland, 2012) and the Egyptian bread/oven tradition originating in the Levant (Haaland, 2012). The fusion of the two cooking routines saw the emergence of the baking of sorghum bread in clay pots in response to the rising preference for bread (Haaland, 2012). The culinary routines spread along with the intra-African trade and exchange networks, eventually reaching South Africa (Osseo-Asare, 2005; Parkington & Hall, 2009; Haaland, 2012; Highfield, 2017). The cooking of broths and steaming of bread with ceramic pots were displaced by metal pots traded with Dutch settlers, and millet was replaced by maize or wheat (Bourquin, 1951; Carson *et al.*, 2000; Fowler, 2006; Lyons & D'Andrea, 2008; Steyn, 2011; Gadaga *et al.*, 2013; Nkhabutlane, 2014).

The colonial era

The colonial era left an indelible mark on South African socio-institutional cookstove-related environments (Osseo-Asare, 2005; Parkington & Hall, 2009; Stanwix, 2012; Chastanet *et al.*, 2014). Much South African history is characterised by clashes of culture, violence, dispossession, and

repression accompanied by racial tensions similar to the rest of the continent (Elphick & Gilliomee, 1991). During the 18th century, a colonial culinary infrastructure was introduced, exerting control over the subjugated populace of South Africa (Osseo-Asare, 2005). Until the mid-19th century, black South Africans still prepared meals over open fires (Osseo-Asare, 2005). Porridges and steamed loaves of bread were cooked in ceramic pots, and served with stews and soups made from various combinations of vegetables, fish and meat (Osseo-Asare, 2005). By the late 19th century, black South African farmers started trading with the white settlers (Osseo-Asare, 2005). Cast-iron metal pots started to displace clay, metal utensils started to appear, and imported wheat started to displace sorghum and millet for baking bread (Viljoen *et al.*, 2010; Steyn, 2011; Chastanet *et al.*, 2014). Colonising the mind would extend to colonising the taste of the indigenous palates (Sellick, 2010; Viljoen *et al.*, 2010; Cusack, 2018). The colonisers would deem the subjugated as primitive until their cooking practices matched the ideals set by the coloniser (Beetham, 2008; Steyn, 2011). Discrimination and even punishment met those that continued to adhere to and follow African culinary traditions (Longo *et al.*, 2014; Trefry *et al.*, 2014). In many cases the subjugated populace attempted to retain their cultural identity in the face of this onslaught through the adherence to and retention of traditional cooking practices (Longo *et al.*, 2014; Trefry *et al.*, 2014).

The era of apartheid

The cookstove-related behaviour of black South Africans has been significantly influenced by the institutional factors associated with South Africa's colonial and Apartheid past in terms of cooking practices, choice of cooking appliances and availability of ingredients (Steyn, 2011). Following the discoveries of diamonds and gold in the 19th century, European food, cooking practices and behaviours profoundly affected an exclusively pastoral agrarian society (Steyn, 2011). The European culinary practices of boiling water for tea and baking bread in an oven epitomise the Western culinary infrastructure in South Africa (Steyn, 2011). By the 1960s, many South Africans still roasted and boiled traditional meals over an open fire, similar to earlier times (Steyn, 2011). The preparation of tea, bread and rice were added, becoming staples in urban areas (Steyn, 2011). During the apartheid era, South Africa's industrial infrastructure and rapid urbanisation led to the displacement of traditional culinary practices (i.e., wheat and rice displaced traditional millet and sorghum) (Steyn, 2011; Stanwix, 2012).

Industrial food production transformed the traditional porridge/pot infrastructure beyond the major cities and into the rural interior (Steyn, 2011). An example of such transformation is the baking and distributing industrially produced bread throughout the country by a few large conglomerates (Stanwix, 2012; Van der Walt, 2016). Subsidies and regulatory protection of food ingredients and fuel prices contributed to the displacement of traditional cooking and baking practices, with the use of coal- and paraffin-powered stoves rising in urban areas (Stanwix, 2012; Van der Walt, 2016). In addition, to open wood fires, the use of coal over open grates for cooking and heating found rapid acceptance after the 1950s (Lee, 2006; Steyn, 2011). The growing use of coal and wood-fired ovens with chimneys for

domestic purposes was reported (Quass, 1953). Coal-fired stoves were widely used in South Africa, peaking in the 1950s with the Welcome Dover brand (Figure 4.7), still recalled in recent household brand surveys (Lee, 2006).

Figure 4.7:   **Welcome Dover newspaper advertisement aimed at black South Africans between 1953 and 1957 (HPRA, 2014)**

Figure 4.8:   Primus stove postcard (HPRA, 2014)

Primus paraffin stoves, depicted in Figure 4.8, started to appear in the late 1950s, manufactured under license in South Africa (BAHCO, 1957). The pressurised stoves were considered expensive compared with wood and coal stoves, yet comparatively safe and well-constructed compared with the unpressurised Panda stoves currently available (Bradnum, 2009; Lloyd, 2009).

The post-apartheid era

Since the fall of Apartheid in 1994, the opening of the domestic economy to global, transnational agricultural and food corporations has transformed the culinary infrastructure of South Africa (Steyn, 2011; Stanwix, 2012; Knox *et al.*, 2017). Culinary palates have become increasingly Western, with the surrounding local material and institutional support infrastructure integrated with nationally and globally connected distribution chains (Stanwix, 2012; Peyton *et al.*, 2015; Knox *et al.*, 2017). The rapid transformation has largely displaced the last remnants of a traditional African culinary infrastructure of local community networks with numerous disconnected small local pastoralists and farmers, with supermarket chains extending their reach into poorer segments of the population (Peyton

et al., 2015; Battersby & Marshak, 2017). South African households now rely on sizeable centralised distribution networks with local suppliers providing basic foodstuffs, cooking fuels and a limited range of cooking appliances (Weatherspoon & Reardon, 2003). However, cooking with poorly constructed flame-based cooking devices has continued unabated despite a nationwide electrification programme (Tait, 2015).

4.1.3   Flame-based cookstoves and fuels in South Africa

A formative understanding of the flame-based cookstoves in use is critical when designing a successful behavioural intervention, given the prominent role that physical cooking appliances play in culinary behaviour, from stoves to chimneys and other technologies (Kimemia & Van Niekerk, 2017). A change in the physical surroundings of impoverished South African households (i.e., adding a room, doors, windows or chimney) can lead to healthier and safer cooking routines (Clark *et al.*, 2015). The material aspects related to flame-based cooking in South Africa include the geographic location (i.e., urban or rural), the setting where cooking takes place, the physical availability of cooking fuel (i.e., fuelwood, paraffin or gas) and the availability of appropriately designed improved cooking appliances (Maré & Annegarn, 2014). The following brief overview of South African flame-based cooking stove appliances categorises the stoves according to the leading fuel carriers underlying the different cooking stove technologies. The flame-based appliances covered in this section include stoves using paraffin, LPG and biomass. Although coal-fired stoves are locally dominant near South Africa's coalfields, they were excluded from this study because of their limited localised use (Balmer, 2007b). Less than 1% of low-income South African households use coal as a cooking fuel (Department of Energy, 2013).

Biomass-powered cooking appliances

Biomass cookstove appliances in South Africa are still widely used in rural villages and informal urban settlements (Stats SA, 2012). Collected fuelwood is still heavily used in rural areas (Madubansi & Shackleton, 2007; Matsika *et al.*, 2013) and informal settlements in urban areas (Kimemia & Annegarn, 2011). Almost half (44.5%) of households in Limpopo still use wood for cooking, followed by the Eastern Cape (19.3%), Mpumalanga (18.9%) and KwaZulu-Natal (18.6%) (Stats SA, 2012). The continued high rates of wood-fuelled cooking methods jeopardise the long-term fuelwood supply in South Africa (Wessels *et al.*, 2013). Wood is predominantly collected from surrounding areas—no formal or informal wood or charcoal market exists (as is common in many other countries in SSA) (Madubansi & Shackleton, 2007; Matsika *et al.*, 2013). The maximum distance to collect fuelwood is approximately one kilometre, leading to the prediction of the imminent exhaustion of biomass in selected study areas (Wessels *et al.*, 2013).

Cooking over a wood-fuelled fire remains prevalent in urban and rural environments, and substantial meals are prepared for the extended family with large pots on weekends and special events (i.e., funerals and weddings). In urban areas on the Witwatersrand, fuelwood is often used as a low-cost alternative

fuel—even in preference to coal (Kimemia & Annegarn, 2011). There is significant divergence in the role wood plays in household culinary routines – with open fires being used alongside electric stoves (Balmer, 2007a; Madubansi & Shackleton, 2007; Maré, 2013; Matsika *et al.*, 2013). The preference for wood-fired culinary routines is often attributed to the taste that wood imparts, which can be likened to the Western preference for a wood-fired oven-baked pizza (Karlin, 2011; Helianty, 2016; Jürisoo *et al.*, 2019). In most households, open fires are occasionally used to prepare food for larger social gatherings (Maré, 2013; Matsika *et al.*, 2013). Cooking over an open fire in rural areas is usually done outside or in a separate traditional kitchen area (Madubansi & Shackleton, 2007; Maré, 2013; Matsika *et al.*, 2013).

The most common urban low-cost cooking appliance used with biomass fuel is the so-called 'imbaula' stove, a basic improvised self-constructed stove made from used metal drums with holes punched into the sides (Kimemia & Annegarn, 2011; Kimemia *et al.*, 2011). Imbaulas are frequently used for warmth in winter outside houses or even along the roadside (Makonese *et al.*, 2016; Buthelezi *et al.*, 2019). While popular among the urban poor because of its affordability, its inefficiency and high emissions have been linked to respiratory health problems and shack fires (Kimemia & Annegarn, 2011; Kimemia *et al.*, 2011). While most people know the carbon monoxide danger of bringing a burning imbaula into the home, many still use them to heat the dwelling once the initially visible smoke emissions have receded (Lloyd, 2012).

Despite a historical legacy of coal-fired cast-iron stoves, large wood-fired appliances with chimneys are rare among impoverished South African households compared with similar contexts in SSA (Lee, 2006; Kabuleta, 2008; Manhiça *et al.*, 2012; Adria *et al.*, 2013). In neighbouring countries, improved flame-based ovens have demonstrated versatility in cooking, baking and heating the home compared with electric or gas-powered cooking appliances while cutting fuelwood use by between 50% and 80% (Lee, 2006; Kabuleta, 2008; Manhiça *et al.*, 2012; Adria *et al.*, 2013). Localised use of cast-iron stoves continues in the vicinity of South African coal fields, with the Laduma stove closest in affordability for low-income households (Ndebele Stoves, 2010; Misra *et al.*, 2018).

Figure 4.9:   Stovetec EcoZoom Versa Cookstove (Aitken *et al.*, 2010)   **Figure 4.10:   ACE Biomass Gasifier Cookstove (GACC, 2015)**

A wide variety of improved biomass stoves have been touted over the years as a solution to reduce the amount of wood consumed while cooking (Kimemia & Van Niekerk, 2017; SEA, 2017). These tend to be expensive relative to other technologies and are not widely available (Matinga *et al.*, 2011; De Chastonay *et al.*, 2012). A version of the Approvechio Rocket Stove called the Stovetec EcoZoom (Figure 4.9) stove had little success despite being widely promoted in South Africa (Aitken *et al.*, 2010). Fuel-based interventions focused on introducing wood pellets have recently unsuccessfully proposed their use as an alternative fuel with large-scale investments made (Petrie, 2014; Bowd *et al.*, 2018). The lack of success is attributed to the institutional failure of the government in leading a collaborative approach (McLean, 2018). A recently touted entrant is the ACE-1 improved biomass stove (Figure 4.10), designed, assembled and distributed by Lesotho-based *African Clean Energy* (GACC, 2015; Rooij, 2016). The ACE-1 is the culmination of a public-private partnership between Philips, the Industrial Development Corporation (IDC) and the United Nations Industrial Development Organization (UNIDO) (GACC, 2015; Rooij, 2016). Like the Philips stove concept, the ACE-1 is a two-stage gasifier stove with a built-in fan, powered by a thermoelectric coupling, suited to burning wood pellets or small pieces of wood (GACC, 2015; Rooij, 2016). The coupling allows charging a mobile phone or using an LED light (GACC, 2015; Rooij, 2016). The ACE-1's intended lifespan of five years has not yet been achieved (GACC, 2015; Rooij, 2016). Due to reliability problems, a rechargeable battery has replaced the thermoelectric charger (Rooij, 2016). The stove project was put on hold when production, marketing and distribution deficiencies were encountered, relaunching in 2010. By 2016, only 35 000 units had been sold (Rooij, 2016). The current version is priced as a premium project, including a one-year warranty (Rooij, 2016). The ACE 1 estimated price of R1 400 is considered unaffordable as an upfront purchase for the targeted population (Rooij, 2016). A Pay-As-You-Save (PAYS) model seeks to overcome this barrier by providing customers with an option of a short term microloan (Rooij, 2016).

Paraffin-powered cooking appliances

Flame-based cooking among low-income South Africans is still characterised by the prominent use of paraffin-based cooking stoves, with an estimated one million purchased yearly (Lloyd, 2009, 2014a). This appears to be because they are cheap, portable, ubiquitous and convenient with a distinct lack of competition, primarily because of their affordability, portability, availability, convenience and lack of competition (Kimemia & Annegarn, 2011, 2012). In South Africa, 70% of low-income households earn less than R1 000 per month and spend up to 20% of their disposable monthly income on energy carriers used for cooking, heating and lighting (Kohler *et al.*, 2012; Stats SA, 2012). While the total (industrial and domestic) consumption of paraffin in South Africa declined (by between 40% and 50% from 1999 to 2009), its use among impoverished households has remained unchanged (Tait *et al.*, 2012). The distribution channel for paraffin fuel destined for low-income customers predominantly follows

informal channels using micro-enterprises (spaza shops), making regulation and enforcement impossible (Tait *et al.*, 2012).

It has been argued that paraffin prices are artificially low through price controls, indirect subsidies, VAT exemption and indirect health costs (Winkler *et al.*, 2007; Kimemia & Van Niekerk, 2017). Furthermore, it is not as strictly regulated as other fuels, such as LPG, where the price incorporates the cost of the cylinders and safe refilling and distribution measures, all of which are strictly regulated (Tait *et al.*, 2012). While a maximum paraffin retail price is set monthly (to prevent price gouging), surveys have found that informal retailers do not adhere to these regulations (Tait *et al.*, 2012). The escalating cost of electricity in recent years has also led to an increase in paraffin for cooking in electrified impoverished households (Winkler *et al.*, 2011; Tait *et al.*, 2012).

| Figure 4.11: Panda unpressurised paraffin cookstove (Bradnum, 2009) | Figure 4.12: ProtoStar unpressurised methanol cookstove (Javan, 2015) |

Non-pressurised paraffin wick stoves account for 90% of the flame-based cookstove market (Tait *et al.*, 2012), with near-total market dominance by the Panda brand Figure 4.11. Pressurised paraffin stoves are less popular than the standard wick stove and have a smaller market share (Tait *et al.*, 2012). The Panda stove is a lightweight, portable, metal appliance with a lifespan of only eight months (Bradnum, 2009; Kimemia & Van Niekerk, 2017), which contrasts with longer-lived home appliances such as fridges, stoves and kettles. The Panda brand stove is ubiquitous in an older form and a newer legally compliant SABS-approved variant, benefiting from its low cost and an excellent distribution network (Bradnum, 2009). The legal version has rudimentary safety features but is poorly constructed from inferior materials and difficult to operate (Lloyd, 2012; Tait *et al.*, 2012). Concerns have been expressed about the quality and safety of the legally compliant stoves (Kimemia & Van Niekerk, 2017). Furthermore, it is suggested that the safety regulations do not adequately focus on aspects concerned with the functionality, quality, affordability, safety and aspirational values associated with their use (Tait *et al.*, 2012).

Improved safe paraffin cooking stoves are available in other countries yet not commercially viable for South Africa's low-income households (Bradnum, 2009). While not strictly speaking an improved

cookstove, the growing use of the Panda Paraffin Heater is recorded during the cold winter months, with an additional advantage of being able to heat water (Wolpe *et al.*, 2015). The Panda heater includes more safety features than the low-cost cookstove offering (Wolpe *et al.*, 2015).

British Petroleum (BP), in collaboration with South African design firm Readymade, proposed a design similar to both the Chinese Xinxiuli Alpaca stove (Xinxiuli, 2013) and the Philippine Butterfly multi-wick stove (Readymade, 2013; Squires, 2013). The multi-wick stove did not enter production due to paraffin being discouraged as household fuel by WHO guidelines (Readymade personal communication, 23 June 2013; Readymade, 2013; WHO, 2014).

Methanol and ethanol-powered stoves have been introduced as improved alternatives to displace unimproved paraffin-powered devices (Masekameni *et al.*, 2015; Makonese *et al.*, 2020). The methanol-fueled ProtoStar cookstove (Figure 4.12) is proposed as an improved alternative to the Panda stove (SEA, 2017). The robust stainless-steel stove designed by South African product designer Ken Hall can boil, fry, bake, roast, and braise if a griddle is added (Javan, 2015; Wolpe *et al.*, 2015). The ProtoStar is priced in the same category as the Panda stove, does not emit unpleasant odours, meets South African air quality standards and complies with the proposed GACC emission standards (Javan, 2015; Wolpe *et al.*, 2015; Makonese *et al.*, 2020).

LPG-powered cooking appliances

The use of LPG among South Africa's low-income households remains low, standing out globally among similar emerging countries (Kojima *et al.*, 2011). The poor diffusion rates can be traced to various structural factors in the distribution and sale of LPG (Kojima *et al.*, 2011; PMG, 2011; Kimemia & Annegarn, 2016). Historical factors are related mainly to monopoly pricing, inappropriate regulation and an ageing supply and storage infrastructure. The result is that the price of LPG in South Africa has been among the highest in the world (Kojima *et al.*, 2011; PMG, 2011). Price controls and subsidies have been introduced in response (South Africa, 2004). With the availability of natural gas in neighbouring countries, such as Mozambique and Namibia, and the discovery of offshore gas reserves in South Africa, the gas industry in South Africa is undergoing a metamorphosis (Matthews, 2014). LPG currently accounts for approximately 2% of the primary net energy consumption (Winkler, 2007; Matthews, 2014), yet the current development of regional gas fields will lead to natural gas becoming a more important fuel in South Africa (Winkler, 2007; Matthews, 2014). The increased availability of LPG for domestic cooking purposes could be influenced by the DoE's promulgated inclusion of LPG in its Free Basic Energy programme (McKenzie, 2011). The safety risks associated with the large-scale LPG strategy proposed by the DoE are the inadequate and ineffectual regulatory and institutional environments at local community levels (Tait *et al.*, 2012; Tatham, 2013b). Should household LPG be radically expanded, the potential for safety risks will increase (Tait *et al.*, 2012). A rapidly expanding

use of cylinders could attract the importation of cheap and low-quality cylinders, a glut of old and rusted cylinders, and illegal refilling in the informal market, as reported in similar contexts (Tait *et al.*, 2012).

Figure 4.13: LK cast-iron LPG stove (Kriel, 2017)

Figure 4.14: KayaGAS LPG cookstove (Tatham, 2013b)

Various LPG stoves are available in many stores (SEA, 2017). In terms of health and safety considerations, the LPG industry currently provides well-designed cylinders and stoves within an effectively regulated framework for gas refilling (GNESD, 2014; SEA, 2017). However, the availability of LPG cylinder refills in rural areas is limited, with negligible focus on urban or rural low-income households (Tatham, 2013a). Customers must carry heavy gas cylinders from filling stations (Tatham, 2013b). An exception is KayaGAS, discussed earlier, which distributes LPG gas, stoves and cylinders in low-income settlements (Tatham, 2013b).

The Kayagas 5 kg single hob gas stove (Figure 4.14) is provided by Kayagas (Pty) Ltd in localised areas of South Africa from major petroleum/gas outlets and local retailers (Tatham, 2013b). The single hob stove is used to cook, heat water and heat the home (Tatham, 2013b). The hob costs R125, while the cylinder can be refilled for under R300 (Tatham, 2013b).

The stove is touted as convenient, clean and relatively safe with the option of an auto-ignition switch, enabling fast and simple cooking sequences (Tatham, 2013b). The disadvantages are the safe management and distribution associated with LPG cylinders; and the risk of cylinder explosions in informal settlements if not correctly used (Tatham, 2013a; Matthews, 2014).

In addition to the Kayagas offering, cast-iron gas stoves are provided by various suppliers, most notably LK (Pty) Ltd (Figure 4.13) (Kriel, 2017). The cast-iron stove is used to cook, heat water and heat the home, retailing at R200 for the single hob variant (Kriel, 2017). It is considered clean and relatively safe with its sturdy construction ideal for uncovered floors (Kriel, 2017). The stove is available from major local retailers (Kriel, 2017). It shares the disadvantages of LPG cylinder supply and requires matches to ignite (Kriel, 2017).

4.1.4 External behavioural factors linked to the diffusion of flame-based cookstoves

The acknowledgement and incorporation of the external behavioural factors related to flame-based cookstove use in impoverished communities are listed as necessary for the sustained diffusion of improved cookstoves (Pachauri & Rao, 2013). The most prominent material and external social factors related to flame-based cooking in South Africa include the influence of rapid urbanisation and the role of women in cooking (Balmer, 2007a; GNESD, 2014).

Cookstove-related behaviour and the material environment

Changing cookstove-related behaviour implies changes to the larger surrounding material environment (Lambe *et al.*, 2018). Studies revealed a need to understand better the cooking spaces and larger homesteads where cooking practices are enacted (Lambe *et al.*, 2018). It has been demonstrated that a physical change in the home (i.e. additional room, doors, windows or chimneys) can lead to healthier and safer cooking practices (Clark *et al.*, 2015). The material environmental factors that influence cookstove-related behaviour include the geographic location (i.e. urban or rural), the physical cooking environment, the physical availability of fuel (i.e. fuelwood) and the availability of appropriately designed improved cookstove technologies (Maré & Annegarn, 2014). South African flame-based cookstove-related behaviour varies across geographical boundaries, with both rural and urban influences present (Maré & Annegarn, 2014). The proximity to an urban environment has shaped and is shaping the culinary practices of urban and rural South Africans (Viljoen *et al.*, 2010; Steyn, 2011). While health, economic and environmental concerns need to be carefully considered when selecting a candidate stove, the affordability of cookstoves and fuels are a crucial factor in local cookstove diffusion (Maré & Annegarn, 2014). The physical attributes of a cookstove must deliver the required benefits demanded by the cooks (i.e. ease of use) while cognisant of the lack of material resources that influence the culinary behaviour of impoverished communities (Gadgil, 2012; Prahalad, 2012). The densely populated urban informal settlement areas force female cooks to prepare meals indoors with paraffin cookstoves or self-constructed metal barrel stoves, leading to injury and disease due to emissions, burns and fires (Kimemia & Van Niekerk, 2017). Proximity to a stove, fuel and food distribution infrastructure linked to an urban centre are factors in adopting novel cooking routines (Viljoen *et al.*, 2010), with most cooking appliances and ingredients sourced from local stores and supermarkets (Viljoen *et al.*, 2010). The reduced time and firewood available for food preparation in both urban and rural settings, lengthy cooking times required for cooking starches and vegetables in pots, the ready availability of paraffin or electric stoves and staple food ingredients, and the increasing difficulty in obtaining traditional ingredients have led to many traditional flame-based cooking routines being relegated to ceremonial or celebratory occasions (Steyn, 2011). The urban time-constraints on cooking have led to a rise in preference for precooked meals (i.e., bread). Moreover, the frying of meat and other high-fat foods in oil is increasingly common (Steyn *et al.*, 2011). However, the higher energy intensity and stimulation of taste buds through salt and sugars associated with the Western influence are directly linked to a rise

in diabetes, cardiovascular disease and obesity among impoverished South African households (Steyn *et al.*, 2011; Temple & Steyn, 2011; Sedibe *et al.*, 2018).

Cookstove-related behaviour and the socio-institutional environment

Given the prominent role that cooking plays in society, the larger social considerations are crucial to a successful clean cooking intervention extending beyond the build quality, durability and serviceability of a stove design (Shankar *et al.*, 2014; Rosenthal, 2015). The socio-institutional factor of gender is a powerful determinant of cookstove-related behaviour directly linked to eradicating energy poverty (Miller & Mobarak, 2013; Pachauri & Rao, 2013). Supporting the personal agency of the women cooks and their families on their own terms is a necessary precondition for achieving meaningful behaviour change (Sovacool *et al.*, 2012). While increasing the role of women's decision-making in the household is vital, a differentiated approach between men and women can achieve increased diffusion of improved cookstoves (Shankar *et al.*, 2015). The complex culinary environment has enabled the human ability to cooperate. The division of labour with multiple individual and group roles (i.e., gendered division) developed over an evolutionary time scale (Lee & DeVore, 1968; Wadley, 2014). Therefore, behavioural interventions must simultaneously stay cognizant of both intra-household differences in cookstove-related motivations and the decision-making power between men and women (Miller & Mobarak, 2013). It is predominantly women who choose what to cook and what type of stove, constrained by the availability of cooking fuel (Maré & Annegarn, 2014). Despite the many changes in South African society, domestic culinary behaviour is defined according to gender roles, with women cooking more than 90% of meals (Ezzati & Kammen, 2002) and thus disproportionately bearing the associated health risks (Daniels *et al.*, 2012; Misra *et al.*, 2018). Among South Africa's energy-poor, black women are the cooks and primary caregivers among the multiple other roles they fulfil in their community out of a sense of moral obligation and caregiving responsibilities. Women are still expected to prepare meals for their families to fulfil their roles as wives and mothers (Daniels *et al.*, 2012; Misra *et al.*, 2018). Therefore, the stove and fuel choices are partly constrained by the women's limited decision-making power, with men choosing what meals women should cook (Mohlakoana & Annecke, 2009). With South African black men historically being the primary income earners and decision-makers, their female counterparts work longer on cooking, food processing, fuel collecting and water carrying (Matsika *et al.*, 2013; Guild & Shackleton, 2018). In impoverished rural South Africa, many women still cook over open fires and face difficulties securing cooking fuel, with each woman carrying 20 kilograms of fuelwood an average of five kilometres daily (Matsika *et al.*, 2013; Guild & Shackleton, 2018). This burden is intensified by male migration from rural to urban areas (FAO, IFAD & WFP, 2013).

4.1.5   Motivations linked to flame-based cookstoves

To achieve a revaluation of a flame-based cooking sequence linked to adopting an improved cookstove requires an understanding of the local cookstove-related motivations in South Africa (Lambe & Senyagwa, 2015; Kar & Zerriffi, 2018). Unique to a BCD approach is linking the distinct biophysical and psychological motivations for nearly all facets of human behaviour to points of interaction (i.e., touchpoints) during an intervention (Aunger & Curtis, 2008, 2013, 2015a; Kenrick *et al.*, 2010). The biophysical motivations are satisfied by absorbing physical resources in our immediate environment into our bodies (e.g., food for hunger and heat for comfort) or avoiding resources that may be harmful to our bodies (e.g., the disgust associated with rotting food or fear of fire) (Aunger & Curtis, 2008). The emotional motivations are influenced by the local physical and social context we live in (i.e. affiliation, nurture, attraction, status and justice). The touchpoints linked to motivations for learning refer to the motivations linked to the brain satisfied by curiosity and play (Aunger & Curtis, 2015a).

Guided by the categories suggested by Aunger and Curtis (2016), the individual motivations most frequently mentioned in the reviewed literature include hoarding stoves and fuels as scarce resources and the motivations for social affiliation and status.

Hunger motivations

Food is primarily cooked as a source of biophysical sustenance to meet the motivations of hunger (Ramirez, 2010; Temple & Steyn, 2011; Walsh & van Rooyen, 2015). Food in impoverished settings is consumed for energy and strength rather than luxury (Maré & Annegarn, 2017). The precarious income levels are directly linked to the levels of hunger (Maré & Annegarn, 2017). Intentional exposure to aromas is frequently targeted in triggering hunger for food items sold among impoverished population segments (Sarafoleanu *et al.*, 2009; Ramaekers *et al.*, 2014; Spence, 2015; Rimkute *et al.*, 2016; Kelley, 2019).

Comfort motivations

Motivations for comfort associated with using cookstoves are an important dimension to consider. The motivations are frequently targeted by tailored stove features that comprise the addition of multiple cooking surfaces, portability or stability when used on untiled and uneven surfaces (Evans *et al.*, 2017). The comfort derived from a warm and dry space is considered important motivation for the continued use of paraffin-fuelled appliances and self-constructed imbaula stoves in South African impoverished households, especially in the colder winter months (Makonese *et al.*, 2016; Twigg *et al.*, 2017; Walls *et al.*, 2017). Furthermore, the literature frequently links comfort motivations to the time saved cooking with an improved stove and cleaner homes due to reduced smoke emissions (Ochieng *et al.*, 2021). While a preference for cleaner air is frequently reported, this does not translate into adopting improved cookstove-related behaviours (Hanna *et al.*, 2012). A study by Matinga and Clancy (2020) conducted in the rural province of the Eastern Cape found that respondents would verbalise the importance of open

windows when cooking indoors (i.e., telling the researcher what they want to hear) yet would block ventilation holes with a cloth when observed cooking indoors over a fire.

Fear motivations

Motivations driven by fear are frequently linked to the danger of injury to the body from gas and paraffin stove explosions or fire (Barnes *et al.*, 2009). The threats of death associated with carbon monoxide poisoning or the death of children from paraffin ingestion are well established (Barnes *et al.*, 2009). The fear of accidents with LPG stoves is attributed to the inferior quality of stoves and a lack of knowledge on how to cook with gas safely (Budya & Arofat, 2011; Abdulai *et al.*, 2018).

Disgust motivations

The motivation of disgust is frequently linked to flame-based cookstoves. The advantages of improved cookstoves are frequently touted as providing a cleaner cooking environment (Goodwin *et al.*, 2015). Disgust motivations are linked to the taste of food cooked over paraffin stoves in South African settings (Lloyd, 2014a). Disgust is attributed to the pungent smell of paraffin or smoke associated with dirty homes and clothes permeated with the odours of smoke and paraffin in South African households (Lloyd, 2014a).

Attraction and love motivations

No relevant literature was found investigating the role of love as motivation in flame-based cooking. Peer-reviewed literature links courtship preferences to the ability of food provisioning during romantic dating (Buss & Duntley, 1999; Alley *et al.*, 2013). Food sharing is linked to perceived attractiveness and intimacy (Alley *et al.*, 2013). While the collection of firewood and food preparation during courtship in a South African context is still observed in a rural context, the changing roles of women in urban contexts have diminished their importance (Ojong & Ndlovu, 2016; Matinga & Clancy, 2020). Partner choice is heavily linked to the ability to cook, following a similar pattern as observed in the Western experience (Alley *et al.*, 2013; Matinga & Clancy, 2020). While the past stereotype was of women considering the ability to cook as necessary to attract a partner, the preparation of romantic meals is now more common to both genders and orientations in higher-income South African contexts (Ojong & Ndlovu, 2016). As the gendered roles around work and home change, cooking will no longer belong to a particular gender (Ojong & Ndlovu, 2016).

Nurture motivations

The maternal nurture motivations are linked to the hazards of unimproved flame-based stoves (Harold *et al.*, 2013). The motives of caring for and protecting children could be targeted as the women cook, nurture and care for their children predominantly close to where the meals were being prepared due to the cramped living conditions (Lusinga & de Groot, 2019).

Hoarding motivations

The effects of resource scarcity are strongly linked to hoarding motivations. The levels of poverty strengthen the motivation to hoard to meet the many competing household decisions (Masera & Saatkamp, 2000; Van der Kroon *et al.*, 2013, 2014); as observed in the activity of stacking multiple cookstove types and fuels (Van der Kroon *et al.*, 2014; Maré & Annegarn, 2017).

An example of the unacknowledged complexity of motivations for changing cookstove use is the long-held assumption that the transition from traditional biomass to modern energy carriers follows a linear progression (i.e., the energy ladder) (Masera & Saatkamp, 2000; Brew-Hammond, 2010; Treiber, 2012; Van der Kroon *et al.*, 2013). This assumption is not borne out in practice. A pattern of accumulating stove and fuel combinations (i.e., stacking) appears accurate (Masera & Saatkamp, 2000; Brew-Hammond, 2010). The hoarding of stoves is confirmed in South Africa, where, despite electricity, cooking and heating in the home are still achieved with traditional methods (Tait & Winkler, 2012). The hoarding contradicts the long-held assumption that transitioning from traditional biomass to modern energy carriers follows a linear progression (i.e., the energy ladder) (Masera & Saatkamp, 2000; Brew-Hammond, 2010; Treiber, 2012; Van der Kroon *et al.*, 2013). Impoverished South African households do not immediately replace flame-based appliances with a single clean cooking appliance but are more inclined to diversify their existing cooking and heating arrangements with available and affordable new appliances and fuels (Pine *et al.*, 2011; Takama *et al.*, 2012). The continued simultaneous use of multiple fuels and stove types is attributed to the precarious nature of impoverished household incomes, the lack of affordability of improved cooking technologies and the distinctly South African culinary routines, despite the availability of electricity and, to a lesser degree, gas (Makonese *et al.*, 2016). The stacking behaviour appears to be driven by motivations to hoard meagre resources, providing resilience against the unpredictable socio-economic circumstances and variations in the affordability and availability of cooking stoves and their fuels (Kowsari & Zerriffi, 2011; Takama *et al.*, 2012; Maré, 2013). Households generally cook with multiple types of stoves during the week, using different stoves for different tasks to maximise efficiency and ensure that dishes are appropriately cooked in taste and appearance (Masera & Saatkamp, 2000; Musango, 2014). The negative impacts of using solid-fuel and paraffin stoves in confined spaces are not deemed as urgent as cooking the next meal and feeding the family (Maré & Annegarn, 2014).

Affiliation motivations

Affiliation motivations to build trust and strengthen social cohesion are frequently observed through cooperation with others by sharing food or cooking together in social settings (Viljoen, 2010; Maré & Annegarn, 2014; Rhodes *et al.*, 2014). The positive motivations gained from cooking together with family and friends can provide motivations to maintain social relationships, form new alliances or conform to the established norm (Minkow, 2016; Kar & Zerriffi, 2018; Rebitski *et al.*, 2019).

In an African context, harnessing communitarian motivations for social affiliation is essential in developing a sense of agency and achieving a change in cookstove-related behaviour (Abdelnour, 2015; Johnson *et al.*, 2015; Michie *et al.*, 2018). A clean cooking intervention focused on enabling the individual to adopt improved cookstoves holds promise if supported by the targeting motivations of social affiliation linked to the surrounding community (Johnson *et al.*, 2015). Interventions in SSA frequently unintentionally target the affiliation motive of social pressure for influencing the decision to adopt novel cooking appliances (Puzzolo *et al.*, 2013; Lambe & Senyagwa, 2015; Lambe *et al.*, 2018). The use of social pressure as a technique in interventions has found success in shifting cookstove-related behaviour by providing the targeted population with information about what other people in similar circumstances are doing (Chase *et al.*, 2015; Goodwin *et al.*, 2015; De Buck *et al.*, 2017).

Status motivations

The status motivations linked to perceptions of exclusivity and luxury are frequently targeted in behavioural interventions aimed at final beneficiaries living in South Africa (Bevan-Dye, 2012). Targeting the motivations of hedonic status is frequently recommended in improved cookstove dissemination interventions (Puzzolo *et al.*, 2013; Lambe & Senyagwa, 2015; Lambe *et al.*, 2018), yet rarely applied (Curtis *et al.*, 2004; Lloyd, 2012; Hamerman, 2016). The motivations for status with an improved stove could be linked to the perception of a higher standard of living (Lloyd, 2014b; Khadilkar *et al.*, 2015; Ravindra *et al.*, 2021). In Kenya, a focus on hedonic status with an available and affordable cookstove appliance increased diffusion, where cooking with improved charcoal stoves was linked to the expression of relative wealth (Treiber *et al.*, 2015). A durable, well-constructed appliance with a brand reputation for quality will take pride in the home, with the user taking great care to maintain it (Oodith & Parumasur, 2017; Jayawickramarathna *et al.*, 2018). The importance of the status motive is observed and confirmed in South Africa by the perceptions of low status associated with the odours emanating from poorly constructed wood and paraffin stoves (Lloyd, 2014b; Maré & Annegarn, 2017). Similarly, in South Africa, the smell of paraffin permeating one's clothing, which emanates from flame-based appliances, is linked to a hedonic status, with people exhibiting a preference for cleaner cooking fuels, if affordable and available, to express a higher social status (Lloyd, 2012).

Create motivations

Creative motivations are observed in the wide variety of pathways and recipes observed in preparing meals under severe constraints often sparked by the severe material, social and economic constraints (Bikombo, 2014; Nkhabutlane *et al.*, 2014). In response to changes in the availability of ingredients, the cooks explore many culinary avenues in preparing meals (Modi, 2009; Bikombo, 2014). An example is the creative adaptations in preparing steam bread in an urban environment diverging from its traditional origins in South Africa (Chirwa *et al.*, 2010).

Justice motivations

Interventions targeting motivations for justice frequently attempt to trigger shame followed by social sanctions or fines associated with using unimproved cookstoves (Pattanayak & Pfaff, 2009; Sesan, 2012; Kornhaber *et al.*, 2018). Motivations of shame and guilt are often experienced by the families of burn victims resulting from cookstove-related conflagrations (Kimemia *et al.*, 2014; Kornhaber *et al.*, 2018). The justice motivation is frequently and ineffectively targeted by regulatory means in South Africa. The preponderance of illegal electric connections and unsafe paraffin stoves continues despite regulations and standards (Kimemia *et al.*, 2018).

Curiosity motivations

Motivations for learning through curiosity could be linked to cooking luxurious foods with a novel, improved stove accentuating dramatic savings in time and money compared to an unimproved stove, as cookstove marketing practice in India indicates (Perry *et al.*, 2000; Beltramo *et al.*, 2015a). In a Malawian case study, curiosity was inadvertently triggered in a cooking demonstration, even leading to the transgression of social norms (Ardrey, 2016). Curiosity was piqued due to the novel way the candidate stove worked, leading to a man cooking with the women.

Play motivations

The role of motivations of play in cooking are well established (Larsen & Österlund-Pötzsch, 2012; Altarriba Bertran *et al.*, 2019). Play motivation can be linked to learning embodied skills and knowledge in using an improved flame-based appliance in simulated activities, demonstrating the dangers of stoves without the risks of injury. Improved cookstove dissemination interventions are frequently accompanied by the physical controlled demonstration of candidate cookstoves (Nuwarinda, 2010; Evans *et al.*, 2017). While present in Northern behavioural interventions, facilitating a playful atmosphere allowing for experimentation with different cooking sequences with improved candidate cookstoves is rare (Kattelmann *et al.*, 2019).

4.2   Population Segmentation and Analysis

A segmentation method was applied to determine the prospective South African population using inefficient cooking stoves facilitated by the *SEM* instrument (Higgs, 2008; Langschmidt, 2017). The four lowest tiers, *SEM1* to *SEM4*, were used to orient the segmentation. They represent South Africans living in poverty who are most affected by the *behavioural challenge* of unimproved flame-based appliances. The data was sourced from the *SEM* Establishment Survey technical reports (BRC, 2017) and the overview of the South African flame-based cookstove-related environment (Section 4.1.4). The Establishment Survey technical reports (BRC, 2017) and corresponding data sourced from the official general household survey reports (Stats SA, 2017) were scanned for data points relating to the four individual *SEM* groups. As the *SEM* groups share many commonalities, variables that distinguished the

groups from each other were given preference. The retrieved data sets were analysed according to the selected variables and the individual *SEM* groups. The following variables were selected:

- Demographic household indicators
- Material indicators in terms of dwelling type and ownership of durable assets
- Cookstove ownership patterns by fuel type
- Access levels to media communication channels.

The selected survey data for each *SEM* group was compared with data sourced from the overview of South African flame-based cookstove-related behaviour discussed in Section 4.1 above and the segmentation by energy use and psychographic profile for the *SEM* groups sourced from the *SEM* survey (BRC, 2017). The relevant population segments were finally summarised and presented in tabular form.

4.3   Observational Study Methodology

An observational study was performed in the representative sample area of Dunoon to explore local flame-based cookstove-related behaviour. The study set out to build a deeper understanding of how selected South African households representative of the *SEM* bands live, interact and work at the intersection of cooking and flame-based cookstoves (Figure 4.15).

Figure 4.15: Dunoon study area: afternoon street scene

The study proceeded with the researcher's short immersion in the study area, which consisted of visual observations of daily behaviour, attendance at social events and facilitated conversations about daily life (Figure 4.16). The immersion was followed by the structured collection of data on aspects of local cookstove-related behaviour, complemented by short questionnaire-based interviews.

The data were collated as a summary of observations for each selected household. The collected data from the observations of household cookstove use were interwoven with the interviews and followed by an analysis according to the following critical aspects:

- The cookstove-related setting by fuel type.
- The local, social and material factors linked to flame-based cooking.
- The observed motivations linked to flame-based cookstove use.

4.3.1 Study sample selection

Assisted by local stakeholders in the Dunoon study area, the participating households were selected with the aid of the local municipal councillor for the larger Dunoon area. Six representative households from the selected sample area were selected to span the spectrum of prospective flame-based cookstove users within the *SEM1* to *SEM4* bands in Dunoon and environs. The participating households were selected according to criteria adapted from the segmentation analysis (Section 5.2.5) and the proviso that each *SEM* group was represented at least once (Table 4.1 and Table 4.2).

The six representative households were chosen to capture the widest possible variations in income level and energy use combinations. Because most cooks in households were expected to be women, it was considered appropriate that a woman was always present during all the site visits. Particular attention was paid to the current reliance on flame-based cooking methods and the propensity for adopting improved cookstoves. As household cooks are predominantly women, the selection process was weighted towards them. Local community leaders were approached for advice and guidance throughout the selection process.

Table 4.1: **Sample household selection criteria**

SEM Group	Dwelling Type	Floor Type	Kitchen Type	Main Cooking Appliance
SEM1-SEM2	Backyard residence	No sealed floor	No built-in kitchen sink	Open fireplace
SEM1-SEM2	Informal shack	No sealed floor	No built-in kitchen sink	Paraffin stove
SEM1-SEM2	Informal shack	No sealed floor	No built-in kitchen sink	Paraffin stove, electric stove
SEM1-SEM2	Informal shack	No sealed floor	No built-in kitchen sink	Open fireplace, electric stove
SEM3-SEM4	RDP house	Sealed floor	Built-in kitchen sink	Electric stove, paraffin stove
SEM3-SEM4	Small house	Sealed floor	Built-in kitchen sink	Electric stove

Table 4.2: **Six households selected according to *SEM* criteria**

SEM Criteria	*SEM1–SEM2*	*SEM1–SEM2*	*SEM1–SEM2*	*SEM1–SEM2*	*SEM3–SEM4*	*SEM3–SEM4*
Gender	Female	Female	Female	Female	Female	Female
Position	Parent	Grandparent	Parent	Parent	Parent	Parent
Children 0–14 years	1	3	3	2	1	3
Women over 14 years	1	4	1	1	1	3

Men 15–59 years		3	2	1		1
Men over 59 years		1				
Primary income sources	Income grant	Selling from home and income grant	Wage labour, income grant, money transfers	Wage labour	Wage labour	Small business Wage Income grant
Gender and age of residents	Women over 14	Children 0–14, Women over 14, Men 15–59	Women over 14	Women over 14	Women over 14	Women over 14
Open fire [How often do you cook?]	Everyday	Everyday	Everyday	Never	Never	Seldom
Imbaula [How often do you cook?]	Never	Everyday	Five times a week	Never	Never	Never
Paraffin stove [How often do you cook?]	Never	Five times a week	Everyday	Everyday	Seldom	Seldom
Electric stove [How often do you cook?]	Never	Seldom	Seldom	Seldom	Everyday	Everyday
LPG stove [How often do you cook?]	Never	Never	Never	Never	Never	Seldom
Electricity access	No	Yes	Yes	Yes	Yes	Yes
SEM Criteria	No sealed floor No built-in kitchen sink	No sealed floor No built-in kitchen sink	No sealed floor No built-in kitchen sink	No sealed floor No built-in kitchen sink	Sealed floor No built-in kitchen sink	Sealed floor Built-in kitchen sink

Household One

The first household, comprising an unmarried woman, her daughter and sister, was selected to represent *SEM1* in the *SEM1–SEM2* supergroup. The dwelling was an informal structure of sheet metal with no sealed floor, had no built-in kitchen sink or no electric connection, and was located in the backyard of a formal house. The primary household income was a social grant. The occupant cooked over an imbaula, occasionally an open fire and infrequently a paraffin stove.

Household Two

The second household was selected to represent a household in the *SEM1–SEM2* supergroup (Stats SA, 2013). A grandmother headed this household, with her daughter and three grandchildren. Social grants were the primary source of income, supplemented by an old-age pension. The dwelling had no sealed floor and no kitchen sink. An old electric stove was occasionally used, but the open fireplace was the predominant cooking technology.

Household Three

A third household, representing *SEM1–SEM2*, was selected with no reliable access to electricity (i.e., illegal backyard connection). The household, consisting of a woman and four children, had no sealed floor nor built-in kitchen sink. The only income was a social grant and remittances from the woman's family.

Household Four

The fourth household was a family of three, headed by a single mother living in an informal dwelling constructed from wood, sheet metal and cement bricks, which exhibited many characteristics of a *SEM1–SEM2* living standard. The main cooking devices used were a paraffin stove and an electric hotplate. The only regular income was a social grant.

Household Five

The fifth selected household displayed typical SEM3–SEM4 household characteristics. The family of three lived in a self-constructed small cement brick house, with an adjoining informal shack made of sheet metal that was rented out for additional income. The house had a sealed floor. The household had access to electricity with an electric hot plate and television on the premises. The primary source of income was a social grant, supplemented with occasional part-time work.

Household Six

The sixth household was selected to represent *SEM3–SEM4*. The primary source of income was the wage labour of the husband, who was away for long periods. The main cooking device was an electric stove. A paraffin stove was occasionally used when the prepaid meter electricity had been exhausted. An LPG double hob stove had recently been purchased. Other durable assets included a television and a refrigerator.

4.3.2   Data collection and analysis

The observational study was conducted over four weeks between April and July 2017. The observational study began with the researcher's immersion in the local study area of Dunoon. The immersion was followed by collecting non-participant observations and interviews with one or more household members in each selected household for one week by the researcher and research assistants while the cooking activities were taking place. The researcher collected the general observations of the households, including the existing use of cookstoves. The research team would arrive before the cooking sequences began, prearranging each visit by mobile telephone. The researcher sponsored all the food and fuel expenses required for the meals. The cookstove-related behaviour was observed in each household over the week, with comments noted. To maintain the household's attention and avoid distractions, other household members, particularly the children, acted as helpers, which kept them engaged in the process while the interviews and cooking sequences were taking place. The interviews were interspersed within each visit whenever time was available.

The researcher interpreted the collected data by subjectively discerning the thematic and structural aspects of the behavioural factors around the existing cooking appliances for each household. The researcher critically examined and synthesised the field notes, videos, images, and tabulated questionnaire results. The collected data has been formulated as a synthesised narrated experience

highlighting the critical behavioural factors for a future BCD intervention. The intention behind obtaining the narrated experience from the participants' perspective was to discover the underlying discrete behavioural factors. The narrative analysis used a combination of ethnographic and phenomenological approaches, underpinned by an interpretive paradigm, to contribute to an in-depth understanding of the participants' perspectives (Arnould & Thompson, 2005; Cardoso, 2014). A subjective perspective was adopted to assist the researcher in understanding the participants' experiences.

The narrative experience that emerged from the synthesis of the observational study is presented and lists the key aspects of the cookstove-related behaviour of the people affected by the hazards associated with flame-based cooking appliances. The descriptive narrative for each household draws on the researcher's impressions of the collected photos, videos, notes and the short questionnaire results.

In generating the main themes the researcher used a coding frame to assist in analysing the impressions gained from the interactions with the people, situations, and events as suggested by Braun (2016). The researcher transcribed and scanned the data noting down initial themes. An initial set of codes were generated. The emerging aspects of the entire data set were then systematically coded and collated assisted by a guiding frame (sample frame attached in Appendix VIII). The emerging themes were then collated against the coded data points. The themes were then assessed for congruency with the coded data, culminating in the final thematic structure.

The analysis began during the immersion. The researcher reflected on the personal experiences and integrated them into the final summary. The information from individual households was organised and summarised to uncover the patterns, ideas and explanations for the observed cookstove-related behaviours. The key emerging aspects and verbatim quotes were synthesised and reported in a summarised form.

The findings are presented as a summary of the researcher's and the cookstove-related observations around the key narrated thematic points yielded by the interviews. A summary of each household is followed by a description of the main behavioural factors gleaned from the study.

The collected data were collated and analysed against the pre-defined categories of cookstove-related behavioural factors adapted for an improved cookstove-related intervention, namely a summary of insights collected on the external cookstove-related environment, followed by a summary of the various flame-based cookstoves observed during the study. The observed cooking sequences have also been summarised. In addition, the motivations related to flame-based cookstove-related behaviour gleaned from the observational study have been included.

Study immersion

The observational study began with the short immersive preparation of the researcher in the sample study area of Dunoon for two weeks to provide the researcher with a deeper understanding of the representative targeted population and establish relationships of trust with community members, as suggested by Bidwell *et al.* (2013). While the researcher had previously conducted research in similar contexts in South Africa, this was his first exposure to the community in Dunoon. The researcher immersed himself in the life of the local community to learn how its people lived and challenge the researcher's mindset. The researcher walked the streets, observing and absorbing the social and economic life of the community. The immersion included informal meetings, observations of households using locally available flame-based cooking appliances and participation in community events (Figure 4.15 & Figure 4.16).

Figure 4.16: Dunoon immersion: Youth day social event Dunoon community hall

Existing cookstove-related behaviour observations

All the households were followed through the entire process of preparing a meal using their own cooking appliances. This process extended from buying or collecting the fuel and food to cooking the meal and cleaning up afterwards. The interviewer could converse with the cooks about their cooking habits, understand their daily cooking sequences, interact with other people in their households, and discover tangible insights about their cookstove-related needs and desires. To further understand the pertinent customer behaviour, discussions and observations of other purchases and decisions helped identify which customer attitudes applied to all the products and which were specific to cooking stoves.

Semi-structured interviews

A phenomenological interview method was applied to elicit information about the activities during the study (Riley, 1996; Darker *et al.*, 2007; Høffding & Martiny, 2016). The researcher noted the situated impressions of the cooking activities in the household, adding perspective to understand and contextualise the cookstove-related behaviour. The interviews consisted of in-depth user interviews in the homes of cookstove users to gain a deeper insight into who they were and the local context beyond cookstove-related topics. The cooks were interviewed about their household-related circumstances (family members, income, spending habits and chores). Their use of existing cooking stoves was also explored. The structured interviews were guided by set questions designed to guide the discussions, with tacit observations noted, utilising the motivations suggested by Aunger and Curtis (2016). The integration of unstructured interviews throughout the field study ensured that impromptu interview opportunities could be utilised, with the tacit assumptions and motivations expressed providing invaluable insights for the research. The interviews were conducted in English and Xhosa for Dunoon households. Answers were not suggested nor read out aloud. The household respondents were asked what they thought of alternative flame-based cookstove alternatives. The existing and locally available improved candidate flame-based stoves were presented in illustrated tabular form (Figure 4.17), drawing on the review in Section 4.1.3.

Traditional Fireplace

Lowcost, traditional flame-based cooking method

Biomass

Cooking, water heating and partial space heating

R0 - R120 (including tripod)

R0 - R280

Imbaula Cookstove

Improvised self-constructed metal drum stove

Biomass or Coal

Cooking, water heating and space heating

R0 - R140 (self-constructed)

R0 - R280

Panda Stove (legal version)

Low-cost, poorly constructed, unpressurised, wick stove

Paraffin

Cooking, water heating and partial space heating

R120 - R200

R330

Panda Paraffin Heater

Dual-use, portable, low-cost, paraffin heater and cooker

Paraffin

Space heating, partial cooking and Water heating

R350 - R1239

R260

Protostar Bhubezi Cookstove

Improved liquid fuel stove

Methanol

Cooking, water heating and partial space heating

R400

R135 - R315

CleanCook Cookstove

Improved liquid fuel stove

Ethanol or Methanol

Cooking, water heating and partial space heating

R1100

R90 per hob

Mbaula Green Cookstove

Improved solid fuel stove

Biomass Or Coal

Cooking, water heating and partial space heating

R450

R0 - R280

Ecozoom Versa Stove

Improved solid fuel stove

Biomass Or Coal

Cooking, water heating and partial space heating

R505

R0 - R280

Laduma Cast-Iron Stove with Chimney

Enclosed cast-iron stove with 3m external chimney

Biomass Or Coal

Cooking, water heating and space heating

R1990 - R2400

R0 - R280

Campmaster Portable Cooker

Cast-iron double hob gas stove

LP Gas

Cooking, water heating and partial space heating

R200 excluding cylinder

R125 per hob

Kayagas 5kg Single Hob Combo (gas stove)

Single cooker plate with 4.5kg gas cylinder

LP Gas

Cooking, water heating and partial space heating

R220 - R350 incl. cylinder

R125 per hob

Alva Double Hob Gas Stove and 9kg Cylinder

Stainless steel single gas stove with auto-ignition switch

LP Gas

Cooking, water heating and partial space heating

R299 excluding cylinder

R125 per hob

Figure 4.17: Locally available flame-based cookstoves and selected improved flame-based alternatives

The interviews were captured and transcribed by the researcher. The structured observations and interview transcripts for each of the six households are reflected in Appendix IV.

4.4   Formulation of a Behavioural Framework

As Aunger *et al.* (2017) suggested, the researcher formulated a behavioural framework to guide the co-creative design of a cookstove-related intervention. The selected aspects of the framework were formulated comprising the behavioural goal tailored to the targeted community for the specific setting. The motivations that could be linked to the performance of the behavioural goal are proposed.

4.4.1   Data collection and analysis

The large amounts of information obtained in the previous sections were scanned for the main aspects pertinent to a South African BCD intervention (Giorgi, 1994; Yin, 2009). The researcher reviewed the case study analysis of previous stove dissemination projects (Section 2.1.4), the overview of the different cooking appliances common in South African settings (Section 4.1.2), the targeted population characteristics gleaned from the segmentation (Section 5.2) and the observational study of existing and improved cookstove use (Section 5.3). The synthesis of insights was guided by an inductive research

approach, with the results reflecting the researcher's subjective observations of the information collected (Kelle, 2006; Suri, 2006).

The proposed components of the behavioural framework were synthesised. The researcher iteratively reviewed the results until they were suitable for guiding the design of an intervention that could trigger a revaluation of motivations in the participants, leading to the measurable performance of the behavioural goal.

The insights drawn from the literature review and observational study were thematically categorised according to the following:

- Behavioural goal
- Roles and norms of the targeted population
- A description of the prospective cookstove-related setting
- The most prominent motivations linked to flame-based cooking

Behavioural goal

The main behavioural goal is formulated to provide a focus for designing an intervention. The formulation of the goal is guided by the review of hazardous behavioural factors related to South African flame-based cooking (Section 4.1), the description of the targeted population (Section 5.2), and the insights gleaned from the observational study (Section 5.3).

Roles and norms of the targeted population

The roles and norms of the targeted population who use inefficient flame-based cooking devices were distilled around the *SEM* groups identified in Section 5.2 and the corresponding results of the observational study in Section 5.3.

Behaviour setting for a prospective intervention

The behaviour setting critical to achieving the behavioural goal was summarised. The researcher synthesised the results of the cookstove-related overview covering the different stove appliances common in the South African context (Section 4.1.2), the cookstove-related aspects of the targeted population gleaned from the segmentation (Section 5.2) and the exploratory observations of existing and improved cookstove use in a South African context (Section 5.3).

Motivations related to flame-based cooking

The motivations of the targeted population for using flame-based cookstoves were distilled and synthesised around the categories suggested by Aunger and Curtis (2015a). The results were informed by the results of the literature review (Section 4.1.5), the segmentation analysis (Section 5.2.5) and the observational study findings.

4.5   Intervention Design Methodology

A multi-method co-creative methodology was employed to design a BCD intervention for a pilot implementation in South Africa.

As Mor *et al.* (2012) and Kwon (2016) suggested, a co-creative workshop methodology facilitated a series of collaborative activities to explore proposed sequences linked to key touchpoints for an intervention. The workshop activities were facilitated by BREADrev, the local change agency discussed in Section 2.2.8, in partnership with a representative group of participants drawn from Dunoon. The co-creative workshop sessions were held at Jedd's Bakery, a community bakery training school established by BREADrev in Fish Hoek, Cape Town, in July 2017 (Figure 4.18).

The data collection related to the emerging intervention sequences and motivational touchpoints during the co-creative workshop activities consisted of non-participant observations and unstructured interviews with the workshop participants. Structured exit interviews were employed to assess the proposed sequences iterated during the workshop activities. An intervention mapping method accompanied the workshop-based activities to synthesise an intervention and its constituent elements. A card-based choice analysis assessed the motivational linkages to the proposed touchpoints identified during the workshop sessions.

4.5.1   Workshop design

The co-creative workshop sessions were facilitated by Jeremy Barty (JB) of BREADrev, a Cape Town behaviour change agency with over ten years of experience facilitating behaviour change workshops. BREADrev specialises in disseminating artisanal bread baking with flame-based improved ovens in under-resourced South African contexts, as reviewed in Section 2.2.8. The facilitator role extended to ensuring a participatory rapport between the participants and guiding the co-creative activities around each selected aspect under investigation. Central to the workshop activities were the performances of proposed intervention sequences locked around the well-established BREADrev baking demonstrations with an improved biomass oven to explore a series of motivational touchpoints. An additional sequence was integrated that focused on an LPG stove. A short sequence with a paraffin stove was initially incorporated yet abandoned during the workshop activities. The workshop design provides active participation by allocating informal interaction, reflection and feedback time. The workshop sessions were designed to accommodate the discovery of possible touchpoints that could generate surprise during the performance of a sequence, thereby prompting the revaluation of targeted motivations and enabling the repeated measurable performance of the behavioural goal.

Intervention concept

The workshop preparations began with BREADrev developing a proposed intervention concept in response to the researcher's briefing on the behavioural framework. An amended BREADrev bread-

baking sequence was adapted for a South African context to confirm the proposed intervention concept, assess the proposed sequences and map a series of corresponding touchpoints to facilitate the achievement of the behavioural goal. The intervention concept prototype was developed to facilitate baking sequences with an improved biomass oven adapted to disseminate clean and efficient flame-based appliances. The design of the intervention concept was supplemented by additional literature-based research around baking bread, summarised in Appendix III.

In addition to the proposed baking sequences, a branded visual identity was designed to provide a consistent narrative. The researcher designed the visual identity with Adobe Illustrator around the concept of an *igoqo* in response to the continued presence of *igoqos* observed in rural and urban areas, as depicted in Figure 5.35. The visual identity was designed to incorporate a female archetype based on the symbolic displays of firewood, signifying the respect and dignity for women observed in rural and urban settings. The final design was approved by mutual consent between the workshop facilitator, the local Dunoon councillor and the researcher.

Workshop participant selection

A purposive sampling method was employed to select the workshop participants constrained by time and resource constraints. Ten prospective participants were sampled from the Dunoon sample area, assisted by the Dunoon council community representative. The selection criteria were set to represent women cooking with unimproved cooking technologies. Five workshop participants were selected from the local community in Dunoon. The participants were selected in consultation with the workshop facilitator and the local community assistant in Dunoon. The participants were required to be able to take part in all the workshop sessions.

Workshop site selection

The fully functional BREADrev baking training venue depicted in Figure 4.18, equipped with an improved flame-based oven, was selected as the physical stage for the co-creative workshop activities. An advantage of the venue was providing a neutral and safe environment conducive to the free flow of communication and ideas and allowing the unobtrusive capture of data in video, audio and pictures. The corrugated iron structure was equipped to facilitate six to seven individuals comfortably working together around a single improved flame-based oven. A large table was placed next to the indoor flame-based oven to allow the workshop activities and participants to take notes during the sessions. A second physical stage was added, equipped with a smaller improved flame-based oven and a table and benches close to the workshop space (Figure 4.19). A table with chairs was added to the exterior space to enable informal discussions during the workshop sessions.

Figure 4.18: Internal first workshop stage in BREADrev, Fish Hoek

Figure 4.19: External second workshop stage in BREADrev, Fish Hoek

4.5.2 Co-creative workshop activities

The co-creative workshop sessions proceeded at the BREADrev venue in Fish Hoek, Cape Town, in July 2017. After each workshop session, activities were adjusted in consultation with the facilitator. The participants were encouraged to make notes during the workshop activities in the provided notebooks. The researcher noted key observations and comments throughout each workshop session guided by the behavioural framework (Section 5.4).

The first workshop session proceeded with personal introductions by the participants, accompanied by cups of coffee and freshly baked goods to encourage an informal, comfortable atmosphere between the community residents, baking staff and the workshop facilitators (Figure 4.20). The intended goals and structure of the workshop were presented. Participants first observed each step in the baking sequence before performing the step individually.

Figure 4.20: Aromatic freshly baked items served at the beginning of each workshop session

The facilitator guided the participants through baking a high-hydration dough bread with an improved flame-based oven following the BREADrev bread-baking sequence for the first workshop session. The indoor intervention activities were performed around a large central table close to the improved rocket oven (Figure 4.21). The steps in the process were verbally outlined and performed by the facilitator, followed by each participant performing the same routine. After resting the dough to allow it to rise and a short lunch break, the participants moved outdoors to bake the bread in the second external rocket oven.

Figure 4.21: Breadrev facilitated sequence of preparation of a high-hydration dough as part of a baking sequence with an improved biomass oven

The outdoor workshop activities involved the facilitator demonstrating all the steps required to light the improved flame-based oven, which the participants then repeated. The steps included chopping the firewood, loading the fire chamber and lighting the kindling, followed by the larger pieces of wood. The regulation of temperature was demonstrated by adding firewood as needed. The speed at which the

oven reached baking temperature was also demonstrated. The absence of visible smoke emanating from the oven was highlighted. The bread loaves were baked in batches of 20-minute duration. The session concluded with the workshop participants cleaning the baking area and preparing it for the following day's session. The workshop participants took the baked goods home and were asked to share them with their families and friends.

The second workshop session proceeded with the same bread-baking sequence as the initial session. The participants baked a high-hydration bread loaf, following the same recipe from the previous day with limited direct assistance from the facilitator. The participants used the second outdoor flame-based oven to bake the bread loaves and operated the biomass oven without assistance. The researcher noted key aspects of the sequence. During the lunch session, the procedures of lighting and using an LPG stove and heater were demonstrated, highlighting the advantages and disadvantages of the appliance. A fire safety video from PASASA (2010) depicted how quickly a shack fire develops and illustrates the damage caused by fires in informal settlements. After the workshop space had been cleaned, participants departed with the baked loaves to share.

The third workshop session involved a shortened sequence of bread-baking activities. A simplified recipe was followed to reduce ingredients' preparation time and cost. The LPG stove demonstration was repeated with preparing tea to serve with freshly baked rolls. During the bread proofing period, the LPG-related activities consisted of serving tea prepared with an LPG stove. Each participant, in turn, switched the LPG stove on and off before boiling the water and serving the tea. After the break, the participants independently fired up the improved flame-based oven and baked the loaves without assistance.

The fourth workshop session centred around the BREADrev sequence of baking scones, with each participant following their own recipe. The facilitator amended the BREADrev sequence by introducing a competitive aspect to the activities, with the participants comparing and judging each participant's batch of scones. The participants baked the scones using the flame-based oven without assistance. The scones were served and sampled, with the participants choosing the best tasting batch.

The fifth workshop session was dedicated to performing the final iteration of the amended BREADrev routine of baking scones with the improved rocket oven. The lunch break included serving tea prepared with an LPG stove. The workshop session included the presentation of certificates of attendance to each participant, followed by the administration of the structured exit interviews. The interactions with each participant were approximately 30 minutes in length. The researcher verbally asked the questions accompanied by an illustrated description of the intervention sequences performed during the workshop sessions. Each participant was asked to assess the intervention concept, the two behavioural sequences, and which motivations were triggered during the sequences. Each response was noted down, collated and tabulated.

4.5.3   Data collection and analysis

The data collected during five consecutive co-creative workshop sessions consisted of the researcher recording the workshop activities comprising non-participant observations and structured exit interviews, resulting in transferable and verifiable data elements. The qualitative data analysis consisted of an intervention mapping, as Bartholomew Eldredge *et al.* (2016) suggested. A combination of phenomenological and narrative methods was applied to the data collected during the workshop. An intervention mapping method assisted the iterative analysis and synthesis process, culminating in an intervention's high-fidelity visual mapping.

Structured observations of intervention sequences and touchpoints

The non-participant observations guided by the behavioural framework and assisted by photos, videos, notes and insights collected during the workshop sessions served to record the sequences and touchpoints for an intervention. The gathered data focused on capturing the critical touchpoints linked to pertinent motivations during the workshop-based activities rather than the complete documentation of the entire workshop process. Individual workshop participants are identified by an abbreviated pseudonym (workshop participant and number, e.g., *WP1* for workshop participant one).

Structured exit interviews

A short structured exit interview was conducted with each participant at the end of the workshop activities to validate the proposed sequences emerging from the workshop-based observations. The interviews were structured to reveal the participants' thoughts and experiences. The researcher asked the questions in a conversational format. The proposed sequences were presented as a series of time-coded images collected by the researcher during the workshop activities, as depicted in Appendix V. Each participant was asked to rank the sequences according to their perceived originality, ability to meet behavioural goals, practical feasibility where they live and desirability. A three-point Likert scale was used – "disagree", "don't know" and "agree". The responses were preliminarily coded according to possible touchpoints and motivations (Appendix IX). The sequences were presented as a matrix of three sequences, namely:

- Demonstrating how to cook tasty food with an improved flame-based appliance.
- Showing how to use LPG stoves safely.
- Showing how to prevent shack fires.

Card based choice card-based choice (CBC) questionnaire

After ranking the sequences, the motivational touchpoints emerging from the workshop-based observations illustrated motivations were assessed by the participants, assisted by a card-based choice (CBC) questionnaire as suggested by Segelström (2010) and Dziegielewski (2011). The researcher consulted with the workshop facilitator and prepared a CBC questionnaire to assess the prospective
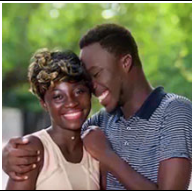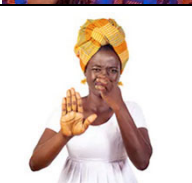
motivational touchpoints emerging from the workshop-based observations. A CBC question set was generated for each of the 13 proposed motivational touchpoints, with five questions developed accommodating all 15 motivations adapted from Section (4.1.5) and Section (5.3.4). A card representing each of the 15 motivations was generated, complemented by a short descriptive narrative and appropriate stock image (Table 4.3). Each of the five questions randomly depicted three of the 15 motivations with a "none" added to accommodate if no choice was deemed relevant (Table 4.4). A sample CBC questionnaire set is added in Appendix VI.

The researcher presented the CBC question sets to the five participants and one trainee BREADrev facilitator a week after concluding the structured exit interviews. The short narrative linked to each motivation was first read out. The participants were asked to choose the most appropriate motivation for each touchpoint as depicted in the sample CBC question set in Figure 4.22. The short narrative linked to each motivation was first read out. The thirteen question sets were presented to each participant. The participants were shown an image representing each motivational touchpoint and asked to choose the motivation that seemed most appropriate. The participants chose a single option for each question. Each participant made 45 choices (i.e., 13 touchpoints x 5 questions).

Figure 4.22: Sample question for the biomass stove lighting touchpoint choice set

Table 4.3:   Pre-coded list of the fifteen illustrated cookstove-related motivations

Motivation	Stock Photo	Description	Motivation	Stock Photo	Description	Motivation	Stock Photo	Description
Lust		An image of a woman or man, with the woman stating, "I will find a better husband/partner".	Attract		A picture of a well-dressed woman saying, "I like looking beautiful and desirable when cooking".	Affiliation		An illustration of a woman caregiver typical of the neighbourhood saying, "You showed you are one of us, well done!"
Hunger		An illustration of a woman saying, "I never want to go hungry again".	Love		An illustration of a young child saying, "I love you for doing that!"	Status		A respected elder saying, "Everyone in the community will admire you for doing that!"
Comfort		A woman appearing comfortable at home stating, "I like being warm and comfortable when cooking at home".	Nurture		A confident women caregiver says to herself, "Now my child will be safe!"	Justice		An illustration of a male or female elder saying, "That was the right thing to do, well done!"
Fear		An image of a woman stating, "I am safe from accidents and dangers".	Hoard		A depiction of a woman in a well-stocked home saying, "I will never need anything for cooking a meal".	Curiosity		An illustration of a woman saying, "I like being well informed about what is going on in my community".
Disgust		An illustration of a woman elder pulling her face and thinking to herself, "The smell is disgusting; you did well!"	Create		An illustration of a woman saying to herself, "I've made the household better now; I did well!"	Play		A woman saying to herself, "I really learned a new way of doing things; I did well!"

Table 4.4: Matrix of the thirteen question sets and fifteen illustrated motivations

Questions	Q.1 Att.1	Q.1 Att.2	Q.1 Att.3	Q.1 None	Q.2 Att.1	Q.2 Att.2	Q.2 Att.3	Q.2 None	Q.3 Att.1	Q.3 Att.2	Q.3 Att.3	Q.3 None	Q.4 Att.1	Q.4 Att.2	Q.4 Att.3	Q.4 None	Q.5 Att.1	Q.5 Att.2	Q.5 Att.3	Q.5 None
1. Lighting of the oven (biomass seq.)	CREATE	AFFILIATE	NURTURE	JOKER	PLAY	JUSTICE	HOARD	JOKER	STATUS	HUNGER	CURIOUS	JOKER	LUST	FEAR	COMFORT	JOKER	DISGUST	LOVE	ATTRACT	JOKER
2. Warmth from the oven (biomass seq.)	ATTRACT	NURTURE	LUST	JOKER	PLAY	CURIOUS	FEAR	JOKER	HOARD	AFFILIATE	LOVE	JOKER	JUSTICE	COMFORT	CREATE	JOKER	STATUS	HUNGER	DISGUST	JOKER
3. Aroma of baking with the oven (biomass seq.)	ATTRACT	CREATE	HUNGER	JOKER	PLAY	LOVE	HOARD	JOKER	NURTURE	LUST	CURIOUS	JOKER	STATUS	AFFILIATE	FEAR	JOKER	COMFORT	DISGUST	JUSTICE	JOKER
4. Baking luxuries together (biomass seq.)	DISGUST	AFFILIATE	HUNGER	JOKER	CREATE	PLAY	JUSTICE	JOKER	STATUS	CURIOUS	ATTRACT	JOKER	FEAR	NURTURE	HOARD	JOKER	COMFORT	LUST	LOVE	JOKER
5. Ceremony recognising oven mastery (biomass seq.)	JUSTICE	COMFORT	FEAR	JOKER	AFFILIATE	LUST	ATTRACT	JOKER	HUNGER	NURTURE	PLAY	JOKER	CREATE	DISGUST	HOARD	JOKER	LOVE	STATUS	CURIOUS	JOKER
6. Share baked luxuries (biomass seq.)	ATTRACT	HUNGER	CREATE	JOKER	JUSTICE	COMFORT	NURTURE	JOKER	LUST	DISGUST	LOVE	JOKER	CURIOUS	AFFILIATE	FEAR	JOKER	PLAY	STATUS	HOARD	JOKER
7. Show fuelwood savings (biomass seq.)	ATTRACT	AFFILIATE	JUSTICE	JOKER	NURTURE	CREATE	DISGUST	JOKER	HUNGER	CURIOUS	PLAY	JOKER	LUST	FEAR	HOARD	JOKER	STATUS	LOVE	COMFORT	JOKER
8. Clean cooking area (biomass seq.)	LUST	NURTURE	FEAR	JOKER	LOVE	STATUS	HOARD	JOKER	DISGUST	JUSTICE	HUNGER	JOKER	ATTRACT	CURIOUS	AFFILIATE	JOKER	CREATE	PLAY	COMFORT	JOKER
9. Repeated lighting of an LPG stove (LPG seq.)	LUST	FEAR	NURTURE	JOKER	CURIOUS	LOVE	PLAY	JOKER	HUNGER	AFFILIATE	COMFORT	JOKER	DISGUST	ATTRACT	JUSTICE	JOKER	HOARD	CREATE	STATUS	JOKER
10. Auto-switch on an LPG stove (LPG seq.)	CURIOUS	PLAY	LOVE	JOKER	FEAR	DISGUST	HUNGER	JOKER	CREATE	STATUS	AFFILIATE	JOKER	LUST	JUSTICE	ATTRACT	JOKER	HOARD	COMFORT	NURTURE	JOKER
11. Warmth of an LPG heater (LPG seq.)	ATTRACT	LOVE	HUNGER	JOKER	NURTURE	FEAR	AFFILIATE	JOKER	DISGUST	CREATE	LUST	JOKER	PLAY	COMFORT	CURIOUS	JOKER	STATUS	JUSTICE	HOARD	JOKER
12. Clean clothes vs dirty paraffin (paraffin seq.)	FEAR	LUST	AFFILIATE	JOKER	CURIOUS	HUNGER	DISGUST	JOKER	COMFORT	ATTRACT	PLAY	JOKER	LOVE	HOARD	STATUS	JOKER	CREATE	JUSTICE	NURTURE	JOKER
13. Viewing a dangerous paraffin fire (paraffin seq.)	PLAY	JUSTICE	HUNGER	JOKER	ATTRACT	STATUS	CURIOUS	JOKER	COMFORT	LOVE	HOARD	JOKER	LUST	AFFILIATE	FEAR	JOKER	CREATE	DISGUST	NURTURE	JOKER

The participants used their phones to access the form URL, as depicted in Figure 4.23. The respondents were guided through the process. The researcher explained each question verbally as they proceeded through the question set. Each respondent's choice was recorded, with the chosen options collated and transposed according to the highest-ranking motivations for each presented touchpoint. The results are presented in tabular form. After concluding the questionnaire, respondents were again reminded of the confidentiality of the survey and thanked for their participation.

Figure 4.23: Administration of the CBC question sets on the participant's phones

Intervention mapping method

An intervention mapping method was employed to map a testable intervention strategy guided by the results emerging from the workshop activities, as suggested by Saldaña, Miles and Huberman (2014) and Bartholomew Eldredge *et al.* (2016). Through an inductive analysis process, the multiple strands of data were collated and thematically categorised around the intervention concept, sequences, touchpoints, communication channels, stage, props and the supporting infrastructure required for an

intervention. The thematic patterning of the collected data was facilitated by inductive thematic analysis (Braun & Clarke, 2006). The researcher repeatedly read the workshop transcripts and other data to become immersed and familiarised with the content. They were initially scanned with no specific focus except actions mediated by cookstove-related motivations. The researcher made notes of the emerging analytic insights. Notable features were coded with a focus on the expressed motivations. The emerging codes were then reviewed and sorted into salient themes, assisted by the workshop facilitator. The data relating to each theme were collected together. The themes and subthemes were repeatedly mapped and refined to ensure a congruent fit with the collected data.

The results of the intervention mapping are presented as a high-fidelity visual mapping outlining the proposed intervention for pilot implementation. The mapping includes an illustrated description of the final BCD intervention incorporating the intervention concept proposed during the workshop design phase, the sequences and the mapped touchpoints confirmed by the CBC questionnaire. In addition, the strategy includes the communication channels, intervention stage, the intervention props and the supporting infrastructure informed by the guiding components articulated in the behavioural framework (Section 5.4) and targeted population (Section 5.2) to meet the behavioural challenge assessed in the literature review (Section 4.1).

4.6   Intervention Implementation Methodology

A differentiated SP methodology assessing exposure to the pilot BCD implementation was used to assess the dissemination of improved cookstoves in the two representative sample areas. The first pilot implementation was conducted from the 24th of August to the 12th of September 2017 in the representative sample area of Mamelodi, Gauteng. The second implementation was conducted by the behaviour change agency BREADrev from the 12th of August to the 27th of September 2017 in the representative sample area of Dunoon, Western Cape.

The surveys were administered before the pilot implementation in the two representative sample areas of Dunoon and Mamelodi to provide a control group for assessing the intervention. The Dunoon survey was conducted in English and Xhosa, while the Mamelodi survey was conducted in English and Northern Sotho. The intervention design emerging from Section 5.5 was then piloted in each of the sample areas after the administration of the control SP survey. Six months later, the survey was repeated in the two sample areas, with the section assessing the level of exposure to the intervention. The success of the pilot implementation was then assessed through the analysis of the data collected from the household-related questions, structured observations and card-based choice (CBC) questionnaires before and after the interventions in each study area.

The effect of the intervention implementation on adopting the behavioural goal was surveyed through structured observations of household stove ownership. Each SP survey consisted of field workers

recording the cookstoves observed in each sampled household categorised by the fuel types suggested in the literature: LPG, biomass and paraffin. A CBC questionnaire complemented the structured observations to assess changes in the touchpoint-linked motivations associated with the available improved flame-based stove types. The SP survey conducted after the pilot implementation included questions that recorded the level of exposure to the BCD interventions.

Each respondent was presented with a CBC questionnaire consisting of a set of 36 cards to assess the touchpoints by targeted motivation (i.e., hunger, fear, disgust) linked to locally available and affordable improved flame-based appliances categorised by the three fuel types (i.e. biomass, LPG and paraffin). A short descriptive narrative of the depicted motivation was read out to each respondent. The respondents were asked to react to the cards illustrating the selected motivations associated with the three types of improved flame-based cookstoves categorised by fuel type.

Survey team selection

The survey team consisted of residents living and working in the two sample areas. To guard against outsider bias, local background knowledge and fluency in Xhosa and Northern Sotho were critical. In Dunoon, two field workers who had participated in the exploratory observational study were selected. In Mamelodi, two local fieldworkers with previous experience in cookstove-related field research experience served as research assistants. The selected survey team were provided with appropriate training and the materials required to undertake the survey.

Survey sample selection

The representivity of the sampled households was secured by screening the sampled respondents to match the expected circumstances using a screening questionnaire. The households in the fieldwork samples were selected to capture various possible combinations of current income levels and energy use, the propensity for the diffusion of improved cooking stoves, the current reliance on traditional cooking methods and the availability of improved cooking stoves reflecting the results of the segmentation analysis (Section 5.2), with the *SEM* groups matched to the geographical location in the sample area. The sampling reflected the relevant household aspects that may influence the motivations linked to improved cooking appliances rather than representing the actual pattern of improved cookstove diffusion in the geographical location.

The control and post-intervention sample groups were drawn from the two selected areas of Dunoon and Mamelodi. The households in the Dunoon study area were sampled in the vicinity of the BCD interventions and Southern Dunoon (approximately two kilometres away). In Mamelodi, the households were sampled from Leeuwfontein Extension 16 and Phumolong (approximately two kilometres apart). The primary female caregiver of the household was selected as the respondent. The baseline and endline sample groups were screened for exposure to the intervention from the two selected areas of Dunoon and Mamelodi to evaluate the outcome of the pilot implementation.

Dunoon Control Sample

A control group of 100 respondents were selected in Dunoon from a larger-screened sample of residents in cooperation with the local council office.

Dunoon Post-Intervention Sample

The post-intervention sample group of 100 respondents was randomly selected from households sourced from Dunoon six months after the pilot implementation.

Mamelodi Control Sample

A control sample in Mamelodi of 100 respondents was selected in consultation with local community leaders, who exhibited a standard of living representative of the targeted population.

Mamelodi Post-Intervention Sample

The post-intervention sample of 100 respondents was sourced from the vicinity of the pilot implementation in Mamelodi after six months.

Ethical considerations

The nature and purpose of the research were explained to the respondents orally and in writing before commencing the survey. It was pointed out that participation in the survey was voluntary and that there were no right or wrong answers. The confidentiality of their identities and responses was assured. Approval for the nature and conduct of the research was obtained from the Cape Peninsula University of Technology Ethics Committee. The respondents were reminded of the confidentiality and thanked for their participation.

4.6.2   Data collection

The data was collected using a card-based SP questionnaire accompanied by structured observations by cookstove type and concluding with assessments of the survey experience. The data collection included questions to confirm the representivity of the respondent and their consent to participate. The nature and purpose of the survey were explained. The intervention implementation was not disclosed to the respondents. The post-intervention data collection was complemented by questions capturing the exposure level after the intervention. A sample set of the SP questionnaire is attached in Appendix VII.

The collected data includes structured observations of household stove ownership by fuel type in both sample areas to assess the level of success in achieving the behavioural goal. The structured observations of stove ownership recorded by the field workers were characterised as nominal data for each stove type (i.e., "yes", "no" and "other/don't know").
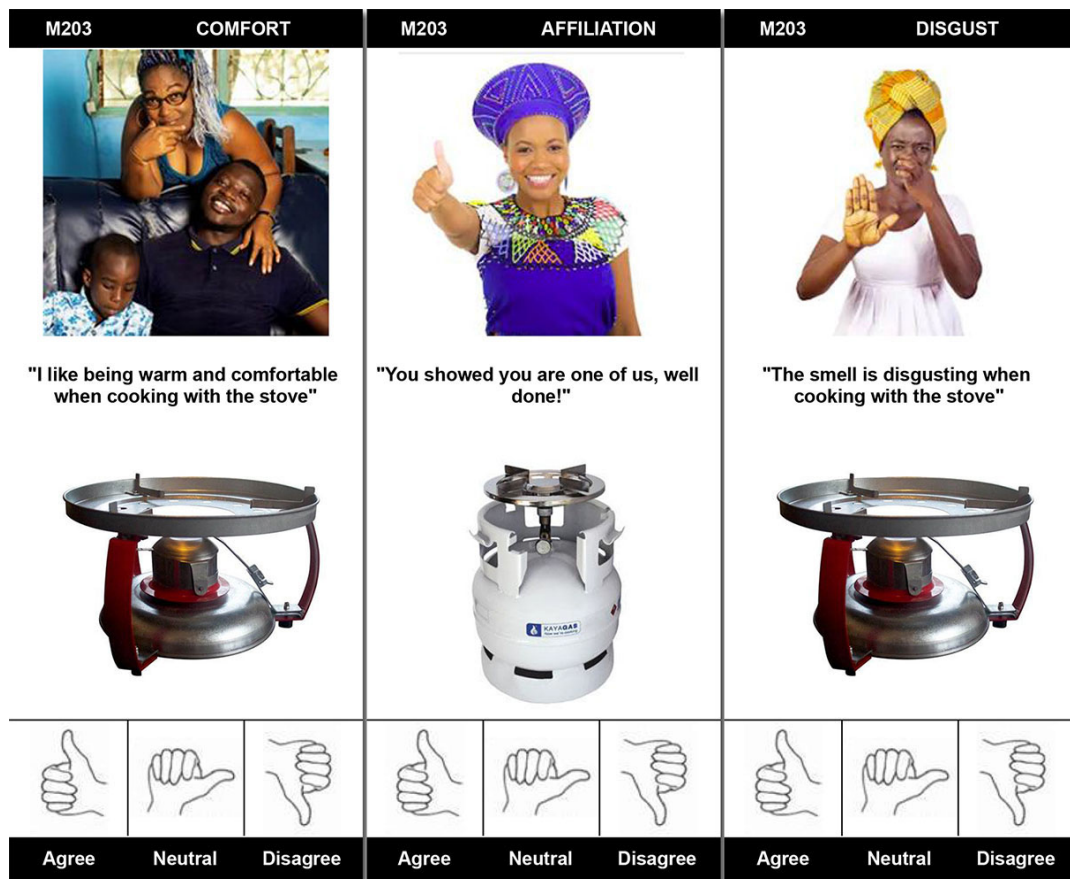
Figure 4.24: Three sample cards depicting the pre-coded list of behavioural motivations targeted by the selected intervention touchpoints

Central to the survey was the card-based SP questionnaire presented to each respondent. The SP methodology employs a visual CBC design to assess the revaluation level of the selected motivations in both sample areas in response to exposure to the intervention touchpoints. The CBC design included choice sets depicting photos of real stoves linked to visualisations of each motivation reflecting the flame-based stove-related attributes under investigation. The CBC design was limited to LPG, biomass and paraffin stoves due to their observed local presence and familiarity in the study area and to reduce the complexity of the survey design to increase the reliability of the results.

The image-based cards were selected to allow the visualisation of the various choices and avoid potential confusion and fatigue from an overload of similar questions. Each choice set of cards incorporates the selected set of motivations drawn from the pre-coded list prepared for the focus group-based interviews administered at the end of the workshop methodology in Table 4.3.

A statement linked to each motivation was prepared to be read out by the field worker to each respondent. The statements were conversational, allowing the field workers leeway in describing each illustration. Each card-based question included ordinal data assessing the perceived positive or negative connotation of each motivation to the three stove types rated as binary choices of *agree* and *disagree*

with the added option of *don't know*. Each level was visually represented with a "thumbs up", "neutral" and "thumbs down" icon below each stove image on each card.

The SP questionnaire included a series of recognition questions, which were presented to the respondents only at the endline evaluation to differentiate between the level of exposure of the targeted population and the interventions in the two study areas. The nominal data was collected for the respondents who actively participated in the intervention, saw the intervention take place, heard about the intervention through word of mouth or had no exposure. The SP questionnaire concluded with questions to assess the respondents' survey experience.

Survey procedure

The survey followed the same format for all the sample groups. Control and post-intervention surveys were administered to the respondents on a door-to-door basis. Given the low literacy rates, the field workers administered the survey verbally to the respondents. The participation of the representative primary caregivers in cooking the majority of meals in each household was secured. After completing the consent form, the questions were presented to the respondents, with the research assistant reading them aloud. The survey questions were presented neutrally, with no health or safety objective specified. During the introductions, the respondents were informed that the survey was to assess what they thought about various types of cooking stoves, what stoves they owned and what they liked or disliked about them.

The short household questionnaire, structured observations of stove ownership patterns and the CBC questionnaire were administered first to the control group in Mamelodi, followed by the control group in Dunoon. Each sample group was presented with the CBC questions eliciting motivations linked to improved flame-based cookstoves. After presenting each card to the respondent, the illustrated motivation was verbally described to the respondents. The responses were recorded, with the choices marked and filed with each consent form. The control survey in each sample area concluded with questions to assess the respondents' survey experience.

After administering the control survey in each study area, the first pilot intervention proceeded in Mamelodi, followed by the second pilot intervention in the Dunoon study area.

The post-intervention survey was administered six months after the pilot implementation of the intervention in the two designated sample areas. The field workers again presented the household and SP questionnaires accompanied by collecting observed stove ownership patterns in each household. In addition, the field workers presented recognition questions assessing exposure to the intervention.

4.6.3   Data analysis

The collected data were analysed to determine the level of success the intervention had achieved, using the individual household as the unit of analysis. The observation unit was the ownership of flame-based

cookstoves and the cookstove-related motivations targeted by the selected touchpoints included in the intervention. The responses were first scanned for completeness. One response set for each sample group was rejected for the Mamelodi control group and the Dunoon control group. One response set was rejected for the Mamelodi post-intervention group, while three were rejected for the Dunoon post-intervention group.

The results of the analysis were plotted, arranged and presented by the representivity of the targeted population, level of exposure to the intervention, ownership of cookstoves differentiated by fuel type, and changes in the revaluation of the targeted touchpoint-related motivations in response to the pilot implementations conducted in Dunoon and Mamelodi. A descriptive statistical analysis was prepared. The survey data were entered and analysed in a statistical model running in .R software. The data were delineated by changes in stove ownership levels and the changes in motivations in response to exposure to the pilot implementation.

Representivity of the targeted population

The study results were first analysed to estimate the representivity of the household living conditions related to the bottom four *SEM* bands in South Africa, where flame-based cooking appliances are prevalent.

Exposure to the pilot implementation

The reach and accuracy of the exposure to the intervention were assessed by analysing a series of included recognition questions. The visual responses to measure exposure to the pilot implementation are calculated as a binary variable of 1 for "true", -1 for "false" and 0 corresponding to a "don't know" response.

Stove ownership observations

The mean proportions of the observed stove ownership for the selected stove categories were compared between the control group and after the intervention to assess whether an increase in improved flame-based cookstove ownership was achieved in Mamelodi and Dunoon as a result of the intervention exposure. The analysis was stratified by the cookstove ownership patterns for the two sample areas. The changes in ownership were analysed for changes in stove ownership patterns between the respondents exposed to the intervention (endline) and those not exposed to the intervention (baseline). The data were separated by the sample groups exposed and unexposed to the intervention as the dependent variable (y-axis) and the mean stove ownership levels (x-axis) plotted against it. The effect of the exposure to the intervention was assessed by calculating the difference in the differences of the changes (i.e., differences-in-differences approach) in stove ownership between the exposed and unexposed respondents adjusted for the control group. A non-parametric two-sample Wilcoxon rank-sum test was applied (i.e., Mann-Whitney U) to compare the means and to estimate statistical support.

Changes in cookstove-related behavioural motivations

The CBC results of the control and post-intervention groups were screened and collated according to a baseline of exposed or not exposed respondents to the intervention. The data were separated by the sample groups exposed and unexposed to the intervention as the dependent variable (y-axis) and the behavioural motivation levels (x-axis) plotted against it. Statistical support for exposure to the intervention leading to a revaluation of the selected motivations targeted by the linked touchpoints was assessed by comparing the mean difference in the stove-related motivations between the control and post-intervention groups at baseline and endline collected through the SP survey. The intra-group correlation coefficient was again calculated using the non-parametric two-sample Wilcoxon rank-sum test (i.e. Mann-Whitney U) to compare the means and to estimate statistical support.

4.7   Triangulation Methodology

The data were synthesised and assessed with a triangulation methodology to increase the rigour, consistency and trustworthiness of the results emerging from multiple sources and qualitative approaches. Triangulations are frequently applied as a method of analysis in design-centred multi-method research methodologies (Krippendorff, 1990; Perry, 1999; Guion *et al.*, 2002; Homburg *et al.*, 2009). During analysis, the insights were abstracted to the level of prescriptive knowledge (regarding the initial results of the literature review, the contextualised behavioural framework and the development and pilot implementation of the intervention design) to provide applicable recommendations for practitioners intending to apply interventions in similar contexts. The triangulation concludes by addressing the research objectives.

4.8   Chapter Summary

The case study-based methodology followed along the phases described in the research design framework. The case study proceeded with a formative assessment of the behavioural challenge faced by impoverished South African households related to flame-based cookstove use is first provided. The case study continues with a segmentation to identify the targeted population, guided by the formative literature-based assessment of the behavioural challenges. An observational study followed the segmentation to explore the critical behavioural aspects in a South African context. The main results are distilled within a behavioural framework articulating a behavioural goal and a set of contextualised motivations. Critical aspects of a testable intervention are developed using a co-creative workshop method guided by the behavioural framework. The case study then proceeds to pilot implementation in two representative sample areas to assess selected aspects of the intervention assisted by a SP analysis. The case study concludes with a triangulation method that crosscuts selected aspects of the BCD intervention process and outcomes.

5 RESULTS AND DISCUSSION

This chapter presents the results of the multi-phase case study-based development of a BCD intervention and its partial implementation. The description and evaluation of the selected research methods employed across the phases culminate in presenting the results from the triangulation. The results are provided in chronological order of application:

i. A summary of the cookstove-related challenges in South Africa resulting from the literature-based assessment.

ii. Population segmentation, which estimates the targeted population affected by the cookstove-related challenges related to unimproved flame-based cooking appliances.

iii. Observational survey results exploring the cookstove-related behavioural context in a South African setting.

iv. The behavioural framework comprising a description of the interrelated behavioural components pertinent for designing an intervention.

v. A description of the intervention and its constituent elements for a pilot implementation resulting from the co-creative workshop results confirmed by the observations, CBC questionnaires and intervention mapping method.

vi. The results of the pilot implementation of selected aspects of the intervention conducted in the Dunoon and Mamelodi sample areas are presented.

vii. The prediction for a large-scale implementation resulting from the triangulation of the essential aspects of the multi-phase BCD process and implementation outcomes at the pilot scale is presented.

The chapter concludes with a discussion on the extent to which a BCD approach to designing and implementing an intervention is necessary to achieve large-scale diffusion of improved cooking technologies among indigent South African households.

5.1 Formative Assessment of the Behavioural Challenge

Despite dramatic changes in South African culinary behaviour, the widespread use of flame-based cooking appliances persists among South African indigent households. Despite a large-scale electrification programme, the widespread use of inefficient paraffin and solid-fuel flame stoves in South Africa with their associated adverse health effects continues. Cooking with poorly constructed, inefficient and dangerous flame-based cookstoves is a pivotal contributor to the problem of respiratory illness, shack fires, burn-related injuries and high levels of food insecurity.

A broad range of divergent needs, desires and expectations influence the culinary behaviours of impoverished South African communities. The health hazards associated with flame-based cooking are particularly affected by the overcrowded living arrangements, the poorly designed and manufactured appliances and weakening support structures, with the brunt of these effects falling on the female cooks and their children. South African flame-based appliances predominantly use paraffin, LPG gas and biomass as fuel with coal-fired stoves localised to central urban areas and close to South African coalfields. The well-being of South African impoverished households is constrained by a lack of material and financial resources. The critical material factors related to flame-based cooking in South Africa include the geographic location (i.e., urban or rural), the stage where cooking takes place (indoors or outdoors), the affordability and availability of cooking fuel (i.e., fuelwood, paraffin or gas) and the availability of durable, affordable improved cooking appliances. Changing the material environment (i.e., adding a room, doors, windows or chimney) could lead to healthier and safer cooking sequences. In addition to the material and financial constraints, the socio-institutional legacy of South Africa's history of colonisation, racial segregation and limited industrialisation dependent on mining is still visible. The hazards associated with flame-based cooking continue to fall mainly on impoverished South African women. Rapid urbanisation has significantly affected the socio-institutional environment of South African flame-based cookstove-related behaviour. The cramped living spaces in urban settlements force the female cooks to prepare meals with portable and cheap paraffin cookstoves or self-constructed metal barrel stoves, leading to injury and disease resulting from hazardous emissions, burns and fires.

A shortening of cooking routines with a rising preference for pre-cooked meals has been recorded. The frying of meat and other high-fat foods in oil is increasingly common. The stacking of stoves and fuels is reported. The urgency of cooking the next meal outweighs the negative impacts of using solid and liquid-fuelled stoves in confined spaces.

5.2   Population Segmentation and Analysis Results

The segmentation situates the representative population affected by the deleterious effects of unimproved flame-based cooking stoves in South Africa within the bottom four SEM groups (*SEM1–SEM4*). The bottom four bands have been segmented as two supergroups (BRC, 2017). The selected *SEM1–SEM2 and SEM3–SEM4* segments exhibit distinct household demographics, dwelling types, ownership of durable assets, cookstove ownership patterns and media access.

5.2.1   Demographic household indicators

The use of inefficient flame-based cookstoves is prevalent among Black South African households occupying the bottom four *SEM* bands (Peck *et al.*, 2008; Barnes, 2011; Ellis *et al.*, 2011; World Bank, 2014a; Kimemia & Annegarn, 2016). The number of South Africans living in poverty is estimated at

20.9 million (BRC, 2017). Although the number of impoverished people in South Africa has declined considerably since 1994, the levels have increased again over the last decade. Fifty-seven per cent of the population live below the upper threshold of the poverty line described by the bands of *SEM1 to SEM4*, and almost 28% of the population still live below the food poverty line described by the two lowest bands of *SEM1 and SEM2* (BRC, 2017; Stats SA, 2018). High unemployment levels characterise the four SEM bands. The most recent South African Household Survey (Stats SA, 2017) confirmed the widespread dependence on social grants as a vital source of income for 44.8% of all households in 2017.
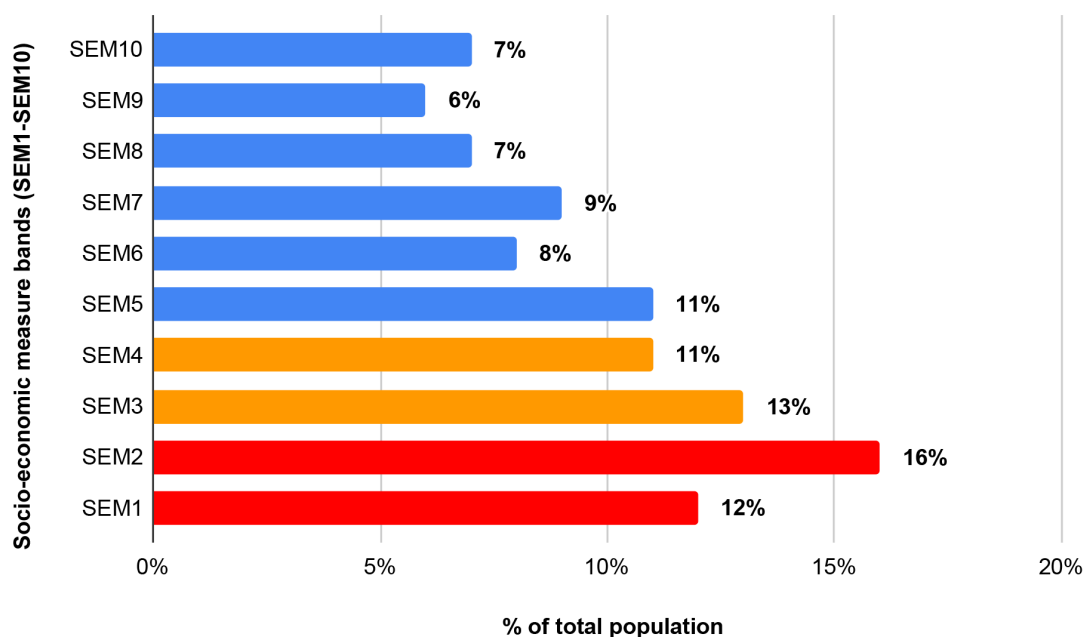
Figure 5.1: Size of the *SEM1–SEM2* supergroup denoted as red, and the *SEM3–SEM4* supergroup denoted as orange (derived from BRC, 2017)

In segmenting the population according to living standards using the *SEM* band method (Higgs, 2015; Langschmidt, 2017), the *SEM1–SEM2 group* is estimated to number 11.6 million (28%) people, while *SEM3–SEM4* is estimated to contain 9.3 million (24%) people. See Figure 5.1 (BRC, 2017).

5.2.2 Material indicators

The status of the dwelling quality and appliances owned shows a clear progression from *SEM1* up to *SEM4*. Unsealed floors and no running water characterise the dwelling type common to the *SEM1– SEM2* group. *SEM1-SEM2* households in urban areas predominantly live in rudimentary shacks in informal settlements. *SEM3–SEM4* residents live in formal, albeit small, housing units with sealed finished floors in which over half of the households have a kitchen sink (Figure 5.2) (BRC, 2017).
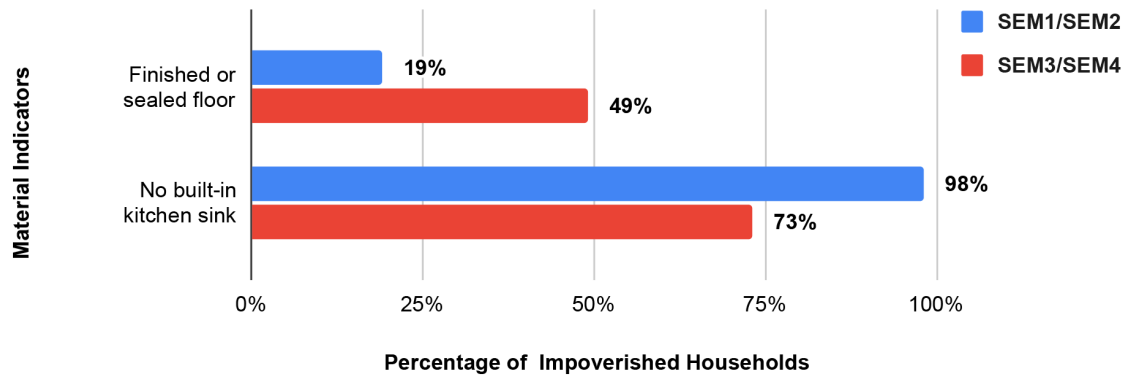
Figure 5.2: Frequency of material indicators for the *SEM1–SEM2* and the *SEM3–SEM4* supergroups (derived from BRC, 2017)

The ownership of microwave ovens is negligible in *SEM1–SEM2,* but a dramatic uptake of such can be seen in *SEM3–SEM4* (Figure 5.3). The lack of durable appliances in the two lowest groups indicates that electricity access and use only become affordable within the *SEM3* and *SEM4* groups or above (SAARF, 2014).
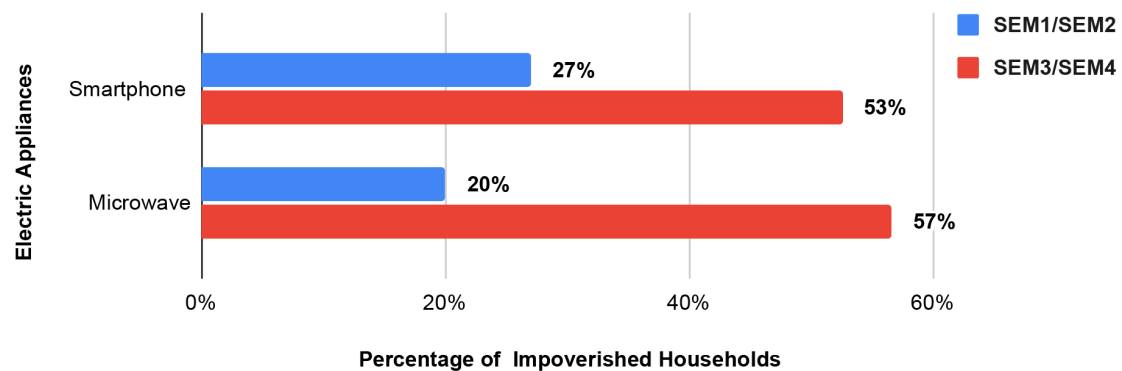
Figure 5.3: Selected electric appliances for the *SEM1–SEM2* and the *SEM3–SEM4* supergroups (derived from BRC, 2017)

5.2.3 Cookstove-related ownership patterns

Cookstove stacking of cookstoves is confirmed, with flame-based appliances being used despite the ownership of an electric stove. However, the ownership of electric stoves does not necessarily translate into actual use, as shown in Figure 5.4. Even though 72% of households in the *SEM1* to *SEM4* bands reported having an electric connection, only 5% exclusively cook with electricity, with most households stacking cooking appliances and fuels (Department of Energy, 2013; BRC, 2017). The regular use of electricity for cooking appears relevant only within the *SEM4*, with a noticeable increase in the purchase of large electric appliances. The ownership of small electric appliances (i.e., microwaves) increases from a low of 5% in *SEM1* households to nearly 84% in *SEM4* households (Figure 5.3).
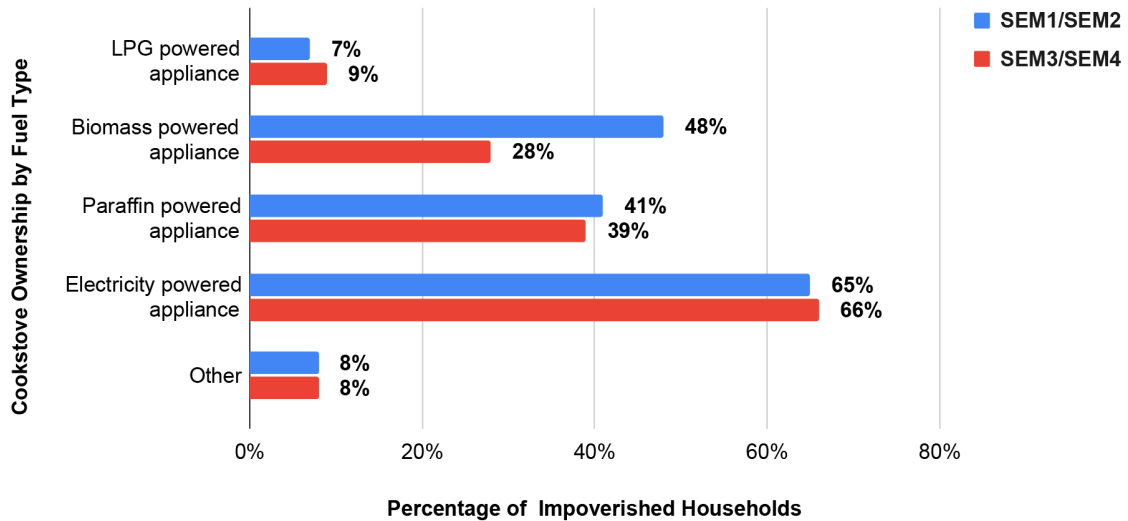
Figure 5.4: Cookstove ownership by fuel type for the *SEM1–SEM2* and the *SEM3–SEM4* supergroups (derived from Department of Energy, 2013; BRC, 2017)

5.2.4   Media communication channel access

Access to mass media channels is dominated by radio and television among all households (Figure 5.5), with a fast-growing mobile internet adoption rate. While television ownership is not universal, the nature of shared community life means that many households occasionally view television with their neighbours, as borne out by the viewership figures (BRC, 2017). The mobile telephone is ubiquitous among all *SEM* households, with a rapid growth recorded in smartphone ownership between *SEM1* to *SEM4* (BRC, 2017). The ownership of mobile phones correlates to mass social media use through the mobile internet (e.g., Facebook).
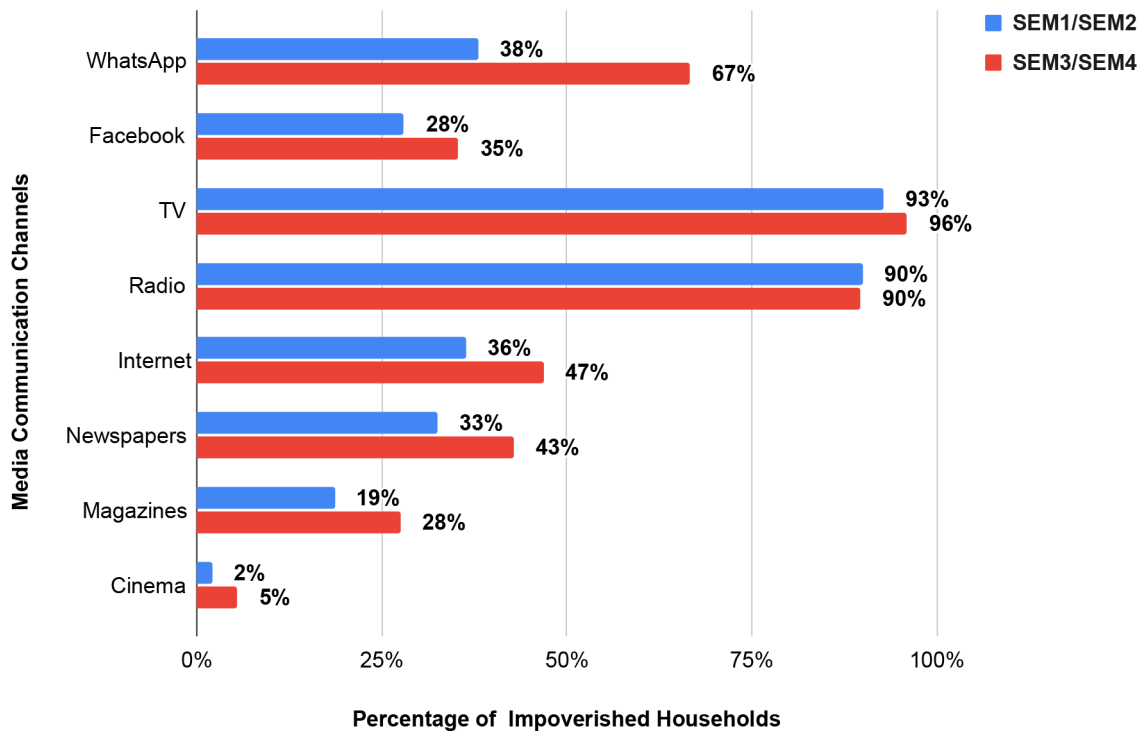
Figure 5.5:   **Media channel access within groups *SEM1* to *SEM4* (derived from BRC, 2017)**

5.2.5   Segmentation analysis results by *SEM* group

The segmentation analysis indicates the following characteristics for the two *SEM* super groups representative of the targeted population, as summarised in Table 5.1.

Table 5.1:   *SEM* **group results summary (*SEM1–SEM4*)**

Household Criteria by *SEM* Group	*SEM1–SEM2*	*SEM3–SEM4*
Primary caregiver	> 50% Female	> 50% Female
Location	Rural, urban	Urban, rural
Income type	Social grant Irregular income	Social grant Irregular income Some wages
Monthly income, including social grants	R3 404 – R4 275	R5 210 – R6 434
Cooking energy source	Paraffin Electricity Biomass	Electricity Paraffin LPG
Decision Horizon	Short-term convenience	Short-term convenience

Socio-economic measure group: SEM1–SEM2 segment analysis

The S*EM1* and *SEM2* households are found in rural and urban settings, with residents living in informal shacks, "matchbox"/RDP houses and traditional dwellings with communal access to water still evident (SAARF, 2014; BRC, 2017). The average household incomes are below R3 404 per month (R441 per month, excluding social grants) for *SEM1* and between R3 404 and R4 275 per month (R882 per month,

excluding social grants) for *SEM2*. Adult genders are evenly distributed between males and females. The S*EM1* and *SEM2* household cooks are predominantly adult females, with children or grandchildren present within the household. Rural households living in *SEM1* and *SEM2* predominantly depend on fuelwood as a fuel source (Stats SA, 2012); many households do not own durable cookstoves. The use of paraffin as a fuel source is reported at 41% (Stats SA, 2015; BRC, 2017). There is minimal access to piped water and sanitation services, and ownership of durable assets is limited, with electric hob ownership estimated at 14% (Stats SA, 2012). Radios, old television sets and mobile phones are ubiquitous, yet many households still cook over a fire. Radio and television are ubiquitous mass communication channels (Stats SA, 2012). The highest level of education is predominantly primary school attendance; however, some high school attendance is evident. Most households have access to a bank account linked to the payment of social grants (BRC, 2017).

Socio-economic measure group: SEM3–SEM4 segment analysis

Men between 15 and 34 typically head households in the SEM3 and SEM4 supergroup. They have an average monthly household income between R5 210 (R1,294 excluding social grants) and R6 434 (Table 5.1). The *SEM3–SEM4* dwellings are still physically located close to the lower SEMs (By contrast, from *SEM5* and above, there is distinct spatial segregation). *SEM4* household heads tend to own a title deed to the house where they reside and can take out credit for purchases such as larger stoves and furniture. They have some high school education (BRC, 2017). Urban households reside in small state-built cement brick and self-constructed houses in proximity to informal settlements characterised by the *SEM1* to *SEM2* bands, while rural residents live in traditional dwellings (BRC, 2017). Almost all households have access to electricity. The ownership of durable appliances is dominated by television sets, radios, fridges and electric hot plates. Electric stove ownership is high, with four-hob stoves typical. Media is dominated by television and radio (BRC, 2017). All the households have access to a bank account (BRC, 2017). Social activities are characterised by regular attendance at church gatherings, burial society meetings and stokvel gatherings (BRC, 2017). In addition to traditional social events, these householders attend many other gatherings, with the younger household members also frequenting nightclubs (BRC, 2017).

5.3   Observational Study Results

The observational study's results exploring the intervention's behavioural context provided a deeper understanding of how a representative sample of the South African population is affected by the adverse effects of unimproved and poorly constructed flame-based cooking appliances. The observations of the different households in the selected context confirmed the targeted population selected in the segmentation and analysis.

The cookstove-related behaviour is driven by the challenge of cooking the next meal for the family, which outweighs the long-term respiratory health benefits that an improved cookstove could provide.

The observed cookstove-related behaviours of the targeted population were influenced by what food ingredients, fuels, and appliances were available and constrained by the precarious income levels. The cash directly influenced the choice of the cooking appliance on hand to pay for food and fuel. The greater the fluctuations in available income, the greater the number of cooking stoves and fuels used, thus, confirming the stacking phenomena. If the materials are not affordable despite their availability, the next most convenient option is used.

Figure 5.6:   Typical Dunoon street scene

The study found that an electrical connection does not imply using an electric cooking appliance, as evidenced by the stacking of fuels and cooking appliances. Electric hobs and microwaves are used in conjunction with flame-based cooking appliances. While households may have cited cooking with electricity as their preferred option, using unimproved flame-based cooking appliances was observed.

The households expressed an awareness of the danger associated with paraffin-powered stoves. The households were unanimous in their aversion to the smell of paraffin fuel. LPG stoves were perceived as dangerous when no previous experience of actual use had occurred.

The cooks related numerous benefits of using flame-based appliances, especially in using large cast iron ovens for cooking, baking and heating the home in winter. Despite the preference shown for improved wood-fired appliances, limited ownership was observed.

The observational study results are presented as a summary of the individual household observations, representing the four *SEM* categories identified by the segmentation. The observations are followed by a synthesis of the cookstove-related settings categorised by the material props and surrounding infrastructure. The observations related to external material and social factors associated with flame-based cookstoves are summarised. Finally, the motivations from observations that could be linked to touchpoints in a behaviour-focused cookstove dissemination intervention are presented.

5.3.1 Summary of household observations

The households representing *SEM1* and *SEM2* showed similar cookstove-related behaviours with the continued predominance of biomass and paraffin stove use, accompanied by the limited use of electric devices where electricity is available and the near total absence of LPG-powered devices. Conversely, *SEM3* and *SEM4* showed no particular preference for any cookstove technology, with increased electricity use observed in the *SEM4* households.

Observations: Household One

The participating cook representing the *SEM1* group was a woman living with her son in an informal structure made from cardboard, rusted corrugated iron and wood. Her husband was away for extended periods looking for work. The family rents a backyard dwelling situated on the unoccupied space from the legal titleholder's piece of land. The family hail from the Eastern Cape Province and moved to the area two years ago after the woman's husband found work in Cape Town. Her husband is frequently away for prolonged periods, occasionally contributing financially. The child grant she receives is her only stable source of income.

Figure 5.7:   Household One: Firewood collected from neighbouring open field

The household caregiver spends between two and three hours three times a week collecting firewood (Figure 5.7). She prepares the meals outside her home using an imbaula stove. She uses a paraffin stove occasionally in the mornings to make tea because it is quick and convenient, but she commented that "paraffin is expensive". She reflects:

> "I cook with wood like back home in Cutwini (Eastern Cape). We've been cooking with wood all of our lives. It is hard work. But you have to. If you have money you can just buy what you want. We used to cook some things with paraffin. But paraffin is expensive"

The caregiver uses the paraffin stove and occasionally an imbaula stove for space heating in winter. The caregiver uses fuelwood for most of her meals, even though access to electricity has recently been provided. The reason she gave for her fuel choice is that electricity for cooking is expensive and it does not heat the house. She comments:

> "Electricity cost too much. I will boil tea sometimes but can't afford it now. If I get money maybe next month"

She moves the imbaula and paraffin stove indoors to provide space heating in winter. This could be because the electric connection is illegal, implying that she does not receive the government's free basic electricity allowance and pays the neighbour for the connection. Collecting firewood is considered time-consuming, and she has to wake up early to do so. She stoically describes the circumstances as "What can we do?" and is accustomed to them.

Observations: Household Two

The cook heading the second household representing *SEM2* prepares meals with various cooking technologies, frequently using an (illegal) Panda paraffin stove and an imbaula stove. In addition, the recently urbanised household representative of *SEM2* still prepares food using a traditional open fire. Two imbaula stoves were found at the back of her property. The cook collects fuelwood twice or thrice weekly, sourced from the open fields adjoining Dunoon. She said:

> "There is lots of wood that side (pointing in the direction of an open field to the west). If I start early it is easy. Last weekend we cooked a big stew for a wedding right here. I got the wood with a friend from church. We got the wood early in the morning. Everything was done in time. We could buy more meat."

Figure 5.8:   Household Two: Afternoon porridge cooked over an imbaula stove

She is a grandmother, and her daughter refers to her as a *makoti* (i.e., a woman of high standing) who moved to the city to join her husband. Her decisions on what to cook and which stove to use depend on available cash and time. The cook uses a paraffin stove and an electric kettle to make tea in the mornings for her family, which is served with bread or leftover porridge. The electric kettle is preferred.

> "Electric kettle is nice but sometimes the meter (indicator on the pre-paid electricity meter) is finished – especially in the morning"

The imbaula depicted in Figure 5.8 is used occasionally in the afternoon to cook porridge and barbecue, especially when money is unavailable for purchasing paraffin.

Figure 5.9:   Household Two: Cooking over open fires for social gatherings

Occasionally, once a month, her relatives living in the neighbourhood assist her in cooking over an open fire for family and church gatherings, as shown in Figure 5.9. In winter, the paraffin stove is used to heat the dwelling.

Observations: Household Three

The third household cook, representing *SEM2,* is the head of a single-parent household with four children. She is unemployed and dependent on the government social grant and the wages her 22-year-old daughter earns from working as a cleaner at a logistics warehouse in the vicinity. She uses both an old unpressurised paraffin stove and an electric stove daily.

Figure 5.10: Household Three: Cooking a stew with a paraffin stove

The cook reported that the Panda paraffin stove, similar to the one shown in Figure 5.10, lasts about three to seven months before it breaks.

> "These stoves are *umgangatho ombi* (bad quality). They break easy. The one before three months maybe seven months. I don't like them"

When financial resources are low, she reverts to cooking with an imbaula or over an open fire because free fuelwood is available within walking distance. The family uses the paraffin stove and firewood to warm themselves in winter. The cook's daughter said:

"the paraffin stove makes my clothes smell bad"

A single hob electric hotplate is also used, mainly for cooking vegetables. She has also started boiling tea on the electric hob due to her electric kettle breaking. The electric stove is used in the mornings to save time getting the children ready for school.

"In the mornings there is no time. Defy (stove brand name) *upheka ngokukhawuleza* (cooks fast)"

Observations: Household Four

The cook representing the *SEM2* segment reported that her default cooking option is a four-plate electric stove and a paraffin stove. She, however, uses her electric stove on weekends to cook large family meals when her budget allows for it, as depicted in Figure 5.11.

"I like the oven. I use it on weekends for when everyone is here. In the week it takes too much electricity. Sometimes you see the meter move. *Isibane sidanyaza ngokukhawuleza* (The light on the meter flashes fast)."

She uses an electric kettle and occasionally a paraffin stove to make tea before the children go to school in the mornings. When she has guests for a meal, she will use her electric stove or a three-stone fire for larger meals on weekends.

Figure 5.11: Household Four: Cooking a stew on the electric four-plate stove

She dislikes that the paraffin stove cannot accommodate more than one pot at a time and its low quality but likes the heat it gives off in winter, using it as a makeshift space heater. She occasionally uses the Panda because it is considered affordable and convenient.

> "The (paraffin) stove is too small. I can't cook supper. I like cooking and frying at the same time on my oven. This one is only good for small things. It's nice in winter in the mornings when it is very cold. Look at the switch, (pointing at the Panda stove regulator hanging haphazardly in place) it broke after one week only"

She uses an imbaula on occasion outdoors in winter. When credit or large sums of money become available, the money is invested in fixed assets such as building materials to complete her home. A finished home represents stability for her.

> "Money is scarce. I want to finish the house. It want it to look nice. When we get money we buy from *Build & Save* (a local building supplies store)"

Observations: Household Five

This household is representative of the *SEM3* segment. The caregiver and participating cook of the family of three lives in a self-constructed house. She cooks indoors and outdoors and spends approximately R700 per month on electricity. She loves her electric stove (four-plate hob and oven) and occasionally uses it for baking.

> "I love cooking. I always wanted a good stove. I cook with it every day."

Figure 5.12: Household Five: Cooking with a paraffin stove with the four-plate oven in the background

The primary cooking method in the household is the electric oven. According to her, electricity is excessively expensive. The stove was purchased from a large department store five years previously for R4 000.

> "Eskom is now expensive. It runs out fast. In the past R200 was enough for a long time. Now R200 is gone quick-quick. My sister gave me her paraffin stove She had an extra one. I use it

when Eskom goes off. Last winter I used an imbaula. My husband made it. It is warm but very smoky"

She has started to use a paraffin stove and an imbaula for heating and occasional cooking in place of the electric stove, as depicted in Figure 5.12. She purchases firewood locally as needed due to its scarcity and the physical effort required to collect firewood.

Observations: Household Six

The sixth household was selected to be representative of the *SEM4* band. The participating cook runs a cooking business from home.

> "I use *imbaula* to cook the meat for *ishishini* (business) to make money. Tsk, Tsk.. Electricity makes me poor. It eats too much for the business. And goes off too much. I use gas now it cooks nice and is easy for the big (aluminium) pots."

She prepares chicken and pork offal on an imbaula at home and sells it at the local taxi rank. She does not collect fuelwood but purchases fuelwood every month from a local entrepreneur. A small pickup delivers the wood at R500 per delivery. Her husband is a wage earner, often away during the week. His wages provide stability in the household budget, making it easier to plan purchases. A stove and fridge have pride of place in her home, together with a television and furniture. She expressed satisfaction with her stove, a standard four-plated electric stove.

> "Gas is nice. It cooks fast. It is expensive. I refill here in Potsdam (local refilling station). My husband takes the cylinder to be refilled. I was worried when my husband got it. But now it works fine."

Decisions about cooking are made daily, dependent on how much electricity remains on the prepaid meter. Her husband has recently bought an LPG stove for use during electricity blackouts. At first, she was apprehensive about using the gas stove, but it has become a popular choice, especially when electricity is running low. While, according to her, it "feels expensive", it cooks "very fast". She has not used a paraffin stove for more than two years. She has switched cooking for her business to her LPG stove to accommodate the large volumes of meat (Figure 5.13).

Figure 5.13: Household Six: Cooking with a cast iron stove balanced above a four-plate electric stove

The family is satisfied with her current cooking stoves and would only switch to a new stove if it was cheaper to run or heats the home. According to her, the cost of electricity is a serious concern.

> "Eskom has become too much. And it always goes off. We try to cook more on the stove and switch the geyser off. Since then we saved a lot of money. We use more electricity over the weekend."

5.3.2   Summary of observations related to cookstove-related settings

The observations related to flame-based cookstove-related settings are influenced by various material and social factors related to performing the observed culinary sequences. Households use a variety of flame-based cooking appliances with the stacking of fuels and appliances observed. The dual use of a paraffin heater to heat water for cooking and cleaning is notable. Electric connections are ubiquitous, with prepaid and illegal electric connections used for illuminating the home, boiling water with kettles, intermittent microwave cooking and cooking with electric hot plates. While households still prepare traditional meals occasionally, cookstove-related behaviours are now characterised by individual households cooking with various appliances. The behaviour setting consists of households cooking with paraffin stoves, open fires, imbaulas and electric stoves in multiple combinations. When LPG stoves are locally available, their use is limited. Communal cooking settings common in rural environments are increasingly limited to ceremonial purposes.

Furthermore, a rise in pre-cooked and ready-to-eat meals was observed with an increasing amount of flame-based cooking shifting to small roadside settings with entrepreneurial cooks preparing meals during the day. The ubiquitous pre-cooked ready-to-eat foods are inexpensive compared to traditional home-cooked meals. The meals being cooked are increasingly deep-fried and prepared in a shorter time.

Overall, simplified cooking sequences with few ingredients are preferred, allowing the cook to adapt to any available fuel type or cooking appliance. The daily cookstove-related behaviours regularly consist of breakfast - tea consumed with purchased bread and jam, cooked leftovers from the previous evening or seasonally available fruit; lunch - ready-to-eat fried foods or leftovers; and dinner - boiled porridge or rice served with vegetables, beans or meat with gravy. Supper was observed being cooked with a multiplicity of appliances. In all six households, starches (maize porridge or rice) cooked with vegetables dominated the cooking sequences, with salt and chilli powder used to improve taste and palatability. Meat is added occasionally. On weekends, lunch and supper become social occasions. More meat is consumed, and open fires are used. The researcher observed the rare baking of traditional steamed bread in a metal pot on an imbaula stove only once, during a weekend in the immersion phase.

Cooking with biomass

Three households use imbaula stoves combined with paraffin and electric stoves to fulfil a cross-section of cooking needs. In addition to cooking, imbaulas are regularly used to heat water for washing and space heating at night. The fuel consists of scraps of construction lumber and fuelwood sourced from the neighbouring farmlands. The firewood is generally collected by informal networks of women from neighbouring farmlands and consists of pruned branches and wood disposed of by local factories. Small food vendors purchase fuelwood from local informal traders. Wood or coal-powered cast iron ovens are considered desirable yet too expensive. A single improved biomass stove was observed during the immersion.

Cooking with paraffin

Unpressurised paraffin stoves are still used. Despite the lingering smell of paraffin and the awareness of the many dangers associated with its use, paraffin was present in four of the six households. One of the households owns a paraffin heater and uses it throughout the year in the mornings to heat the home and water for washing. Paraffin is sourced from the local supermarket or spaza, depending on the time of day and availability. Paraffin is often purchased in small quantities, making it difficult to differentiate between its use and a more efficient stove, as the long-term saving cannot be discerned against the cost of a single meal. The short-term decision-making in needing to cook a meal outweighs the long-term health benefits, with the paraffin stove positioned as an affordable consumable and the fuel in plastic sachets priced per meal.

Cooking with LPG

Only one household accredited the greatest ease of cooking to an LPG stove. Four of the six households expressed fear concerning gas cylinders. However, the cooks were aware of the convenience of cooking with LPG stoves compared to paraffin stoves, especially the speed of lighting them and the ability to regulate the temperature. The availability of LP gas is limited to two local spaza shops in the vicinity of the taxi rank. LPG can also be bought at the petrol station on the southern outskirts of the settlement in 9 kg cylinders, approximately 30 minutes away by foot. The cook using LPG attributed the popularity of the double hob gas stove to its sturdy cast iron construction and flexibility for outdoor use. An additional advantage is the height afforded by its legs providing ground clearance on uneven cooking areas.

5.3.3 Observed social and material factors linked to flame-based cooking

The flame-based cookstove-related behaviour is characterised by an insecure and precarious material and social environment. All six surveyed households reported that paying for food, fuel, and transport consumes most of their monthly income. All the households confirmed the importance of the affordability of food, fuel and stoves. All households depend on social grants, wage-based labour or informal entrepreneurial activities. As reported in the literature review, the rapid changes that have occurred in the material and socio-institutional factors influencing cookstove-related behaviour are confirmed in the observational study. The Western culinary infrastructure heavily influences flame-based cookstove-related behaviour, determining the ingredients, utensils and fuels used when cooking. The reliance on local community networks as a source for food ingredients, fuel and cooking appliances is being supplanted by national supermarket chains on the outskirts of South African informal settlements (i.e. Shoprite and Pick and Pay; Figure 5.14).

Figure 5.14: **A popular supermarket on the outskirts of the Dunoon sample area depicting the growing influence of retail centres in informal settlements**

The social environment includes traditional and local municipal services. The households readily attend community events and church services to improve their immediate living circumstances and secure a better future for their children. They rely on traditional and local council structures within their communities. Social grants, considered necessary household support provided by the government, are appreciated yet insufficient to meet the increasing household burdens (i.e., food, fuel, clothes and school fees). Transport and education costs compete against daily decisions concerning what meals to cook.

The cookstove-related settings observed in the study confirmed the insights from the literature review. Cooking with flame-based cookstoves takes place inside and outside the cramped dwellings, with a dedicated kitchen absent in most cases. Cookstoves are moved frequently to different places both inside and outside the home. Cooking often occurs at ground level without any tables or shelves used to stabilise the cooking appliance or lift the cooking activities to a convenient working height. The indoor setting for cooking is typically a cramped single-roomed dwelling constructed from locally sourced materials that span discarded wooden pallets and corrugated iron sheeting. The room is frequently poorly ventilated, filled with combustible building materials and usually insulated with a combination of wood and cardboard. All indoor cooking areas have at least one door to the outside or an adjacent room. No physical barriers prevent small children from playing near the cooking area, with children often exposed to combustion fumes.

Despite the presence in the behavioural setting of fridges, televisions, microwaves, electric kettles and electric stoves after an electric connection has been secured, the use of open fires, paraffin stoves and self-constructed imbaulas persists in the cramped living conditions. While households may verbalise a

preference for electric cooking appliances, imbaulas, paraffin stoves and open fires are frequently used for cooking a variety of meals and for heating the homes and water required for washing bodies, clothes and household items, including cooking utensils. While the convenience and time-saving attributes of an electric stove were confirmed in the interviews, the high cost of electricity was cited as the reason for the persistence of paraffin and wood-fired cooking stoves in practice. Unpressurised Panda paraffin stoves are often used to boil tea, cook small meals, and occasionally heat the home. A single old pressurised Primus stove was found to be in operation. Only one household was using an LPG stove prior to the observational study.

Traditional culinary sequences adapted to urban settings

A mixture of urban and rural culinary sequences was observed in urban settings. Traditional rural sequences included cooking sheep heads, trotters, tripe, chicken feet and heads over open fires and imbaulas. Maize, samp and beans are prepared with meat and gravy, albeit mostly on weekends over open fires. While rare, the preparation of traditional steamed bread was observed. An example of a rural tradition still observed in an urban setting is the rendition of a traditional *igoqo*, stacking firewood on an urban shack's roof, as depicted in Figure 5.15. An *igoqo* refers to the Xhosa tradition of storing firewood around a homestead for cooking and heating. Beyond the practical considerations, the stacked firewood is intended to communicate the industriousness and preparedness of the resident woman. *Igoqos* are often made during lobola negotiations or pregnancy to signify that the inhabitant of the well-run homestead is a *makoti* – a woman of high standing.

Figure 5.15: Example of a traditional *igoqo* in urban Dunoon

Pre-cooked meals displacing home cooking sequences

A substantial observation was the household consumption of bread as a pre-cooked meal, reducing the number of meals cooked in the home. Industrially produced white bread purchased from local supermarkets was present in all households and served as a breakfast and lunch staple. All households consumed at least one loaf every two days, displacing the cooking of maize porridge for breakfast and lunch. The growing preference for purchased bread was attributed to its convenience and the time it saved, thus, reducing the meals cooked at home, specifically the long time required for cooking porridge in the mornings. The white bread loaves, sealed in plastic with a shelf life of over a week, are widely available and retail between R8.50 and R12.00. The loaves observed contained a mix of soya and wheat and a long list of preservatives.

Deep frying sequences

Culinary sequences incorporating deep-fat frying are rising in popularity compared to boiling. Frying bread and meat in sunflower oil at high temperatures is ubiquitous. The reason given for frying was that the food is considered tastier and not as bland as when it is boiled. An additional reason given was the reduced cooking time. The pervasive availability of ready-to-eat deep-fried foods is confirmed by the number of small female-run enterprises preparing meals in oil over paraffin stoves or wood fires by the side of the road. The popularity of deep-fried dough balls exemplifies the convenience and affordability of the deep-fried items – commonly referred to as *magwinyas*. These are consumed as a snack or breakfast with a cup of hot tea. Alternatively, they are served with a wide variety of energy-dense fillings, including cheese, ground beef or polony. A single serving of fried bread costs between R3 and R5. which is well within the budget of the household caregiver.

The observed households prepare between two and three meals a day during the week, depending on the availability of income and time, confirming the literature review findings. There was little complexity in the cooking sequences, with most meals prepared in less than an hour. Baking or steaming bread or cooking samp can take over two hours to prepare. Maize porridge or rice is cooked within an hour. The roasting of meat does not take longer than an hour to prepare.

Summarised weekly cooking sequences

The observed weekly culinary sequences with flame-based cookstoves are summarised according to breakfast, lunch and supper during the week. Weekend settings are described separately.

Breakfast generally consists of serving bread with margarine, peanut butter, jam, egg, polony, cheese or leftover gravy spread, supplemented with tea boiled over a paraffin stove or electric kettle when available. Leftover cold maize porridge mixed with fermented thickened sour milk was prepared twice. Soft maize porridge is rarely cooked in the mornings.

Lunch is increasingly prepared by informal cooking establishments within walking distance of the households, consisting of stiff maize porridge, relish, marog, spinach, cabbage, and potatoes served with a tomato-and-onion gravy or achaar. In summer, grilled or steamed maize cobs are prepared over imbaula fires. Informal ready-to-eat establishments fry the meat in oil or griddles over various stoves. Deep-fried foods are popular. The deep frying of food in metal pots has increased markedly. Savoury deep-fried doughnuts (i.e., *maginyas*) are served as ready-to-eat meals with various fillings. When an oven is available, traditional steamed loaves of bread have been supplanted by scones. Deep-fried potato chips are popular, served with fish or as part of the popular *kota* – a quarter loaf of bread filled with cheese, French polony and achaar.

The main cooking sequences with flame-based appliances occur during preparations for supper, with a stiff maize porridge cooked with a vegetable or protein-based relish over various cooking appliances. Meat is sometimes included during the week – often offal from chicken or beef, or grilled, stewed or fried intestines. Beef and chicken are more frequently prepared on weekends. After supper, tea is often prepared on a wood fire, paraffin stove, or electric kettle.

A larger variety of food and more expensive items are cooked on weekends. Sundays are regarded as the culinary highlight of the week, with large meals cooked for families. Some do not eat breakfast due to religious prescriptions over weekends. In most households, rice or stiff maize porridge is prepared, often still over a fire, with grilled chicken or beef, accompanied by different vegetable dishes. Most households prepare large meals on Sundays. The leftovers are consumed later for supper or breakfast the following day. In the absence of leftovers, in most homes, dinner on weekends consists of a simple meal of purchased bread and tea.

5.3.4   Summary of observed motivations linked to flame-based cooking

The motivations for using flame-based cookstoves confirmed the observations summarised in the literature review (4.1.5). The motivations related to flame-based cookstoves inferred from the household observations in Dunoon confirmed the literature-based assessments related to the biophysical drives of hunger, disgust, fear and comfort. As alluded to in the literature, an awareness of the respiratory health risks and fire hazards associated with flame-based cooking is known yet not considered a strong motivation for using a particular category of cooking appliance. Cooking is primarily considered to be drudgery. All the households reported and were observed expending large amounts of time and effort to clean the home when cooking over a fire. Three households expressed their frustration at not being able to leave home when the electric connection became unaffordable or unavailable during the month. While preparing traditional dishes and meals for special occasions is considered important in keeping familial bonds and relationships intact, these events are rare. No observations were recorded that alluded to lust as a motivating factor.

Hunger motivations

The observations confirm that food is primarily cooked as a source of biophysical sustenance and consumed for energy and strength rather than as a luxury. The precarious income levels are directly linked to the levels of hunger and daily decision-making regarding what cooking technology to use to prepare a meal. Hunger motivates the short-term decisions regarding what meals are cooked, thus overriding drivers governing long-term health.

Comfort motivations

The observed comfort derived from a warm and dry space provided by an improved flame-based appliance appears to be linked to paraffin-powered appliances and wood-fired self-constructed barrel stoves during the winter months, as confirmed in the literature review. The observation concerning home heating for physical comfort in winter is essential in using paraffin-fuelled appliances or self-constructed imbaula stoves. The flame-based appliances were used to heat the homes at night, despite the availability of electricity in the sample area.

Fear motivations

The fear motivations observed include the fear of injury to the body from gas and paraffin stove explosions or fires, the threats of death associated with carbon monoxide poisoning and the threats of death to children from paraffin ingestion. In contrast, the household caregiver regularly using an LPG gas stove expressed no fear of explosions associated with LPG gas cylinders, indicating that physical exposure to a sequence with an LPG stove is necessary for revaluing associated motivations of fear.

Disgust motivations

No clear link to disgust motivations emerged from the observations. Attempts could be made to link the disgust motive to the odours of cooking over paraffin or the dirt associated with soot emanating from an imbaula stove. The cook in the setting with tiled floors cooked outdoors over a fire to "keep the house clean". One participant mentioned clothes being permeated with the odours of smoke and paraffin.

Nurture motivations

The maternal motives of caring for and protecting children could be targeted in a behaviour centred intervention as the women cook predominantly in settings with young children nearby. The women cooks will do whatever they perceive necessary to nurture and support their children. The observations confirmed that the children played continually while the meals were being prepared, with a mother moving the child away from a boiling pot in one case. The nurture motive could be linked to the hazards of unimproved flame-based stoves. Another indirect link would be higher disposable income due to savings in fuel and time, thereby providing precious resources to support their families. A case was

observed in a multigenerational household where the matriarch used her savings to pay her grandchildren's school fees.

Hoarding motivations

The observed precarious levels of poverty appear to lead to hoarding options between the many competing household decisions. Noticeable among the cookstove behaviours observed was the activity of stacking multiple cookstove types and fuels as a hedging measure. The effects of resource scarcity among vulnerable households lead to hedging options to insure themselves against catastrophic risks. Long-term purchase decisions do not appear to translate into the daily use of cookstoves. In all six households, cooking decisions are determined by which fuel source is affordable and available at that moment. In all six households, women do most of the daily household purchasing. The availability of an electric stove does not translate into its daily use. The next most convenient fuel source is used when prepaid electricity is depleted.

Creative motivations

Creative motivations were observed in various pathways and recipes in preparing meals under severe constraints. Creativity can be sparked by the behavioural context's material, social, and economic constraints. The observation of steamed bread being prepared in an urban environment diverging from its traditional origins in the Eastern Cape confirms the creativity of providing food. This creativity is confirmed by the multitude of iterations in preparing traditional meals, as confirmed in the literature. A further example was the observed increase in frying meals in oil, leading to the appearance of new culinary traditions (i.e., deep-fried bread).

Motivations of affiliation

Affiliation motivations to build trust and strengthen social cohesion were frequently observed through cooperation with others by sharing food or cooking in social settings. The positive motivations gained from cooking with family and friends can provide a sense of self-efficacy and personal agency. Cooking interesting and tasty meals with an improved cookstove for social occasions could motivate to maintain social relationships, form new alliances or conform to the established norms in the context.

Status motivations

The observations confirm that cooking with an improved stove is linked to perceptions of a higher living standard. A durable, well-constructed appliance with a brand reputation for quality will take pride in the home, with the user taking great care to maintain it. The observations found four-plate electric ovens in immaculate condition yet not in daily use in three households, with other cooking appliances bearing the brunt of the daily cooking. Furthermore, the importance of the status motive was observed and confirmed by the perceptions of low status associated with the odours emanating from wood and paraffin stoves.

Justice motivations

The use of a justice motivation by regulatory means is ill-advised in a behaviour centred intervention based on observations of the preponderance of illegal electric connections and unsafe paraffin stoves despite regulations and standards in place. However, linking feelings of shame and guilt to the damage of shack fires in a local community caused by dangerous, flame-based practices could provide a different avenue to pursue as a motivational factor in an intervention. The shame of being a poor mother causing the detrimental health effects suffered by particular children could, for instance, be linked to the justice motivation.

Curiosity motivations

Motivations for learning through curiosity could be linked to cooking demonstrations with an improved stove and accentuating the dramatic savings in time and money compared to an unimproved stove. Four households showed keen interest in the images of improved biomass appliances, specifically the Laduma cast-iron stove option. Incorporating income-earning opportunities linked to improved cookstoves could also be attempted. One household member enquired about the cost of an improved biomass oven and its ability to cook food for sale.

Play motivations

The household observations confirm that cooking is drudgery. All household caregivers cook a meal in the least amount of time, constrained by the resources at their disposal. The play motivations could be linked to learning the embodied skills and knowledge required to use an improved flame-based appliance through touchpoints focussing on the playful use of cookstoves in a simulated environment to disrupt the drudgery of cooking. Simulated activities demonstrating the dangers of unimproved paraffin stoves could be integrated without the risks of injury in a controlled setting.

5.4 Behavioural Framework for a Cookstove Dissemination Intervention

This section presents the proposed behavioural framework comprising the critical aspects required to guide the development of an intervention to positively influence the deleterious effects associated with the continued use of unimproved cooking appliances in a South African context. The aspects of the behavioural framework include a summary description of the targeted population identified in Section 5.2. The cross-pattern search results are tabulated in Table 5.2, followed by a discussion of the synthesis of the resulting components. The behavioural goal to guide the intervention is proposed. Included is a summary of the behavioural challenge and an overview of the roles and norms pertaining to the people cooking with flame-based cookstoves. The expected cookstove-related settings are outlined. Suggestions are made for possible motivations in an intervention for adopting improved cookstoves.

5.4.1 Behavioural challenge

The behavioural challenge is confirmed as the continued use of unimproved flame-based cookstoves – paraffin stoves, open fires and imbaulas – despite a large-scale national electrification programme. Cooking with poorly constructed, inefficient and dangerous flame-based cookstoves leads to respiratory illness, shack fires, burn-related injuries and high levels of food insecurity. South African culinary behaviour is mismatched to the available cooking technologies. The evidence for the deleterious health hazards associated with flame-based appliances is confirmed in literature and local observations.

5.4.2 Roles and norms of the targeted population

The roles and norms of the women cooking with flame-based stoves are inextricably linked to the provision, management, and safeguarding of their households. The female caregivers navigate severe constraints and dangers in maintaining their households. The burden of managing the financial and time resources of cooking with the locally available cooking appliances falls primarily on them. A keen interest is shown in saving time or generating an additional income source for the whole family's benefit. The segmentation results (Section 5.2) suggest that the role-players who represent the targeted population using inefficient flame-based cooking stoves are contained in the four lowest *SEM* bands. The role-players have neither financial stability nor employment. The instability requires resilience and the hoarding of resources. Unemployment among the young household members is high. The high levels of youth unemployment are attributed to the low skill levels, with the households in these bands bearing the brunt of drug and gang-related crime. The households are rapidly urbanising, attracted by the perception of income-earning prospects and improved access to institutions and services. Many households still follow traditional roles and norms related to cooking and lament the erosion of traditional family values. They perceive that their traditional norms are disappearing.

Table 5.2:   Cross-pattern search of critical aspects for a behavioural framework BCD intervention

BCD Aspects	Formative Review (Section 4.1)	Segmentation results (Section 5.2)	Observational study results (Section 5.3)
Behavioural Challenge	Widespread use of inefficient paraffin and solid-fuel flame stoves is pivotal to respiratory illness, shack fires, burn-related injuries and high levels of food insecurity.	The use of paraffin stoves, open fires and imbaulas with limited use of electric appliances among SEM1–SEM2. The use of paraffin stoves and imbaula stoves among SEM3–SEM4 households. The segmentation suggests the continued use of unimproved stoves despite the presence of microwave ovens, kettles and small electric ovens.	
Behavioural Setting	Overcrowded settings with poorly designed and manufactured stoves. The role players are female cooks and their children constrained by a lack of material and financial resources. The urban and rural stages (indoors or outdoors) are affected by the affordability and availability of fuel (i.e., fuelwood, paraffin or gas) and durable, affordable improved stoves.	Rural and urban households living in traditional dwellings, informal housing and RDP housing and cooking using paraffin, electricity and biomass. Urban households living in traditional dwellings, informal housing, RDP and small houses. Cooking with electricity and paraffin	Newly urbanised households living in informal dwellings predominantly cooking with flame-based stoves and open fires, and occasionally with a Panda paraffin stove and an electric single hob stove when electricity is available and affordable. Urban households living in improved RDP r self-constructed small houses, cooking with an electric double hotplate or occasionally with firewood or a Panda paraffin stove.

BCD Aspects	Formative Review (Section 4.1)	Segmentation results (Section 5.2)	Observational study results (Section 5.3)
Behavioural Goal			The first behavioural goal is to facilitate the dissemination of an improved biomass stove, similar to Stovetec EcoZoom (SEM1 and SEM2) and a single hob LPG stove (similar to the KayaGAS Combo for SEM2). A second behavioural goal suggests the dissemination of an LPG double hob and cylinder (similar to the KayaGAS offering for SEM3 and SEM4).
Roles and Norms of the Targeted Population	SA culinary norms are influenced by colonisation, racial segregation, and limited industrialisation. Cooking is used to communicate norms and values. Cooking forms identity and gives pleasure and status. Gender determines cookstove-related behaviour. Women prepare meals as wives and mothers and bear the risks. Women choose how to cook. Men choose what meals women should cook. Women work longer on cooking, food processing, fuel collecting and water carrying than men. The work is not remunerated.	S*EM1* and *SEM2* households in rural and urban settings live in informal shacks, "matchbox"/RDP houses and traditional dwellings with communal access to water. The S*EM1* and *SEM2* cooks are adult females dependent on fuelwood and paraffin as a fuel source. *SEM3* and *SEM4* households live physically close to the lower SEMs in small state-built cement brick and self-constructed houses with access to electricity. They predominantly cook with electric hot plates and wood-fueled and paraffin stoves.	The role-players have no financial stability or employment, instilling the need for resilience expressed as hoarding resources. High levels of youth unemployment and low skill levels. Rapid urbanisation is changing roles and norms. Traditional roles and norms related to cooking are still present yet waning.
Motivations	Status motivations, hunger and social affiliation, are frequent. Hoarding is prominent.	The SEM1–4 groups are strongly linked to hunger, comfort and affiliation motivations. Material hoarding is prominent. The general motivational structure reflects an openness to change behaviour.	Hunger, comfort, fear and disgust related to the daily grind of poverty appear critical in cookstove-related motivations. Hoarding, creativity, affiliation and status are noted. Motivations for learning linked to curiosity and play could be included in proposed emo-demos.

5.4.3 Behavioural goal

The behavioural goal for an intervention in a South African context proposed in this section advocates the diffusion of improved flame-based cooking appliances as a catalyst for improvements in the challenges experienced by energy-impoverished households.

The literature review and cooking stove observations indicate a clear difference in the cookstove-related behaviour was found between the impoverished households (i.e., SEM1 and SEM2) and the households beginning to emerge from poverty (i.e., SEM3 and SEM4). A common aspect of the behavioural goal for both groups is the increased use of improved flame-based appliances for households without ready access to firewood, accompanied by a reduction in paraffin stove use.

The behavioural goal for an intervention in a South African context for the two tiers is expected to diverge in the following manner:

- The behavioural goal for the SEM1 and SEM2 segments is to shift flame-based cooking to improved biomass stoves. The literature review and cooking stove observations indicate that the practical experience of cooking with an improved biomass stove could demonstrate advantages for the SEM1 and SEM2 segments that depend on firewood as their fuel source. The improved version of a candidate biomass stove should be modified to include the ability to use larger pieces of wood. The main barrier to adopting improved flame-based cookstoves is the continued use of paraffin stoves (both legal and illegal variants), self-constructed stoves (i.e., imbaulas) and open fireplaces.
- The behavioural goal for the SEM3 to SEM4 segments is to shift from flame-based cooking to an LPG stove. An LPG gas stove provides a cheaper, cleaner, safer and faster cooking experience with indirect but significant health and safety benefits. An improved LPG stove, similar to the stove disseminated by KayaGAS, would be the most effective cooking stove to address the needs of the *SEM3* and *SEM4* segments. The main barriers to the diffusion are cooking sequences employing paraffin stoves and open fireplaces.

5.4.4 Flame-based cookstove-related settings

Two distinct settings emerge for the use of flame-based cookstoves in a South African context:

- The predominant cookstove-related setting of the SEM1 and SEM2 segments comprises traditional dwellings and newly urbanised informal homes constructed of sheet metal and wood. The SEM1 households usually cook on a stage with fuelwood over open fires or self-constructed stoves, and the SEM2 segment, despite the presence of electricity, still concurrently uses paraffin and biomass. The floor in the cooking area is frequently outdoors with uneven earthen floors. When located indoors, settings for cooking are frequently located close to a bed or other combustible materials. Outdoor cooking among SEM1–SEM2 households

accommodate cooking over a traditional fire or imbaula, with the imbaula occasionally moved indoors to provide space heating at night. Windows are often absent, which can be attributed to high crime levels.

- The SEM3 and SEM4 segments are characterised by the use of electricity and the continued use of paraffin and biomass fuels. SEM4 households often use a designated enclosed kitchen with a tiled surface. The setting among SEM3–SEM4 households frequently consists of a cement floor with cement brick walls, with a dedicated cooking area often added as an adjunct as space and resources become available. Kitchen sinks appear among SEM3 households and have become commonplace among SEM4 households. Cooking with fire is frequently shifted to second makeshift outside settings.

5.4.5 Flame-based cookstove-related motivations

The synthesis of the literature review in 4.1.5 and the observational study results in 5.3 provide the following motivations for a proposed cookstove-related intervention tabulated in Table 5.3.

Table 5.3: Individual motivations linked to flame-based cookstoves

Motive	Description of Behavioural Motivation
Hunger	Food is primarily cooked as a source of biophysical sustenance and consumed for energy and strength rather than as a luxury. The precarious income levels are directly linked to the levels of hunger. Intentional exposure to aromas is frequently targeted in triggering hunger for food items sold among impoverished population segments.
Comfort	The comfort derived from a warm and dry space provided by an improved flame-based appliance appears to be a critical motivation linked to paraffin-fuelled appliances or self-constructed imbaula stoves.
Fear	The fear motivation could be linked to the fear of injury to the body from gas and paraffin stove explosions or fires, the threats of death associated with carbon monoxide poisoning or the threats of death to children from paraffin ingestion.
Disgust	Disgust motivations could be linked to the taste of food cooked over paraffin. Disgust is caused by the pungent smell of paraffin or smoke associated with dirty homes and clothes permeated with the odours of smoke and paraffin in South African households.
Nurture	The maternal nurturing motive is linked to the hazards of unimproved flame-based stoves. The motives of caring for and protecting children could be targeted as the women nurture, cook and care for their children predominantly near where the meals are being prepared, due to the cramped living conditions.
Hoard	The precarious levels of poverty lead to hoarding of options related to the many competing household decisions, as observed in the activity of the stacking of multiple cookstove types and fuels as a hedging measure. The effects of resource scarcity are strongly linked to hoarding motivations.
Create	Motivations to create were witnessed in the wide variety of pathways and recipes observed in preparing meals within severe constraints. Motivations to create are often sparked by material, social and economic constraints. The creativity of cooks exhibited through many iterations in the preparation of meals is confirmed in the literature. An example is the adaptations to preparing steamed bread in an urban environment that diverge from its traditional South African origins.

Motive	Description of Behavioural Motivation
Affiliation	Affiliation motivations to build trust and strengthen social cohesion are frequently observed through cooperation by sharing food or cooking together in social settings. The positive motivations gained from cooking together with family and friends can provide the motivation to maintain social relationships, form new alliances or conform to the established norm.
Status	The motivation of status obtained through an improved stove could be linked to the perception of a higher standard of living. A durable, well-constructed appliance with a brand reputation for quality will take pride in the home, with the user taking great care to maintain it. Furthermore, the importance of the status motive is observed and confirmed by the perceptions of low status associated with the odours emanating from poorly constructed wood and paraffin stoves.
Justice	The justice motivation is frequently ill-advisedly targeted using regulatory means. The preponderance of illegal electric connections and unsafe paraffin stoves continues despite regulations and standards.
Curiosity	Motivation for learning through curiosity could be linked to cooking luxurious foods with a novel improved stove, accentuating dramatic savings in time and money compared to an unimproved stove, as cookstove marketing practices in India indicate.
Play	The role of the motivation of play in cooking is well established. The play motive can be linked to learning embodied skills and knowledge in using an improved flame-based appliance in simulated activities, thereby demonstrating the dangers of stoves without the risks of injury.

The spatial and temporal motivations of hunger, comfort, fear and disgust related to the daily grind of poverty are proposed for inclusion in a prospective intervention sequence. The lust drive is excluded as it does not appear relevant as a motivational factor in cookstove use. The summarised observations of motivations categorised by hoarding, creativity, affiliation and status are included. Motivations for learning linked to curiosity and play are included that could act as possible touchpoints in an intervention. Motivations of love and attraction are excluded from further investigation to reduce complexity. The excluded motivations could be harnessed in traditional rural contexts yet not in urban contexts due to the rapid changes observed in gender roles at home and in the workplace in South Africa.

5.5 Intervention Mapping Results

The mapping of the co-creative workshop-based development confirmed by the observations, interviews and card-based choice assessments proposes an intervention around two sequences of baking scones with an improved biomass oven and boiling tea with an LPG stove. The two sequences accommodate a series of motivation-linked touchpoints targeting the selected cookstove-related behavioural goal identified for the targeted population. The results suggest a first sequence demonstrating an improved biomass oven targeting SEM1–SEM2 households. A short second sequence demonstrating an LPG stove has been included to target SEM3–SEM4 households.

A critical result of the co-creative workshop activities facilitated by BREADrev, the local change agency, is the successful incorporation of the motivations proposed by the behavioural framework (Section 5.4.5).

The mapping results propose an intervention that integrates the sequences and touchpoints from the co-creative workshop activities with the proposed communication channels, stage, props and supporting infrastructure for a pilot intervention implementation in South Africa.

5.5.1 Summarised observations of co-created intervention sequences

The workshop-based observations indicate that the employment of a baking sequence with an efficient flame-based biomass oven to disseminate improved flame-based cookstoves provided a flexible narrative structure to accommodate additional cooking sequences. A sequence of boiling water for tea with a single hob LPG device and cylinder to achieve the second behavioural goal of driving the diffusion of LPG-powered appliances was easily integrated.

Improved biomass oven sequences

The sequences of baking with an improved oven were performed during each workshop session. The facilitator initially demonstrated each step of the adapted BREADrev baking sequence, followed by each participant repeating every step. The facilitator took care to inculcate the proposed motivational touchpoints. With each workshop session over the following days, the participants performed the baking sequences with greater autonomy, culminating in baking sequences following recipes they had adapted. All participants were able to operate the oven with ease.

LPG single hob stove sequences

The observations of the LPG stove demonstrations during the lunch sessions noted that three participants appeared impressed with the LPG stove's adjustment switch (*WP1*; *WP2*; *WP4*); however, they seemed uneasy when lighting the stove, wincing each time during the lighting process before using it. *WP3* perceived the LPG stove used during the workshop as convenient but considered dangerous and only safe for outdoor use. *WP3* would consider an LPG stove if she lived in a house with a separate kitchen.

Paraffin stove sequences

The demonstration of lighting an unimproved paraffin stove set for the third workshop session was abandoned due to the device breaking during the lunch session. All participants expressed disinterest in a prospective sequence, including using a paraffin stove. The digital video on a mobile phone demonstrating the destructive force of an overturned paraffin stove prompted expressions of shock by all participants, followed by expressions of disapproval (i.e., "*tsk tsk*" in Xhosa vernacular). *WP2* mentioned a recent conflagration in the study area of Dunoon attributed to a paraffin lamp, prompting the rest of participants to nod in agreement.

5.5.2 Summarised observations of prospective touchpoints

The results of the card-based choice analysis suggest the following two sets of touchpoints matching selected motivations for inclusion in an intervention emerging from the co-creative workshop activities. The paraffin sequence is excluded. The viewing of a paraffin stove conflagration is included as a touchpoint during the LPG sequence. The prospective touchpoints during the two sequences suggest that the first eight motivational touchpoints for the first sequence of baking bread with an improved biomass oven should be followed by five touchpoints for the second sequence focussing on serving tea and snacks with an LPG stove.

Lighting the improved biomass oven (Curiosity)

The first touchpoint proposes demonstrating the ignition of an improved flame-based oven, linked to motivations of curiosity, as depicted in Figure 5.16. The novelty of the biomass oven for all participants was observed during the workshop activities and highlighted in the exit questionnaire. The exposure to lighting the novel improved rocket oven during the workshop activities generated unsolicited positive comments from the workshop participants. *WP1*, *WP2* and *WP5* expressed interest in the chimney and how the oven worked. The comments made included:

> "The oven (is) is nice. It looks professional" (*WP1*-013442).

> "It is big inside. You can bake a lot" (*WP2*-013451).

> "How much is the chimney?" (*WP2*-013521).

> "It looks proper. I was surprised it uses wood" (*WP3*-013473).

> "I have never seen such an oven. It looks solid" (*WP4*-013481).

> "There is no smell." (*WP5*-013467).

> "It is nice and warm" (*WP5*-013477).

> "How is it possible that the fireplace (rocket reactor box) is so small without smoke?" (*WP5*-013541).

During the exit interviews, *WP1*, *WP2*, *WP3* and *WP5* commented on the speed at which the oven attained the heat required for baking. An example was the entrepreneur *WP2*:

> "It works fast. I remember the Dover stove from my mother in Cutwini (growing up). It was nice. But this one is fast and I can do more. Next time I want to cook chicken. If it can cook chicken fast I can use it for my business. Sunflower oil is becoming expensive. Maybe this is better." (*WP2*-013847).

Figure 5.16: Touchpoint of lighting the improved flame-based oven

Warmth of an improved biomass oven (Comfort)

The touchpoint of the warmth emanating from the flame-based oven linked to the comfort motivation is included in the first sequence. All the participants immediately noticed and commented on the warmth emanating from the oven. *WP1*, *WP2*, *WP3* and *WP4* huddled near the oven at the beginning of each session (Figure 5.17). The warmth of the biomass oven was confirmed as a positive experience in the exit interviews by *WP1* and *WP2*:

> "It is so nice and warm. I feel relaxed here" (*WP1*-0143821)

> "I liked the early morning warming up next to oven after the cold outside" (*WP2*-0143865)

The warmth of the flame-based oven prompted *WP2* to mention memories of cast iron wood and coal stoves in the rural Eastern Cape. The warmth of the oven facilitated a relaxed atmosphere between the participants.

Figure 5.17: A workshop participant seeking out the warmth of the improved rocket oven

Aroma from fresh oven-baked goods (Curiosity and hunger)

The aroma of fresh bread is selected as the third touchpoint, which targets curiosity motivations and hunger, as depicted in Figure 5.18. The workshop results confirmed by all participants indicate that the aroma emanating from the baking process could attract curious and hungry audiences. The baking activities attracted the interest of mechanics working in a car repair workshop situated next to the baking workshop. The selection of aroma as a touchpoint is confirmed by the large body of research suggesting that exposure to aromas directs the preferences of food items.

Figure 5.18: Touchpoint of aroma emanating from freshly baked items

Baking luxuries together (Creativity and play)

The touchpoint of baking luxurious items with the improved biomass oven by the participants is included to facilitate motivations for creativity and playfulness. The observations confirm that baking staple foods can become dull. The baking of interesting and tasty snacks during the workshop sessions in the form of pizzas, as depicted in Figure 5.19, sparked creativity and playfulness about the possibilities presented by flame-based ovens. The competitive baking of scones by each participant garnered particular attention. Baking scones in a controlled setting is recommended, as it sparked playfulness without the risk of injury.

Figure 5.19: Baking a pizza with the improved rocket oven

Figure 5.20: Participants competitively baking their own recipes

Ceremonial recognition of baking prowess (Status and affiliation)

The ceremonial recognition of champion bakers and cooks targeting the affiliation and status motive is also recommended for inclusion in the first sequence (Figure 5.21). The friendly competitive baking of their own recipe with the biomass oven by each participant was well received and generated high levels of interest and participation.

Figure 5.21: Touchpoint of the presentation of a certificate recognising the demonstrated baking skills

Sharing baked items (Affiliation)

A touchpoint related to sharing the items baked during an intervention in the local setting is suggested (Figure 5.22). After each workshop session, the participants were encouraged to take home baked items from the workshop activities to share with friends and family. The exit interviews recorded a strong positive response to this activity by all the workshop participants.

Figure 5.22: Packing of loaves baked during the workshop session to take them home to share with family and friends

Demonstrating fuel savings (Hoarding)

A touchpoint demonstrating the fuel savings when using an improved flame-based cookstove is suggested. The recording of recipes by the participants, observed during the workshop sessions as depicted in Figure 5.23, is suggested to form the basis of the facilitator highlighting the savings of using an improved flame-based cookstove compared to alternative energy carriers. The financial savings

received positive responses from the two entrepreneurs (*WP2* and *WP5*) participating in the workshop sessions.

Figure 5.23: Touchpoint of demonstrating savings in money and time when baking with the improved biomass oven

Clean home versus dirty paraffin stove together (Affiliation, disgust and status)

The touchpoint of a clean stove and working environment linked to affiliation motivations has also been selected for use in the first sequence. The soot, smoke and odour of cooking indoors are frequently linked to cooking with flame-based stoves. A clean cooking environment is observed as important among women and could be linked to the motivation of being regarded as a good housekeeper among one's peers (Figure 5.24). It is suggested that a paraffin stove is briefly lit to generate the pungent odour linked to the status motivations and disgust (Figure 5.25). *WP1*, *WP2* and *WP4* confirmed the disgust and low status associated with the pungent odour that impregnated the clothes and homes of the cooks recorded in the literature and observed in the households.

Raging paraffin fire (Fear and disgust)

The touchpoint of experiencing the uncontrolled destructive force of a fire caused by a paraffin stove, linked to fear motivations and disgust, is suggested. The workshop utilised the viewing of a video sourced from the Household Energy Safety Association of Southern Africa (formerly known as PASASA) during the third workshop session, which showed a shack burning down due to an overturned paraffin stove fire for the touchpoint. Viewing the video created a noticeable shock among all the participants regarding the uncontrolled kinetic power of fire (Figure 5.26). In response to the video *WP2*, *WP3* and *WP5* expressed concern about the quality of the paraffin stove. After watching the shack fire video, *WP2* related a recent conflagration she had witnessed, attributed to a paraffin heater. The smell and smoke emanating from paraffin stoves were expressed as a concern by *WP1*, *WP2* ,*WP4* and *WP5*.

Figure 5.26: Touchpoint of the destructive force of an uncontrolled fire caused by an overturned paraffin stove (PASASA, 2010).

Repeatedly lighting an LPG stove with ease (Fear)

A touchpoint that concerns repeatedly lighting an LPG stove is recommended. The touchpoint demonstrating the ease of use, safety and speed at which an LPG stove reaches cooking temperature is linked to challenging the most potent barrier to adopting LPG stoves – the motivation of fear.

The repeated lighting of LPG appliances appears to hold promise for overcoming the automatic response of flinching away from the device. The workshop observations confirmed the fear and automatic flinching response when lighting the LPG stoves for boiling tea during breaks in the workshop sessions (*WP1*, *WP2*, *WP4*). The repeated lighting of the LPG stove by all the participants during the workshop reduced flinching during proceedings (Figure 5.27).

Figure 5.27: Touchpoint of repeatedly lighting an LPG stove

Auto-switch on a shiny stove (Status)

The touchpoint of using a high-quality LPG device linked to the status motivations has also been selected. The demonstration of the auto-switch mechanism on the LPG stove elicited positive responses from all the workshop participants. A visually appealing, locally available, high-quality appliance is suggested, similar to the external LPG stove depicted in Figure 5.28. South Africans associate paraffin stoves with a lower status due to odours permeating clothes and the home. The silver colour and switch of the Alva stove were commented on as similar to that of an electric stove by *WP3* (Figure 5.28).

Figure 5.28: Touchpoint of an automatic ignition switch and temperature control

Warmth of an LPG heater (Comfort)

A touchpoint centred around the warmth emitted by an LPG heater is suggested for the second sequence of the intervention. All the workshop participants were observed seeking out the warmth of the LPG-

powered heater during the outdoor sessions on the cold winter mornings (Figure 5.29 and Figure 5.30). However, the LPG heater was not mentioned during the exit interviews.

Figure 5.29: Participants seeking out the warmth emanating from the LPG heater

Figure 5.30: LPG heater used in the outdoor setting as a proxy for the touchpoint of warmth

Serving snacks and tea (Play and affiliation)

A touchpoint that includes serving snacks and tea prepared during the sequence is recommended. The touchpoint appeared to elicit motivations of play among all the participants as gleaned from the workshop observations and exit interviews. The touchpoints of sharing snacks throughout the workshop activities facilitated the informal exchange of personal pleasantries. They established an open atmosphere conducive to the motivation of play during the workshop activities (Figure 5.32 and Figure 5.32).

Figure 5.31: Touchpoint of serving tea made with an LPG stove

Sharing tea, coffee and cakes during the workshop activities established a setting that facilitated sharing of time, resources, skills and trust between the participants. The sharing of tea and scones, as depicted in Figure 5.33, prompted the participants' unscripted informal sharing of personal experiences and feelings related to cooking and baking.

Figure 5.32: Touchpoint of sharing snacks with tea at the beginning of workshop proceedings

Figure 5.33: Lunch break during the second workshop session accompanied by coffee, tea and fresh rolls

5.5.3   Summarised interview results of co-created intervention sequences

The interview-based assessment of the resulting intervention sequences, as reflected in the evaluation matrix (Table 5.4), indicates that the sequences using improved biomass-powered appliances scored

highest, followed by sequences demonstrating safe use of LPG stoves. The sequence showing the danger of shack fires linked to the paraffin stoves scored lowest.

Table 5.4:   Sequence ranking by desirability, viability and feasibility (n-=-6)

Intervention Sequence Description	Viability	Feasibility	Desirability
Sequences with an improved flame-based oven	●●●	●●●●	●●●●●●
Sequences with LPG stoves	●●●●●	●●●●	●●●
Sequences showing the danger of paraffin stoves	●●●●	●●●●●	●

The assessment of the intervention sequences according to the viability, feasibility and desirability suggest the following. The sequences that demonstrated the improved biomass oven linked strongly to the desires and needs expected of households experiencing high poverty levels and unemployment. The sequences with an improved biomass oven followed by an LPG stove single hob and cylinder (similar to the KayaGAS offering) were ranked as the most desirable option. The feasibility of all the sequences requires locally available improved flame-based appliances. Demonstrating that food cooked with improved cookstoves improves the taste was scored highly in originality and desirability. Teaching how to prevent shack fires was voted low in desirability, despite three participants reasoning that "it is important to know what to do". The feasibility and viability of demonstrating a paraffin sequence were voted as high. This can be attributed to the relative ease of viewing a video of the sequence on a mobile phone.

Improved biomass oven sequences

The exit interviews found that all participants were surprised at the baking speed of the biomass oven and satisfied that the oven was easy to clean. *WP2*, *WP3* and *WP5* commented on its sturdy construction and quality but thought it was too expensive. *WP2* said it reminded her of a Dover stove she had seen in the Eastern Cape hinterland from where she hails. However, *WP1* and *WP3* expressed that chopping the wood into small pieces in the biomass oven (a necessity because of its limited fuel opening) was a chore. A more affordable smaller oven was requested as a prospective improved cookstove category.

The ability to heat the home and bake greatly enhances the desirability of a biomass-powered appliance (*WP1* and *WP3*). However, the high desirability of a sequence with an improved biomass oven can be attributed to the possibility of starting a ready-to-eat business (*WP2* and *WP5*).

The feasibility of an improved flame-based oven was scored the highest. On further enquiry, the participants mentioned that the intervention could "sell bread on the side" (*WP2* and *WP5*). A safe stage is essential as the prospect of the theft of the demonstration equipment was also mentioned (*WP2*, *WP3*).

Two participants stated that the price of the biomass oven is too high (*WP2* and *WP5*), indicating that the purchase price of improved biomass appliances needs to be affordable or available with financial assistance. A smaller, more affordable and portable biomass oven is suggested as a stove category

worthy of further investigation; however, this option was outside the scope of this thesis. The interest in income-earning opportunities and the expense involved in conducting sustained interventions suggest that intervention should incorporate a parallel cooking or baking business to ensure long-term financial viability without donor funding.

LPG single hob stove sequences

According to the observation results, all the workshop participants positively affirmed the inclusion of sequences demonstrating the LPG stove in an intervention. All the participants expressed concerns about the safety of the gas cylinders and were initially wary when using them.

Performing the LPG sequence was rated second highest in desirability. The LPG stove could incorporate additional product elements to make it more desirable to the targeted population (i.e., an auto-ignition switch mechanism). *WP1* and *WP2* considered the baking of unfamiliar luxuries particularly appealing. The baking of pizzas and croissants was mentioned in their responses.

The LPG stove sequence was rated second highest in terms of feasibility. The high feasibility reasons included "I did not know it can switch on without matches", referring to the LPG stove ignition switch demonstrated during the workshop activities. However, according to the participants, current LPG stove options rarely include these options. The possibility of a dual-fuel oven accommodating LPG gas and biomass is suggested for further exploration. The added flexibility of a dual-fuel oven could accommodate more variations of the intervention sequences, providing the ability to respond to changes in local culinary practices, available food ingredients and fuels.

Sequence showing shack fires resulting from paraffin stoves

The workshop participants showed no interest in a sequence demonstrating a paraffin stove as part of an intervention. All the participants expressed shock after demonstrating the destructive force of a paraffin fire facilitated by viewing a video showing a shack engulfed by the fire emanating from an overturned paraffin stove. Performing a paraffin sequence was rated lowest in desirability. Despite the problems with lighting the stove during the workshop sessions, the paraffin stove sequence was rated highest in feasibility and second highest in viability. The reasons given for the high feasibility included that "we can get them at the taxi rank" (*WP2)*, referring to the local availability of the stoves in Dunoon. A sequence could incorporate viewing a paraffin-induced shack fire as a touchpoint linked to the motivations of fear.

5.5.4   Card-based choice analysis results

The card-based analysis of the prospective touchpoint-linked motivations suggests eight touchpoints for the first sequence of baking bread with an improved biomass oven, followed by five touchpoints for the second sequence focusing on serving tea and snacks with an LPG stove, as tabulated in Table 5.5.

Table 5.5:   Card-based mapping of intervention touchpoints (n = 30 choices around each touchpoint selected by the six participants)

Sequences	Touchpoints	Affiliation	Attraction	Comfort	Create	Curiosity	Disgust	Fear	Hoard	Hunger	Lust	Love	Nurture	Play	Status	Justice	No choice
Bread-baking sequence with an improved biomass-powered stove	Lighting of the biomass oven	●		●●	●●	●●●●●●	●	●●●	●●			●	●●●●	●	●●●	●	●
	Warmth from biomass oven			●●●●●●	●	●●	●	●	●●	●●●		●●	●●●	●	●●●	●●	
	Aroma of baking in the biomass oven	●		●●			●	●●●	●●●	●●●●●●	●●		●●●●	●●	●	●●	●
	Baking luxuries together	●●				●	●●●	●●	●		●●	●	●●	●●●●●●	●	●	●●●●
	Ceremonial recognition of oven mastery	●		●	●●●●		●	●●	●●		●	●●	●●	●	●●●●●●	●●●●	●●
	Share baked luxuries	●●●●●●		●	●●		●●●●	●	●	●	●	●●	●●		●	●●●●	●●
	Show fuelwood savings	●●		●		●●	●●●	●●	●●●●●●	●●		●●●	●●		●●	●●	●●
	Clean cooking area	●●		●	●●	●●	●●●		●	●	●		●●		●●●●●●	●●●●	●●●
Sequence boiling tea with a LPG powered appliance	Repeated lighting of an LPG stove	●		●●●		●●●	●●	●●●●●●	●●●	●●	●●	●	●	●	●●	●●	
	Auto-switch on a modern LPG stove			●●		●		●●	●	●●●●●	●●●	●●●		●●●	●●●●●●	●●	
	Warmth of an LPG heater	●●●		●●●●●●		●●		●	●	●●●●	●●	●	●		●●●●●		●●●
	Clean clothes vs dirty paraffin	●●		●●	●●●	●●●●●			●	●●	●	●●	●		●●●●●●	●	●●●
	Viewing a dangerous paraffin fire	●●		●●●	●●●●		●●	●●●●●●	●●	●●	●●●			●	●●	●	●

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Lighting the improved biomass oven (Curiosity)

The lighting of the flame-based biomass oven was primarily linked to the *curiosity* motivation by the participants (6 choices), followed by the *nurture* motivation (4 choices).

Warmth of an improved biomass oven (Comfort)

The warmth of the flame-based biomass oven primarily chose *comfort* motivation (6 choices), followed by the *hunger*, *nurture* and *status* motivations (3 choices each).

Aroma from fresh oven-baked goods (Curiosity and hunger)

The aroma of bread baking in the biomass oven primarily chose *hunger* motivation (6 choices) followed by the *nurture* motivation (4 choices).

Baking luxuries together (Creativity and play)

Baking luxuries together was primarily linked to the *play* motivation (6 choices), with no second choices tendered on four occasions.

Ceremonial recognition of baking prowess (Status and affiliation)

The ceremonial recognition of baking skills primarily chose *status* motivation (6 choices) and joint secondarily *create* and *justice* motivations (4 choices each).

Sharing baked items (Affiliation)

Share baked luxuries with the immediate community primarily chose *affiliation* motivation (6 choices) and joint secondarily *disgust* and *justice* motivations (4 choices).

Demonstrating fuel savings (Hoarding)

Showing fuelwood savings was linked six times to status motivations, followed by *create* and *justice* motivations on three occasions.

Clean home versus dirty paraffin stove together (Affiliation, disgust and status)

Clean clothes and dirty paraffin stoves primarily chose *status* motivation (6 choices) and joint secondarily *curiosity* motivations (5 choices).

Raging paraffin fire (Fear and disgust)

Viewing a video of an uncontrolled paraffin stove conflagration was primarily linked to *fear* (6 choices), followed by *create* motivations (4 choices).

Repeatedly lighting an LPG stove with ease (Fear)

Repeated lighting of an LPG stove primarily chose the *fear* motivation (6 choices) followed by the *comfort*, *curiosity* and *hoard* motivations (3 choices each).

Auto-switch on a shiny stove (Status)

Auto-switch on a shiny stove primarily chose *status* motivation (6 choices) and secondarily *hunger* motivations (5 choices).

Warmth of an LPG heater (Comfort)

The warmth of the LPG heater primarily chose *comfort* motivation (6 choices), followed by the *status* motivations (5 choices).

Serving snacks and tea (Play and Affiliation)

The clean cooking area primarily chose *status* motivation (6 choices) and *justice* motivation (4 choices).

5.5.5 Intervention mapping results

The final intervention mapping for a future South African implementation presents a concept that blends selected intervention elements around the sequences and touchpoints confirmed by the workshop-based observations and interviews, as illustrated in Figure 5.34. The intervention elements include the proposed communication channels, the stage and the required props and infrastructure to facilitate the performance of the two selected baking and cooking sequences guided by the selected touchpoints. The intervention mapping incorporates the critical elements of the behavioural framework (i.e., the targeted population, the behavioural goal and motivations).

Figure 5.34: Pilot intervention map for the dissemination of improved flame-based cookstoves in South Africa

Intervention concept

The intervention concept developed by BREADrev during the workshop preparations advocates the emotional demonstration of amended bread-baking sequences and touchpoints pertinent to the selected flame-based cookstove-related motivations of the targeted population. The observed application suggests that an adapted community bread-baking intervention, similar to the BREADrev initiatives, could trigger the revaluation of specific cookstove-related motivations linked to the dissemination of improved flame-based appliances by female caregivers and cooks.

The intervention concept includes a branded identity named after an *igoqo*, drawing on the traditional Nguni practice of women displaying stacked firewood. The visual identity incorporates a female archetype based on the symbolic displays of firewood in the proximity of their households, signifying the respect and dignity for women observed in rural and urban settings, as depicted in Figure 5.35.

Figure 5.35: *Igoqo* **branded visual identity**

Intervention sequences

The proposed sequences of the intervention are suggested to facilitate participants in preparing a dish following existing local recipes as suggested by the KCJ and BREADrev case studies (Section 2.2). It is recommended that the selected sequences are limited by the length of the preparation required for a selected dish, not exceeding two hours in length. The two sequences are conceptualised to be performed together either in sequence or parallel. Each sequence can be performed independently, depending on the affordability and availability of resources. The sequences performed with existing locally available flame-based appliances should be given preference.

- The first sequence is intended to trigger the increased diffusion of improved biomass stoves (similar to the Stovetec EcoZoom) among South Africans living in the SEM1 and SEM2 categories. It proposes an amended baking demonstration, centred around an improved biomass oven, performed in a local physical setting and supported by trained change agents drawn from the local community.

- The second sequence is intended to trigger the increased diffusion of LPG double hob stoves (similar to the KayaGAS offering) among South Africans living in the SEM3 and SEM4

categories through the demonstration of serving snacks and tea prepared with an LPG stove in a local setting by trained change agents.

Intervention touchpoints

The intervention touchpoints for the first sequence of baking bread with an improved biomass oven and the second sequence of serving tea with an LPG stove comprised the following steps, as depicted in Figure 5.34. The touchpoints in the first sequence consist of:

- Showing the lighting of the novel improved biomass oven to instil the motivation of curiosity.
- Exposing beneficiaries to the warmth of an improved biomass oven linked to the comfort usually provided by imbaula stoves.
- Spreading the appealing aroma of fresh-baked scones emerging from the improved biomass oven to spark hunger motivations.
- Baking a variety of local scone recipes together during the first biomass sequence triggers the motivation for playful learning.
- Showing the fuel savings associated with the improved biomass oven to revalue motivations related to hoarding household resources.
- Accentuating a clean cooking stage where clothes remain smoke- and odour-free during the biomass sequence targeting status motivations.
- Sharing scones triggers motivations for affiliation associated with cooking together in shared settings.

The intervention touchpoints included in the second sequence are:

- Lighting an LPG stove repeatedly to reduce the fear associated with LPG appliances.
- Demonstrating an auto-ignition switch on a high-quality LPG stove during the LPG sequence to target status motivations.
- Releasing a briefly lit paraffin stove's pungent smell to spark disgust.
- Exhibiting the warmth emanating from an LPG heater linked to the comfort usually provided by paraffin heaters.
- Viewing an uncontrolled paraffin conflagration triggers the motivation of fear linked to paraffin appliances.
- Serving tea and scones with the participating beneficiaries and facilitating light-hearted banter while preparing the tea together during the LPG sequence ensures a safe and relaxed atmosphere to facilitate the affiliation motivation.

Communication channels

It is suggested that the set of communication channels for intervention include the analogue emotional demonstration of cooking with improved flame-based cookstoves as the main channel, as suggested by the successful cases reviewed in Section 2.2.1 and confirmed by the workshop-based results. Accordingly, the analogue emotional demonstration of cooking with an improved biomass oven complemented by a second sequence with an LPG single hob stove is selected as the primary communication channel. This emotional demonstration is supplemented by a printed baking guide illustrating the critical steps in the two sequences to reinforce the motivational touchpoints during the intervention sequences. In addition, the intervention proposes the inclusion of digital media of a fire safety video showing the destructive force of a shack fire caused by a paraffin stove presented on a mobile device.

Intervention stage

The intervention stage must represent the behavioural settings familiar to the targeted population. A stage similar in size to the converted 20-foot container employed in the KayaGAS and BREADrev interventions is recommended. The stage must be large enough to accommodate the comfortable attendance of a small group of participants in close physical proximity to the local community. The stage must accommodate the expected cooking appliances and support the available infrastructure in a representative South African setting. The intervention must provide the targeted population with a safe, attractive and accessible physical stage enabling predictable and repeated exposure to the selected touchpoints during the sequences. The inclusion of security features (security gates and locks) has been identified as a critical feature to provide the participants with the ability to control access to the stage to instil a sense of security and personal security.

Intervention props and supporting infrastructure

The essential props and infrastructure for an improved cookstove dissemination intervention that can directly prevent or support the achievement of the behavioural goal should include an improved flame-based biomass oven and an LPG-powered appliance to perform the two intervention sequences. In addition, the availability of water and the specific cooking fuels and ingredients for the intervention must be ensured. Flexibility in flame-based appliances is advised for each implementation, guided by locally available and affordable resources. The props are suggested to resemble aspirational brands of modern improved cooking appliances.

It is suggested that the improved flame-based oven for the first intervention sequence is similar in design to the improved oven employed by BREADrev for the pilot implementation. The improved flame-based oven design is credited with an estimated 80% fuel savings and 40% reductions in harmful emissions compared to traditional wood-fuelled ovens. The gains in efficiency are attributable to the fuel-efficient

ceramic-lined combustion chamber. The second intervention sequence recommends an LPG single hob stove and cylinder.

A well-designed support infrastructure ensuring the availability of water, specific cooking fuels and culinary ingredients is necessary for the reliable facilitation of positive interactions during the intervention sequences. The support infrastructure includes equipping the intervention facilitators with the human capabilities and skillsets essential for the reliable and accurate emotional demonstration of the selected sequence around the selected motivational touchpoints appropriate for the targeted population. The relative complexity of the intervention sequences and touchpoints requires a practical mastery of cooking with selected flame-based appliances. Reliable and accurate emotional demonstrations of cooking and baking with improved flame-based appliances will engender trust among the targeted population in the facilitating team. The team is required to read the emotions and ethically stimulate the participants' responses to enable the specific behavioural response. Consequently, a prerequisite will be selecting a local facilitating team familiar with the setting's norms, habits, and languages.

5.6   Pilot Implementation Results

This section presents the results of the abridged BCD intervention in Dunoon and Mamelodi. The results of the SP survey indicate that the selected touchpoints achieved significant success in revaluating the selected cookstove-related motivations of the sampled households. A key result observed was the reduction of fear when using LPG-powered appliances after interventions in both study areas. A shift in cookstove-related ownership patterns was confirmed in a representative sample of the targeted population segment, meeting the behavioural goal articulated in the behavioural framework. However, although the results record an increase in the diffusion of LPG stoves and a reduction in paraffin stove ownership levels, no significant diffusion of improved biomass stoves has been recorded.

5.6.1   Targeted population representivity

The household survey results confirm that the respondents in all the sample areas represented the designated targeted population. The baseline results for each of the two sample areas were demographically similar regarding the living standard levels outlined by the *SEM* reported in Section 5.2 (Table 5.6). Despite the geographic and cultural distance between the two study areas, the criteria remained stable from baseline to endline for the indicators of the socio-economic groupings. The results confirm high fuel stacking levels despite electricity access (Table 5.6).

Table 5.6:   **Representivity of targeted population by selected *SEM* criteria**

SEM Representivity *Criteria*		SEM 1 & 2 %	SEM 3 & 4 %	Mamelodi Control		Dunoon Control		Mamelodi Post-Intervention		Dunoon Post-Intervention	
				n-=-99	%	n-=-99	%	n-=-99	%	n-=-97	%
Material indicators	Sealed floor	19	49	52	53%	22	22%	49	49%	34	35%
	No hot water	99	80	66	67%	69	70%	45	45%	71	73%
	No kitchen sink	98	68	64	65%	88	89%	67	68%	91	94%
	No flushing toilet	98	73	66	67%	83	84%	72	73%	86	89%
	Smartphone	27	41	52	53%	32	32%	41	41%	28	29%
	Microwave	20	76	56	57%	34	34%	76	77%	20	21%
Media channel access	WhatsApp	38	50	66	67%	57	58%	50	51%	37	38%
	Facebook	28	38	35	35%	32	32%	38	38%	28	29%
Cookstove ownership patterns	LPG stove	7	9	9	9%	9	9%	16	16%	8	8%
	Biomass stove	48	28	79	80%	66	67%	58	59%	64	66%
	Paraffin stove	41	39	38	38%	47	47%	37	37%	34	35%
	Electric stove	65	66	74	75%	71	72%	73	74%	72	74%
	Other	8	8	4	4%	10	10%	11	11%	5	5%
Fuel & stove stacking	Single stove	35	48	15	15%	15	15%	28	29%	12	12%
	Multiple stoves	65	52	84	85%	84	85%	69	71%	87	88%

Key material indicators

In Dunoon, between 22% and 35% of households had sealed floors, and in Mamelodi, between 49% and 53% (Table 5.6).

Media channel access

In Dunoon, access to the WhatsApp social media platforms ranged between 58% and 38%, and in Mamelodi, between 67% and 51%. Facebook access in Dunoon ranged between 32% and 29%, while in Mamelodi, it ranged between 35% and 38% (Table 5.6).

Cookstove ownership patterns

In Mamelodi, between 9% and 16% of households own an LPG stove. Between 80% and 59% of Mamelodi households own a biomass stove, while 38% and 37% own a paraffin stove. 75% and 74% of households own an electric stove (Table 5.6).

In Dunoon, between 9% and 8% of households own an LPG stove. Between 67% and 66% of Dunoon households own a biomass stove, while 47% and 35% own a paraffin stove. Ownership of an electric stove in Dunoon varies between 72% and 74% (Table 5.6).

Fuel and stove stacking

The stacking of stove and fuel types is confirmed in both areas. In the Mamelodi sample, between 85% and 71% of households own multiple stove types, while in the Dunoon sample, between 85% and 88% of households own multiple stove types (Table 5.6).

5.6.2   Intervention exposure levels

The intervention achieved varying levels of exposure for the actively participating respondents, the respondents who saw the intervention taking place and the respondents who had heard about the intervention, as shown in the breakdown provided in Table 5.7. Overall the Dunoon achieved a higher level of exposure despite a smaller group of people participating in the intervention than Mamelodi. The exposure by word of mouth (i.e., hearing about the intervention) was higher for the Dunoon intervention than for the Mamelodi intervention (Table 5.7).

Table 5.7:   Reach of the pilot implementation for the two study samples

Reach of intervention exposure	Mamelodi Post-Intervention (N = 99)		Dunoon Post-Intervention (N = 97)	
	count	%	count	%
Reported no exposure to the intervention	63	64	49	51
Reported exposure to the intervention	36	36	48	49
Participated in the intervention	6	6	4	4
Saw the intervention	10	10	12	12
Heard about the intervention	20	20	32	33

49% of Dunoon respondents reported being exposed to the intervention compared to 36% in Mamelodi. Of the Dunoon respondents, 4% stated that they had actively participated, compared to 6% of respondents in Mamelodi. In Dunoon, 12% saw the intervention activities take place compared to 10% in Mamelodi. An estimated 33% had heard about the intervention in Dunoon compared to 21% in Mamelodi (Table 5.7).

5.6.3   Changes in targeted motivations linked to improved flame-based cookstoves

The difference-in-difference (DID) statistical analysis results (Table 5.8) indicate significant changes in targeted cookstove-related motivations between households surveyed in the control and post-intervention sample at baseline (i.e., not exposed to the intervention) and endline (i.e., exposed to the intervention).

Household control and post-intervention samples at the endline indicate that the fear motivations associated with LPG stoves were significantly reduced. A significant decrease in fear motivations was

associated with LPG stoves in Mamelodi, while a modest decrease was reported after the Dunoon intervention (Table 5.8).

The results indicate increased fear motivations associated with paraffin stoves in both study areas (Table 5.8). Disgust increased in Dunoon while hoarding and hunger motivations decreased. Motivations associated with status showed a slight increase in Mamelodi (Table 5.8). Disgust showed a slight decrease in Dunoon (Table 5.8). Conversely, hoarding motivations increased when associated with the LPG option (Table 5.8).

No significant change in motivations associated with biomass stoves was reported in Mamelodi, while the motivations linked to comfort, curiosity and play increased after the Dunoon intervention. A significant decrease in motivations linked to disgust and a moderate decrease in fear motivations were observed for Dunoon (Table 5.8). Motivations associated with status showed a slight increase linked to biomass stoves (Table 5.8).

Table 5.8: Changes in cookstove-related motivations for the two sample areas from baseline to endline (direct comparison of differences-in-differences)

Sample Area	Stove Motivations		Baseline			Endline Unexposed				Baseline			Endline Exposed				Effect size (difference in differences)			
	Type	Motive.	n = 99	%	SD	n = 64	%	SD	P-value	n = 99	%	SD	n = 35	%	SD	P-value	% exp.	% unexp.	% DID	P-value
Mamelodi	LPG	Affiliation	35	35.4	0.5	20	31.3	0.5	0.211	35	35.4	0.5	27	77.1	0.4	<0.001	41.8	-4.1	45.9	0.007
		Comfort	85	85.9	0.7	39	60.9	0.8	0.607	85	85.9	0.7	31	88.6	0.6	0.678	2.7	-24.9	27.6	0.686
		Fear	78	78.8	0.8	37	57.8	0.8	0.759	78	78.8	0.8	5	14.3	0.7	<0.001	-64.5	-21.0	-43.5	0.003
		Status	60	60.6	1	35	54.7	0.9	0.318	60	60.6	1	31	88.6	0.6	<0.001	28.0	-5.9	33.9	0.009
	Biomass	Affiliation	12	12.1	0.7	9	14.1	0.7	0.828	12	12.1	0.7	18	51.4	1	<0.001	39.3	1.9	37.4	0.005
		Comfort	39	39.4	1	28	43.8	1	0.612	39	39.4	1	25	71.4	0.9	0.001	32.0	4.4	27.7	0.004
		Create	24	24.2	0.9	4	6.3	0.9	0.849	24	24.2	0.9	5	14.3	0.7	0.162	-10.0	-18.0	8.0	0.162
		Curiosity	81	81.8	0.8	41	64.1	0.9	0.22	81	81.8	0.8	28	80.0	0.8	0.819	-1.8.0	-17.8	15.9	0.827
		Hoarding	59	59.6	1	30	46.9	1	0.54	59	59.6	1	31	88.6	0.6	<0.001	29.0	-12.7	41.7	0.006
		Hunger	90	90.9	0.3	5	7.8	0.3	0.503	90	90.9	0.3	31	88.6	0.3	0.707	-2.3	-83.1	80.8	0.716
		Play	55	55.6	1	26	40.6	1	0.283	55	55.6	1	22	62.9	1	0.454	7.3	-14.9	22.2	0.462
		Status	68	68.7	0.9	19	29.7	0.9	0.843	68	68.7	0.9	29	82.9	0.7	0.045	14.2	-39.0	53.2	0.052
	Paraffin	Disgust	68	68.7	0.5	36	56.3	0.4	0.515	68	68.7	0.5	33	94.3	0.2	<0.001	25.6	-12.4	38.0	0.001
		Fear	84	84.9	0.4	45	70.3	0.4	0.557	84	84.9	0.4	30	85.7	0.4	0.902	0.9	-14.5	15.4	0.911
Dunoon	LPG	Affiliation	47	47.5	0.5	20	37.7	0.5	0.249	47	47.5	0.5	38	86.4	0.3	<0.001	38.9	-9.7	48.6	0.008
		Comfort	78	78.8	0.8	39	73.6	0.9	0.559	78	78.8	0.8	37	84.1	0.7	0.447	5.3	-5.2	10.5	0.449
		Fear	85	85.9	0.7	37	69.8	0.9	0.038	85	85.9	0.7	17	38.6	1	<0.001	-47.2	-16.1	-31.2	0.008
		Status	47	47.5	1	35	66.0	0.9	0.022	47	47.5	1	36	81.8	0.7	<0.001	34.3	18.6	15.8	0.004
	Biomass	Affiliation	19	19.2	0.8	9	17.0	0.8	0.737	19	19.2	0.8	20	45.5	1	0.003	26.3	-2.2	28.5	0.006
		Comfort	41	41.4	1	28	52.8	1	0.147	41	41.4	1	25	56.8	1	0.092	15.4	11.4	4.0	0.098
		Create	11	11.1	0.6	4	7.6	0.6	0.736	11	11.1	0.6	8	18.2	0.8	0.294	7.1	-3.6	10.6	0.301
		Curiosity	72	72.7	0.9	41	77.4	0.8	0.441	72	72.7	0.9	34	77.3	0.8	0.562	4.6	4.6	-0.1	0.564
		Hoarding	49	49.5	1	30	56.6	1	0.44	49	49.5	1	40	90.9	0.6	<0.001	41.4	7.1	34.3	0.003
		Hunger	11	11.1	0.3	5	9.4	0.3	0.745	11	11.1	0.3	6	13.6	0.3	0.681	2.5	-1.7	4.2	0.684
		Play	42	42.4	1	26	49.1	1	0.439	42	42.4	1	31	70.5	0.9	0.002	28.0	6.6	21.4	0.003
		Status	56	56.6	1	19	35.9	1	0.012	56	56.6	1	23	52.3	1	0.686	-4.3	-20.7	16.4	0.694
		Disgust	75	75.8	0.4	36	67.9	0.5	0.317	75	75.8	0.4	42	95.5	0.2	<0.001	19.7	-7.8	27.5	0.005
	Paraffin	Disgust	75	75.8	0.4	36	67.9	0.5	0.317	75	75.8	0.4	42	95.5	0.2	<0.001	19.7	-7.8	27.5	0.005
		Fear	78	78.8	0.4	45	84.9	0.4	0.345	78	78.8	0.4	43	97.7	0.2	<0.001	18.9	6.1	12.8	0.005

Changes in motivations of affiliation linked to LPG stoves

Changes to motivations of affiliation linked to LPG stoves showed a significant difference between baseline and endline in both sample areas, as depicted in Figure 5.36. Motivations of affiliation linked to LPG stoves decreased by 4.1% between control and post-intervention at baseline for Mamelodi. Motivations of affiliation linked to LPG stoves increased by 41.8% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased affiliation motivations by 45.9% (P = 0.007) for Mamelodi.
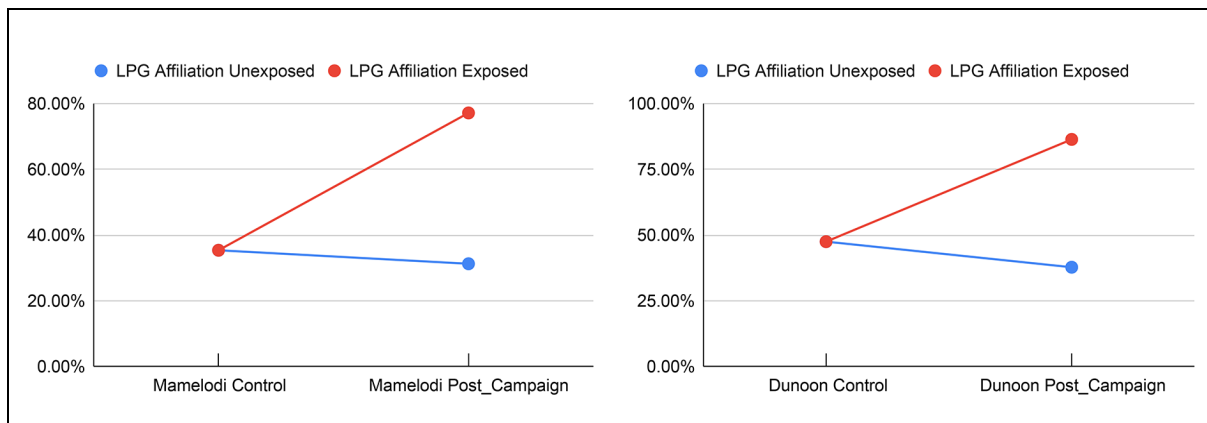
Figure 5.36: Changes in affiliation motivations linked to LPG stoves in Mamelodi and Dunoon samples at baseline and endline

Motivations of affiliation linked to LPG stoves decreased by 9.7% between control and post-intervention at baseline for Dunoon. Motivations of affiliation linked to LPG stoves increased by 38.9% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased affiliation motivations by 48.6% (P = 0.008) for Dunoon.

Changes in comfort motivations linked to LPG stoves

Changes in comfort motivations linked to LPG stoves decreased less in Mamelodi than in Dunoon (Figure 5.37). Comfort motivations linked to LPG stoves decreased by 24.9% between control and post-intervention for Mamelodi at baseline. Comfort motivations linked to LPG stoves increased by 2.7% between control and post-intervention for Mamelodi at the endline. After adjusting for the baseline prevalence, the intervention increased comfort motivations by 27.6% (P = 0.697) for Mamelodi.

Figure 5.37: Changes in comfort motivations linked to LPG cookstoves in Mamelodi and Dunoon samples at baseline and endline

Comfort motivations linked to LPG stoves decreased by 5.2% between control and post-intervention at baseline for Dunoon. Comfort motivations linked to LPG stoves increased by 5.3% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased Comfort motivations by 10.5% (P = 0.449) for Dunoon.

Changes in fear motivations linked to LPG stoves

Fear motivations linked to LPG stoves showed a significant decline in both sample areas after exposure to the post-intervention (Figure 5.38). Fear motivations linked to LPG stoves decreased by 20.9% between control and post-intervention at baseline for Mamelodi. Fear motivations linked to LPG stoves decreased by 64.5% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention decreased fear motivations by 43.5% (P = 0.003) for Mamelodi.

Figure 5.38: Changes in fear motivations linked to LPG cookstoves in Mamelodi and Dunoon samples at baseline and endline

Fear motivations linked to LPG stoves decreased by 16.1% between control and post-intervention at baseline for Dunoon. Fear motivations linked to LPG stoves decreased by 47.2% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention decreased fear motivations by 31.2% (P = 0.008) for Dunoon.

Changes in status motivations linked to LPG stoves

 Status motivations increased significantly in both sample areas (Figure 5.39). Status motivations linked to LPG stoves decreased by 5.9% between control and post-intervention at baseline for Mamelodi. Status motivations linked to LPG stoves increased by 28.0% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased status motivations by 33.9% (P = 0.009) for Mamelodi.

Figure 5.39: Changes in status motivations linked to LPG cookstoves in Mamelodi and Dunoon samples at baseline and endline

 Status motivations linked to LPG stoves increased by 18.6% between control and post-intervention at baseline for Dunoon. Status motivations linked to LPG stoves increased by 34.4% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased status motivations by 15.8% (P = 0.004) for Dunoon.

Changes in affiliation motivations linked to biomass stoves

Affiliation motivations linked to improved biomass stoves increased significantly in both sample areas after exposure to the intervention (Figure 5.40). Motivations of affiliation linked to biomass stoves increased by 2.0% between control and post-intervention at baseline for Mamelodi. Affiliation motivations linked to biomass stoves increased by 39.3% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased affiliation motivations by 37.4% (P = 0.005) for Mamelodi.

Motivations of affiliation linked to biomass stoves decreased by 2.2% between control and post-intervention at baseline for Dunoon. Motivations of affiliation linked to biomass stoves increased by 26.7% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased affiliation by 28.5% (P = 0.005) for Dunoon.

Figure 5.40: Changes in affiliation motivations linked to biomass cookstoves in Mamelodi and Dunoon samples at baseline and endline

Changes in comfort motivations linked to biomass stoves

Comfort motivations linked to improved biomass stoves achieved a significant increase in Mamelodi. The Dunoon sample area showed a limited increase (Figure 5.41). Comfort motivations linked to biomass stoves increased by 4.7% between control and post-intervention at baseline for Mamelodi. Comfort motivations linked to biomass stoves increased by 32.0% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased comfort motivations by 27.7% (P = 0.004) for Mamelodi.
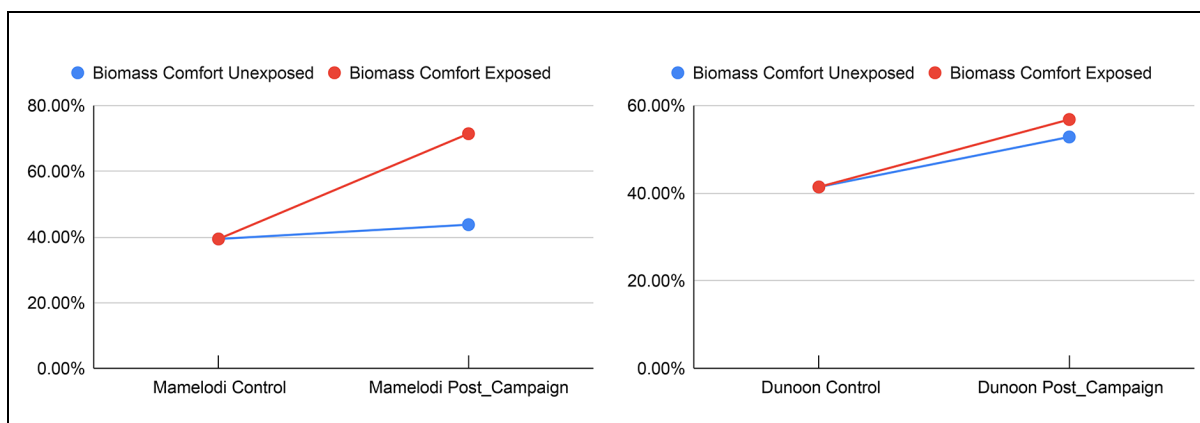
Figure 5.41: Changes in comfort motivations linked to biomass cookstoves in Mamelodi and Dunoon samples at baseline and endline

Comfort motivations linked to biomass stoves increased by 11.4% between control and post-intervention at baseline for Dunoon. Comfort motivations linked to biomass stoves increased by 15.4% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased Dunoon's comfort motivations by 4.0% (P = 0.098).

Changes in motivations to create linked to biomass stoves

Motivations to create linked to biomass stove showed a decline for the endline sample, albeit lower than for the control group. The Dunoon sample area showed a significant increase in motivations to create (Figure 5.42). Motivations to create linked to biomass stoves decreased by 18.0% between control and post-intervention at baseline for Mamelodi. Motivations to create linked to biomass stoves decreased by 10.0% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased motivations to create by 8.0% (P = 0.162) for Mamelodi.

Figure 5.42: Changes in creating motivations linked to biomass cookstoves in Mamelodi and Dunoon Samples at baseline and endline

Motivations to create linked to biomass stoves decreased by 3.6% between control and post-intervention at baseline for Dunoon. Motivations to create linked to biomass stoves increased by 7.1% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased motivations to create by 10.6% (P = 0.301) for Dunoon.

Changes in curiosity motivations linked to biomass stoves

Curiosity motivations showed an unreliable result for Mamelodi. While increasing curiosity levels were reported, Dunoon, exposed to the intervention, showed no change compared to the control sample (Figure 5.43). Curiosity motivations linked to biomass stoves decreased by 17.8% between control and post-intervention at baseline for Mamelodi. Curiosity motivations linked to biomass stoves decreased by 1.8% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased motivations for curiosity by 16.0% (P = 0.827) for Mamelodi.

Curiosity motivations linked to biomass stoves increased by 4.6% between control and post-intervention at baseline for Dunoon. Curiosity motivations linked to biomass stoves increased by 4.6% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention decreased curiosity motivations by 0.1% (P = 0.564) for Dunoon.

Figure 5.43: Changes in curiosity motivations linked to biomass cookstoves in Mamelodi and Dunoon samples at baseline and endline

Changes in hoarding motivations linked to biomass stoves

Hoarding motivations linked to biomass stoves showed significant increases for both sample areas in response to the interventions (Figure 5.44). Hoarding motivations linked to biomass stoves decreased by 12.7% between control and post-intervention at baseline for Mamelodi. Hoarding motivations linked to biomass stoves increased by 29.0% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased hoarding motivations by 41.7% (P = 0.006) for Mamelodi.
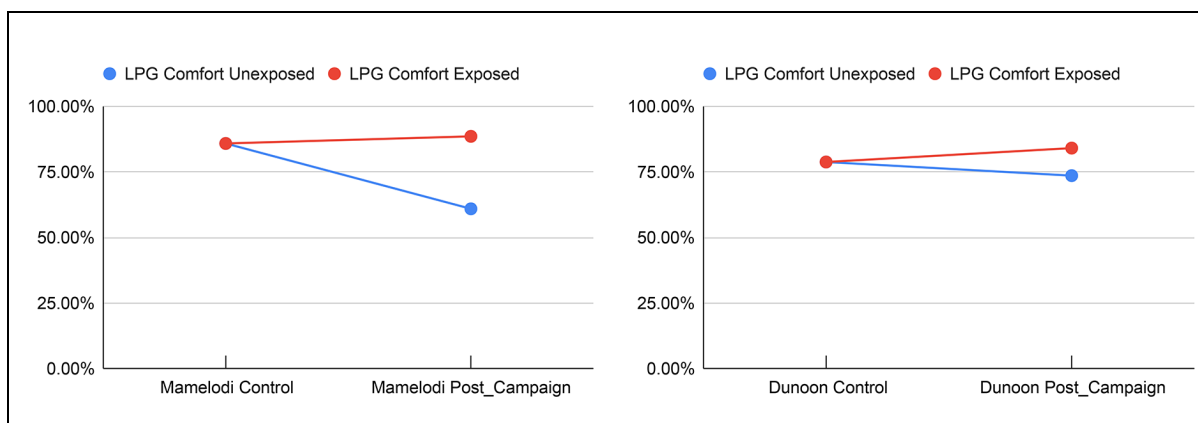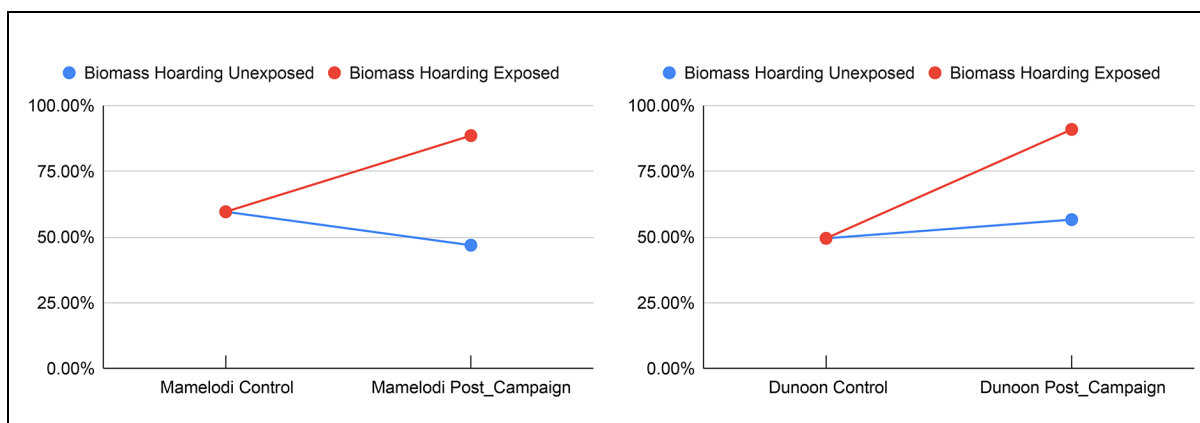

Figure 5.44: Changes in hoarding motivations linked to biomass cookstoves in Mamelodi and Dunoon samples at baseline and endline

Hoarding motivations linked to biomass stoves increased by 7.1% between control and post-intervention at baseline for Dunoon. Hoarding motivations linked to biomass stoves increased by 41.4% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased hoarding motivations by 34.3% (P = 0.003) for Dunoon.

Changes in motivations of hunger linked to biomass stoves

While hunger motivations linked to improved biomass stoves increased in response to the interventions, the results were insignificant Figure 5.45. Motivations of hunger linked to biomass stoves decreased by 83.1% between control and post-intervention at baseline for Mamelodi. Motivations of hunger linked to biomass stoves decreased by 2.3% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased motivations of hunger by 80.8% (P = 0.72) for Mamelodi.
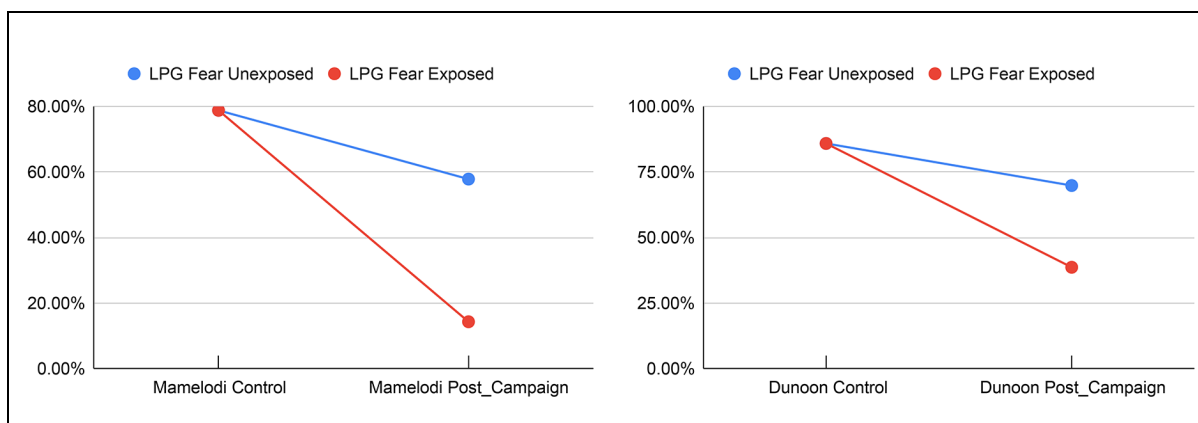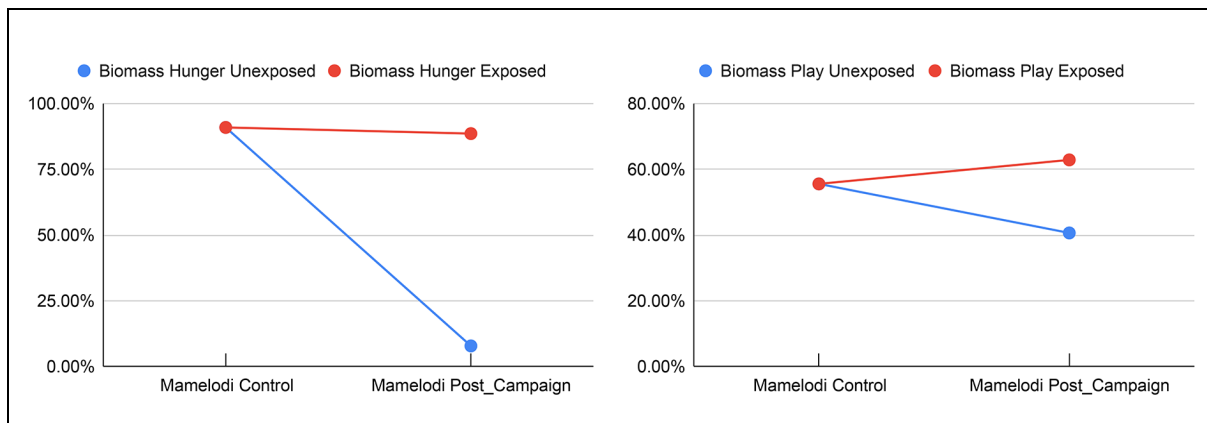

Figure 5.45: Changes in hunger motivations linked to biomass cookstoves in Mamelodi and Dunoon samples at baseline and endline

Hunger motivations linked to biomass stoves decreased by 1.7% between control and post-intervention at baseline for Dunoon. Hunger motivations linked to biomass stoves increased by 2.5% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased motivations of hunger by 4.2% (P = 0.684) for Dunoon.

Changes in play motivations linked to biomass stoves

While the changes in play motivations in Mamelodi showed a slight increase, the Dunoon implementation showed a significant change (Figure 5.46). Play motivations linked to biomass stoves decreased by 15.0% between control and post-intervention at baseline for Mamelodi. Play motivations linked to biomass stoves increased by 7.3% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased play motivations by 22.2% (P = 0.462) for Mamelodi.
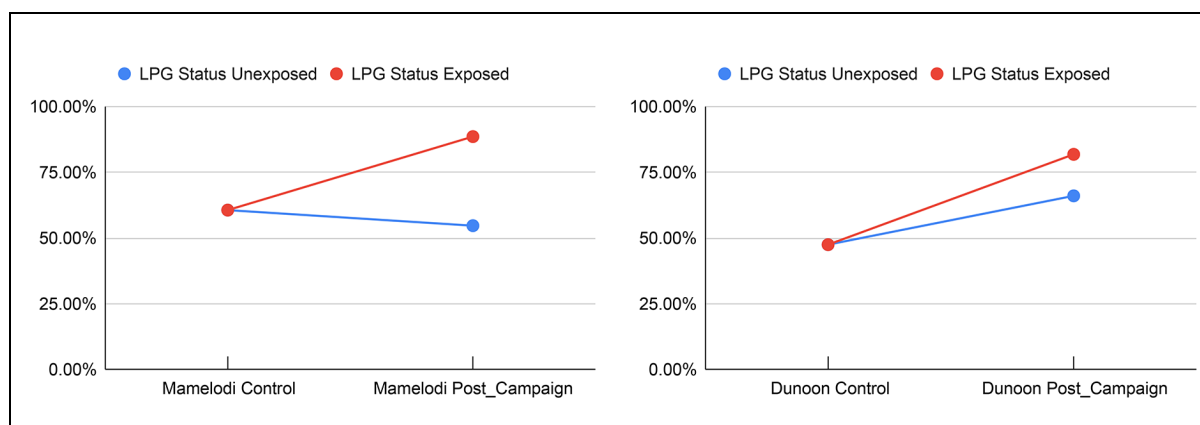
Motivations of play linked to biomass stoves increased by 6.6% between control and post-intervention at baseline for Dunoon. Motivations of play linked to biomass stoves increased by 28.0% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased play motivations by 21.4% (P = 0.003) for Dunoon.
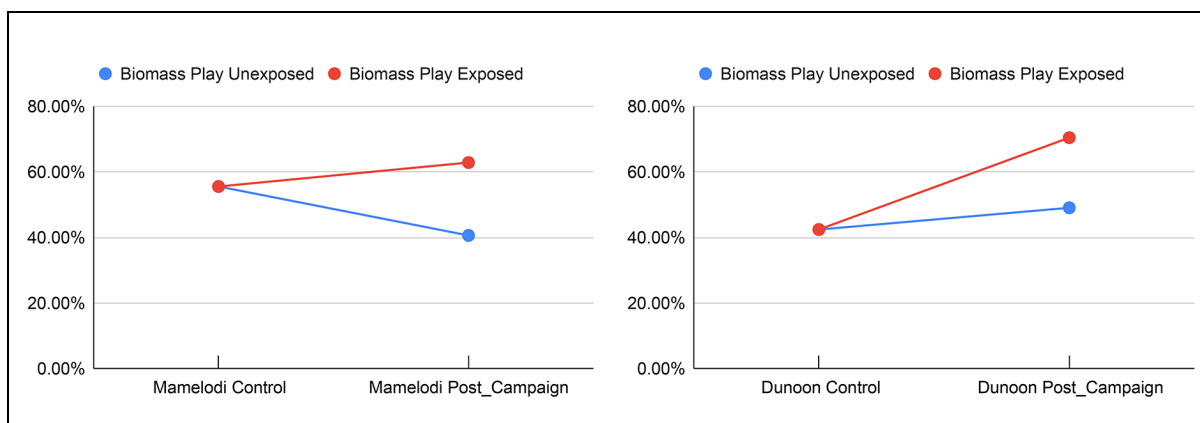
Figure 5.46: Changes in play motivations linked to biomass cookstoves in Mamelodi and Dunoon samples at baseline and endline

Changes in motivations of status linked to biomass stoves

Status motivations linked to paraffin stoves showed a marked change for biomass stoves in both sample areas (Figure 5.47). Status motivations linked to biomass stoves decreased by 39.0% between control and post-intervention at baseline for Mamelodi. Status motivations linked to biomass stoves increased by 14.2% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased status motivations by 53.2% (P = 0.052) for Mamelodi.
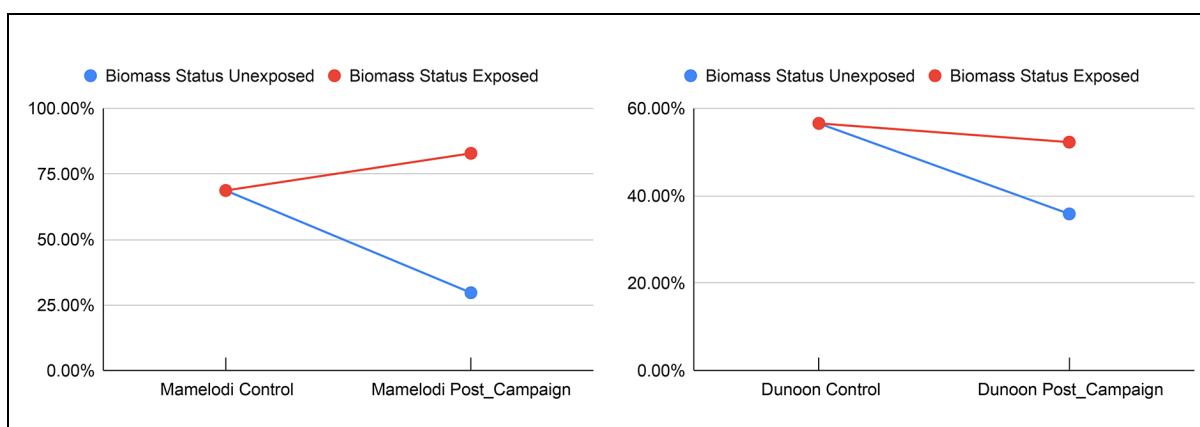
Figure 5.47: Changes in status motivations linked to biomass cookstoves in Mamelodi and Dunoon samples at baseline and endline
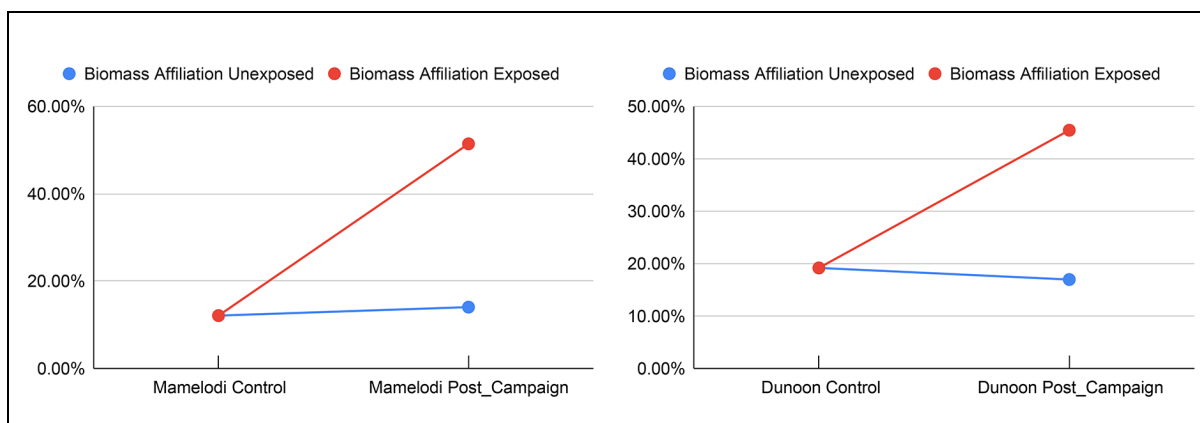
Status motivations linked to biomass stoves decreased by 20.7% between control and post-intervention at baseline for Dunoon. Status motivations linked to biomass stoves decreased by 4.3% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased status motivations by 16.4% (P = 0.694) for Dunoon.

Changes in disgust motivations linked to paraffin stoves

The intervention significantly increased disgust motivations linked to paraffin stoves (Figure 5.48). Motivations of disgust linked to paraffin stoves decreased by 12.4% between control and post-

intervention at baseline for Mamelodi. Motivations of disgust linked to paraffin stoves increased by 25.6% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased disgust motivations by 38.0% (P = 0.001) for Mamelodi.
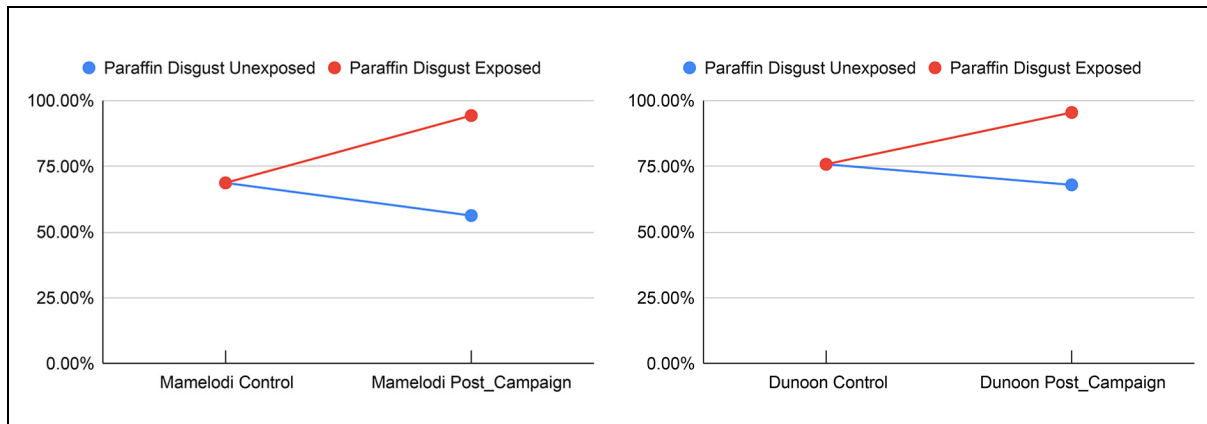
Figure 5.48: Changes in disgust motivations linked to paraffin cookstoves in Mamelodi and Dunoon samples at baseline and endline

Disgust motivations linked to paraffin stoves decreased by 7.8% between control and post-intervention at baseline for Dunoon. Disgust motivations linked to paraffin stoves increased by 19.7% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased disgust motivations by 27.5% (P = 0.005) for Dunoon.

Changes in fear motivations linked to paraffin stoves

While Mamelodi results were unreliable, the implementation in Dunoon achieved significant increases in fear linked to paraffin stoves (Figure 5.49). Fear motivations linked to paraffin stoves decreased by 14.5% between control and post-intervention at baseline for Mamelodi. Fear motivations linked to paraffin stoves increased by 0.9% between control and post-intervention at the endline for Mamelodi. After adjusting for the baseline prevalence, the intervention increased fear motivations by 15.4% (P = 0.911) for Mamelodi.
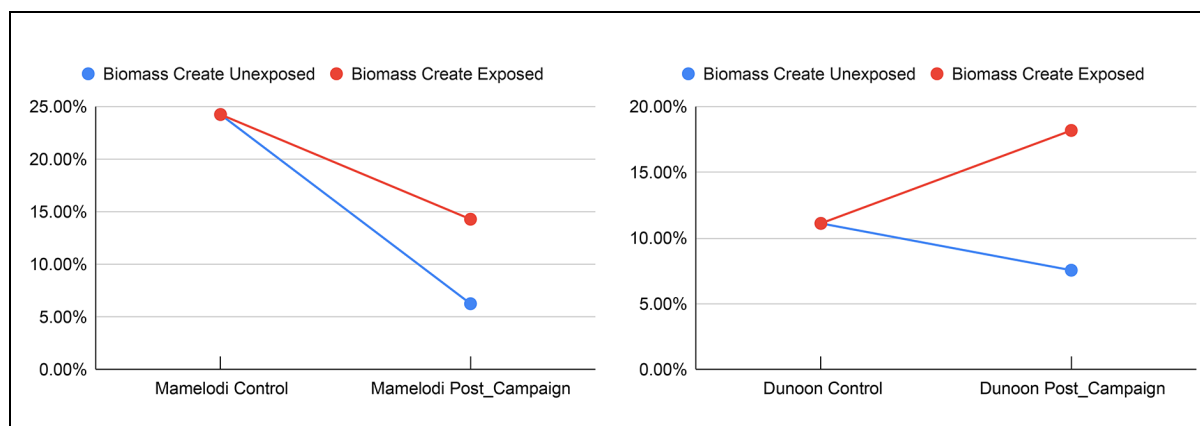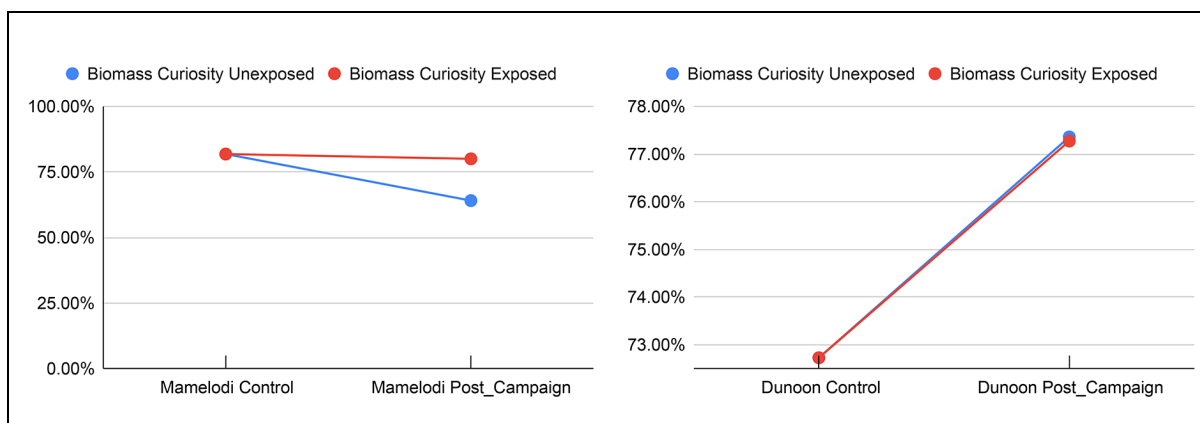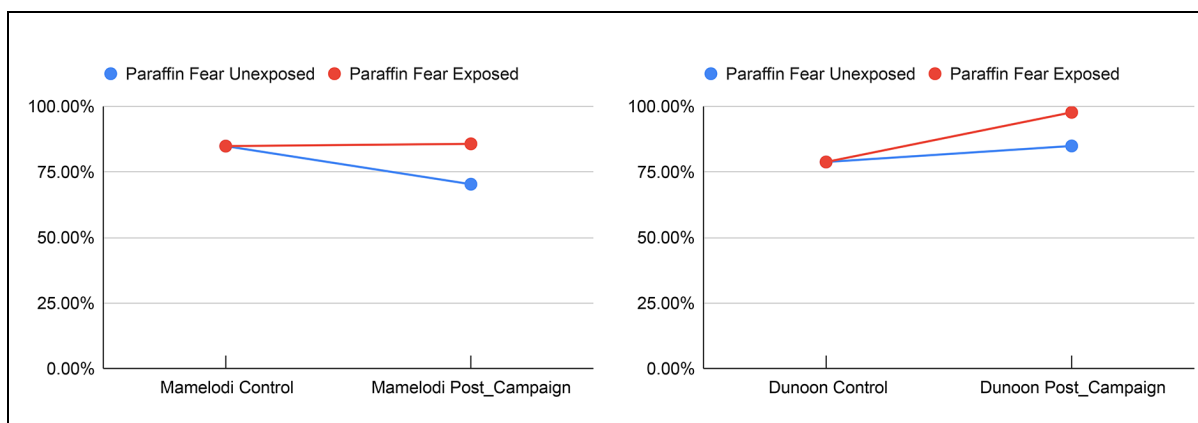
Figure 5.49: Changes in fear motivations linked to paraffin cookstoves in Mamelodi and Dunoon samples at baseline and endline

Fear motivations linked to paraffin stoves increased by 6.1% between control and post-intervention at baseline for Dunoon. Fear motivations linked to paraffin stoves increased by 18.9% between control and post-intervention at the endline for Dunoon. After adjusting for the baseline prevalence, the intervention increased fear motivations by 12.8% (P = 0.005) for Dunoon.

5.6.4   Changes in observed stove ownership levels

The structured observations recorded during the household survey indicate changes in the ownership patterns of flame-based cooking appliances after interventions in the two sample areas, as depicted in Table 5.9 and Table 5.10.

A key result was the significant change in LPG stove ownership in Mamelodi (P = 0.049) and Dunoon (P = 0.046). A significant increase in biomass stove ownership in Dunoon (P = 0.049) was observed. However, the results for the diffusion of biomass stoves indicate that the cookstoves in operation post-intervention were self-improved imbaulas and a cast iron oven. Only a single improved biomass stove was observed. The differences in observed cookstove ownership patterns for the remaining stove types between the control and post-intervention populations were not large enough to be statistically significant.

Changes in LPG stove ownership

As depicted in Figure 5.50, the average of respondents who adopted LPG stoves for Mamelodi at baseline (i.e., unexposed) decreased by 5.0% between control and post-intervention. The average LPG stove diffusion by Mamelodi households at the endline (i.e., exposed) increased by 13.8%. After adjusting for the control group, LPG stove diffusion increased by 8.8% and was statistically significant (P = 0.049).
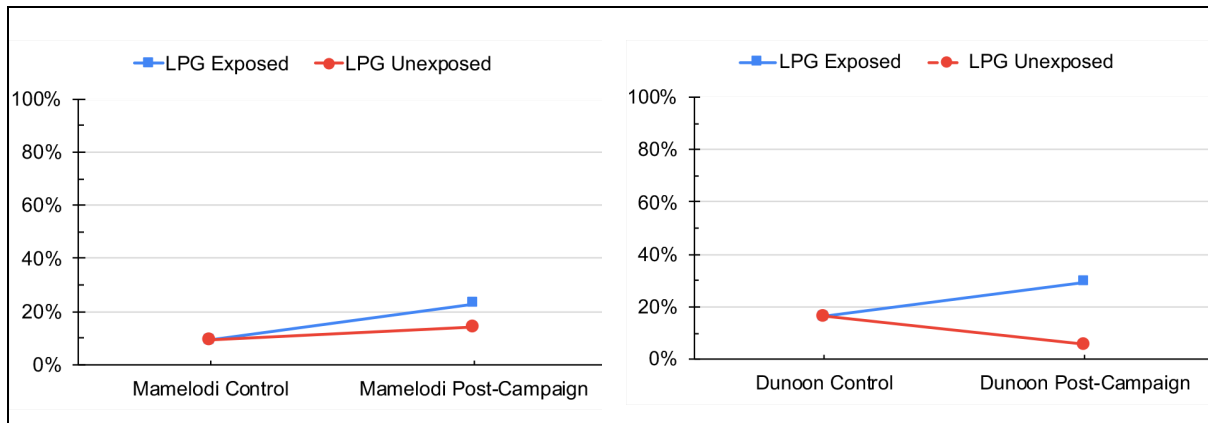
Figure 5.50: **Changes in LPG stove ownership levels before and after the interventions for the Mamelodi and Dunoon Sample Areas**

As depicted in Figure 5.50, the average of respondents who adopted LPG stoves for Dunoon at baseline (i.e., unexposed) decreased by 10.4% between control and post-intervention. The average LPG stove diffusion by Dunoon households at the endline (i.e., exposed to the intervention) increased by 13.4%. After adjusting for the control group, LPG stove diffusion increased by 23.9% and was statistically significant (P = 0.044).

Table 5.9:   Change in flame-based stove ownership patterns for the Mamelodi sample area

Sample Area	Stove Ownership by Energy Carrier	Control			Post-Campaign Unexposed				Control			Post-Campaign Exposed				Effect size (difference of differences)			
		n=99	%	SD	n=64	%	SD	P-value	n=99	%	SD	n=35	%	SD	P-value	% exp.	% unexp.	% DID	P-value
Mamelodi	Biomass stove	79	79.8	0.4	33	51.6	0.5	0.081	79	79.8	0.4	24	68.6	0.5	0.128	-11.2	-28.2	17.0	0.217
	Paraffin stove	38	38.4	0.5	21	32.8	0.5	0.289	38	38.4	0.5	14	40.0	0.5	0.307	1.6	-5.6	7.2	0.825
	LPG stove	9	9.1	0.3	9	14.1	0.3	0.074	9	9.1	0.3	8	22.9	0.3	0.424	13.8	5.0	8.8	0.049

Table 5.10:   Change in flame-based stove ownership patterns for the Dunoon sample area

Sample Area	Stove Ownership by Energy Carrier	Control			Post-Campaign Unexposed				Control			Post-Campaign Exposed				Effect size (difference of differences)			
		n=99	%	SD	n=53	%	SD	P-value	n=99	%	SD	n=44	%	SD	P-value	% exp.	% unexp.	% DID	P-value
Dunoon	Biomass stove	58	58.6	0.5	23	43.4	0.5	0.161	58	58.6	0.5	27	61.4	0.5	0.009	2.8	-15.2	18.0	0.049
	Paraffin stove	37	37.4	0.5	12	22.6	0.5	0.235	37	37.4	0.5	13	29.5	0.5	0.360	-7.8	-14.7	6.9	0.538
	LPG stove	16	16.2	0.4	3	5.7	0.2	0.009	16	16.2	0.4	13	29.5	0.3	0.243	13.4	-10.5	23.9	0.044

Changes in biomass stove ownership

As depicted in Figure 5.51, the average of respondents who adopted biomass stoves for Mamelodi at baseline (i.e., unexposed) decreased by 28.2% between control and post-intervention. The ownership of biomass stoves by Mamelodi households at the endline (i.e., exposed) decreased by 11.2%. After adjusting for the control group, biomass stove ownership increased by 17.0%, which was statistically insignificant (P = 0.217).
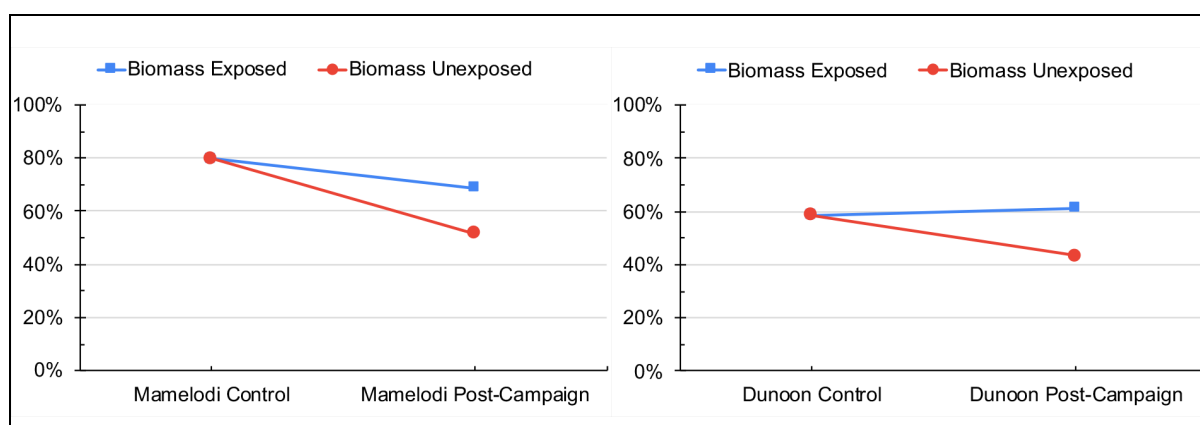
Figure 5.51: Changes in biomass stove ownership levels before and after the interventions for the Mamelodi and Dunoon sample areas

As depicted in Figure 5.51, the average of respondents who adopted biomass stoves for Dunoon at baseline (i.e., unexposed) decreased by 15.2% between control and post-intervention. The average biomass stove ownership by Dunoon households at the endline (i.e., exposed) increased by 2.8%. After adjusting for the control group, biomass stove ownership increased by 18.0% and was statistically significant (P = 0.049).

Changes in paraffin stove ownership

As depicted in Figure 5.52, the average of respondents who adopted paraffin stoves for Mamelodi at baseline (i.e., unexposed) decreased by 5.6% between control and post-intervention. The average of paraffin stove ownership by Mamelodi households at the endline (i.e., exposed) increased by 1.6%. After adjusting for the control group, paraffin stove ownership increased by 7.2%, which was nonetheless statistically insignificant (P = 0.825).
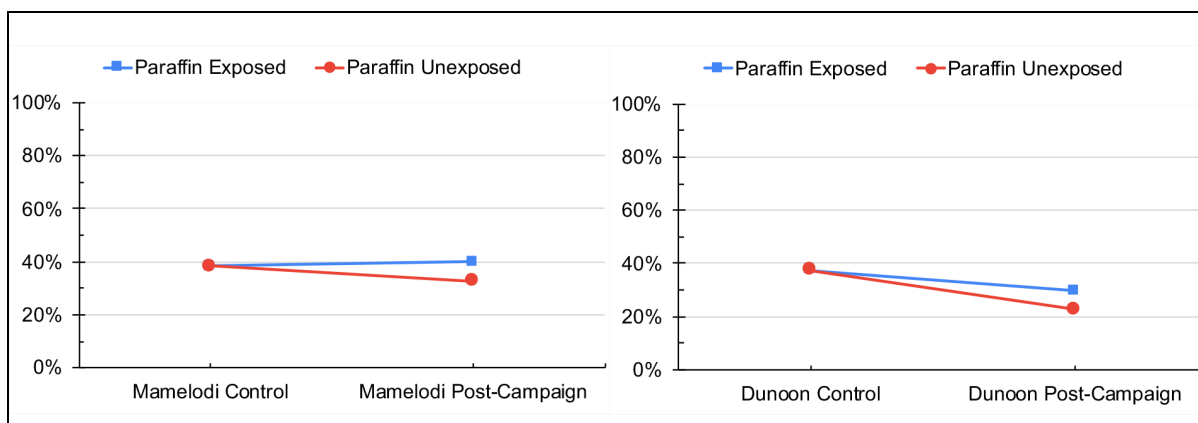
Figure 5.52: **Changes in paraffin stove ownership levels before and after the interventions for the Mamelodi and Dunoon Sample Areas**

As depicted in Figure 5.52, the average who adopted paraffin stoves for Dunoon at baseline (i.e., unexposed) decreased by 14.7% between control and post-intervention. The average paraffin stove ownership by Dunoon households at the endline (i.e., exposed) decreased by 7.8%. After adjusting for the control group, paraffin stove ownership increased by 23.9%, which was nonetheless statistically insignificant (P = 0.538).

5.7   Triangulation Results

The triangulation results indicate that the selected aspects of an intervention design to disseminate improved cookstove behaviours employing a BCD approach are verified by the results of the phase-based case study. The triangulation of selected aspects of the behavioural framework, the intervention strategy and the pilot implementation compared in tabular form (Table 5.11) indicate a coherent pattern emerging.

A prominent thread is the co-creative formulation of touchpoints linked to the pertinent cookstove-related motivations for an intervention assisted by co-creative workshop-based methods. The results in both sample areas confirmed the segmentation of the targeted population. Implementation at the pilot scale achieved a positive change in the ownership patterns, implying the achievement of the behavioural goal of increasing the use of improved flame-based stoves articulated in the behavioural framework.

After exposure to the intervention, a positive change in LPG stove ownership was recorded in both implementations. After exposure to the intervention, the change in the use of improved biomass stoves was inconclusive. The apparent failure to use improved biomass cookstoves can be attributed to a lack of desirable and affordable alternatives. The only locally available option is the Ecozoom Versa stove. The co-creative workshop results indicated that a larger biomass stove with a chimney is desirable, indicating the existence of a possible gap in the market.

Table 5.11:   Triangulation results

Attributes	Behavioural Framework	Intervention Strategy	SP Dunoon Results	SP Mamelodi Results
	Behavioural Challenge	SA households cooking with unimproved cooking technologies		
Targeted Population	The first group (SEM1–SEM2) The second group (SEM3–SEM4)		SEM1–SEM2	SEM3–SEM4
Behavioural Goal	Primary: BIO ↑ Secondary: LPG ↑		LPG↑ PFN↓ BIO↔	LPG↑ PFN↓ BIO↔
Intervention Concept		Emotional demonstrations of cooking and baking sequences. First sequence baking scones with a biomass oven, and the second sequence making tea with an LPG stove	36% Reach	49% Reach
Motivation-Linked Touchpoints	Hunger overrides long-term health	[Hunger - BIO↑] Aroma of baking in the biomass oven (first seq.)	[Hunger - BIO ↔]	[Hunger - BIO ↔]
	The comfort of warm homes at night	[Comfort - BIO↑] Warmth of biomass oven (first seq.)	[Comfort - BIO ↔]	[Comfort - BIO ↑] ✓
		[Comfort - LPG↑] Warmth of LPG heater (second seq.)	[Comfort - LPG ↔]	[Comfort - LPG ↔]
	Fear of gas and paraffin explosions or fires	[Fear - PFN↑] Uncontrolled paraffin fire (first seq.)	[Fear - PFN ↑] ✓	[Fear - PFN ↔]
		[Fear - LPG↓] Repeated lighting of an LPG stove (second seq.)	[Fear - LPG ↓] ✓	[Fear - LPG ↓] ✓
	Disgust - odour from a paraffin stove	[Disgust - PFN↑] Dirty paraffin stove (second seq.)	[Disgust - PFN ↑] ✓	[Disgust - PFN ↑]
	Hoard stoves and fuels	[Hoard - BIO↑] Show fuelwood savings (first seq.)	[Hoard - BIO ↑] ✓	[Hoard - BIO ↑]
	Affiliation by cooking together in social settings	[Affiliation - BIO↑] Share baked luxuries (first seq.)	[Affiliation - BIO ↑] ✓	[Affiliation - BIO ↑]
		[Affiliation - LPG↑] Preparing tea together (second seq.)	[Affiliation - LPG ↑] ✓	[Affiliation - LPG ↑]
	Status - high status linked to durable stoves and low status to poorly constructed wood and paraffin stoves	[Status - BIO↑] Clean clothes, clean stoves (first seq.)	[Status - BIO ↔]	[Status - BIO ↔]
		[Status - LPG↑] Auto-switch on a shiny stove (second seq.)	[Status - LPG ↑] ✓	[Status - LPG ↑] ✓
	Curiosity by cooking luxurious foods with novel improved stoves	[Curiosity - BIO↑] Lighting of the biomass oven (first seq.)	[Curiosity - BIO ↔]	[Curiosity - BIO ↔]
	Play by tradition-based simulated learning of embodied skills and knowledge	[Play - BIO↑] Baking luxuries together (first seq.)	[Play - BIO ↑] ✓	[Play - BIO ↔]
	Nurture of children while cooking			
	Create by adapting culinary methods and recipes to the various constraints			
	Justice by regulatory means is ill-advised due to past failures			

The SP survey results confirm using an intervention strategy centred around the emotional demonstration of improved cookstoves as suggested by the literature review and co-creative workshop-based mapping of an intervention. The development of the intervention sequences and touchpoints with stakeholders of the targeted population appears critical, as indicated by the co-creative workshop sessions.

Behavioural challenge

The formative assessment of the behavioural challenge faced by impoverished South African households related to flame-based cookstove use is confirmed in both sample areas. The survey results in Dunoon and Mamelodi confirmed the continued use of wick paraffin stoves, self-constructed drum stoves and open fires.

Targeted population

The review of previous interventions specified that accurately identifying people affected by the behavioural need was a primary requirement. Furthermore, the literature review suggested that South African residents affected by the deleterious effects of unimproved flame-based cookstoves are primarily impoverished Black households in the bottom four *SEM* categories. A clear difference in flame-based cookstove-related behaviour was apparent between the *SEM1–SEM2* and the *SEM3–SEM4* supergroups. The SP survey results for the implementation in Dunoon reflected the characteristics of the lower band of the targeted populations described in the segmentation results (i.e., *SEM1–SEM2*), while the selected households from Mamelodi reflected the characteristics of the population beginning to emerge from extreme poverty levels (i.e., *SEM3–SEM4*).

Behavioural goal

The behavioural goal formulated in the behavioural framework proposed an increase in the diffusion of improved biomass stoves among the *SEM1–SEM2* band and the diffusion of LPG stoves among the *SEM3–SEM4* band to reduce the use of unimproved flame-based appliances. In response to the BCD intervention guided by the behavioural goal, the Mamelodi sample (*SEM3–SEM4*) reported an increase in LPG stove ownership and a decrease in paraffin stove ownership after exposure, yet no change in biomass stove ownership after exposure. However, the Dunoon sample (*SEM1-SEM2*) did not report any significant change in biomass stove ownership, an insignificant increase in LPG stove ownership, and a decrease in paraffin stove ownership after exposure.

Motivation-linked touchpoints

A thread linking the assessed cookstove-related motivations and the touchpoints advanced by the intervention can be observed, with a clear pattern emerging. The observational study confirmed the cookstove-related motivations of fear, hoarding and status reported by the reviewed literature.

The intervention mapping of selected motivations (including the motivations resulting from the literature review and observational study) to touchpoints in the intervention successfully re-evaluated the motivations. The revaluation of motivations led, in turn, to measurable changes in flame-based cookstove ownership patterns as articulated in the behavioural goal as suggested by the SP survey results.

Intervention concept

The intervention concept of emotional demonstrations, namely cooking and baking sequences in a biomass oven and an LPG stove, achieved levels of exposure spanning 36% (Mamelodi) and 49% (Dunoon). The dissemination of the intervention concept reached beyond the immediate participants with word-of-mouth knowledge of the intervention extending to a significant number of residents in the two representative samples.

5.8 Chapter Summary

A grounded theory methodology was employed in the formative assessment of the behavioural challenge grounded in the review of relevant literature. The clear segmentation of the targeted population identifies a clear difference in cookstove use between the impoverished, mainly rural households (i.e., *SEM1* and *SEM2*) and households beginning to emerge from poverty (i.e., *SEM3* and *SEM4*). The exploratory observational study in Dunoon provided critical insights into a representative context of cooking with unimproved cookstoves. Households use a variety of flame-based cooking appliances with the stacking of fuels and appliances observed. The case study results provide a guiding behavioural framework for designing and assessing a cookstove dissemination intervention that comprises a clear two-tier behavioural goal to reduce the use of unimproved flame-based appliances. The framework proposes the spatial and temporal motivations of hunger, comfort, fear and disgust related to the daily grind of poverty. In addition, the negative and unfounded motivation of the fear of gas explosions is a powerful barrier to cooking with an LPG stove. As part of the case study, the co-creative workshop-based mapping proposes a blended two-tier intervention concept of baking demonstrations with an improved biomass oven aimed at South Africans living in the *SEM1–SEM2* category and demonstrations of an LPG single hob and cylinder combination aimed at South Africans living in the *SEM3–SEM4* category. The assessment of a pilot implementation facilitated by the stated preference (SP) survey, household questionnaire and structured household observations indicates that the proposed intervention positively influenced the flame-based cookstove-related behaviour of impoverished South Africans living in two representative sample areas, leading to a significant decrease in the use of unimproved flame-based cookstoves. The triangulation assessing the process and outcome of the development and implementation strengthened the reliability and validity of the results proposed by the intervention.

6 CONCLUSIONS AND RECOMMENDATIONS

The concluding chapter comprises a summary of the research findings, overall conclusions and recommendations including implications for future behaviour-focused cookstove interventions.

6.1 Summary of Results

6.1.1 Critical aspects of a BCD approach

The BCD approach in WASH applications

The BCD approach to designing and implementing behavioural interventions emerged as a critical contributor to the success of Water, Sanitation and Hygiene (WASH) applications in South Asia and SSA. The interventions achieved a measurable change in sanitation and hygiene indicators in response to targeting the related motives. The critical aspects of the BCD approach gleaned from the main WASH implementations include the development of practical implementations informed by contextually relevant research findings. A critical factor is the co-creative design of campaigns informed by behavioural insights gleaned from contextually relevant observations. Establishing a capacity to implement and monitor an implementation effectively is critical. The structured evaluation of the overall intervention processes and outcomes is key to applying insights from previous implementations.

Theoretical underpinnings of the BCD approach

The theoretical underpinnings of the BCD approach provide support and direction for understanding the behavioural factors for an intervention. The approach supports the design of interventions to influence behavioural patterns in contexts similar to South Africa. The framing and development of an intervention's behavioural components are central to the theoretical approach. Mismatch theory provides direction in exploring the behavioural challenge. Behaviour setting theory guides the identification of contextual behavioural factors for a proposed intervention. Behavioural motivations theory assists in identifying triggers for a behavioural response in an intervention. Finally, reinforcement learning theory provides direction in formulating the mechanism for ensuring a sustained change in a behavioural pattern.

Assessment of the behavioural challenge

The assessment of the behavioural challenge related to unimproved flame-based cookstoves prepares the intervention design process. Recognisable formative assessments of the behavioural factors related to flame-based appliances are sparse and inconsistent in developing improved cookstove dissemination interventions. The nature and scope of the behavioural challenges in this study are confirmed as the continued use of inefficient and poorly constructed flame-based cooking appliances by impoverished households. Section 4.1.1 confirms significant levels of morbidity and mortality due to respiratory disease, shack fires and burns, the economic costs of high fuel expenditure, the time lost in procuring

fuel, and the environmental implications of deforestation and greenhouse gas emissions. Despite a succession of interventions which have sought to promote the uptake of electric and LPG-powered cooking appliances, cooking and heating with inefficient and poorly constructed biomass and paraffin-powered appliances remains high among the South African energy poor.

Identification and inclusion of the targeted population

Successful design-led interventions and the majority of successful improved cookstoves initiatives in under-resourced contexts share the clear identification of the affected segment of the population. The active participation of local beneficiaries (i.e., women cooks) is recommended.

Contextualised exploration of the behavioural factors

A BCD intervention must be cognisant of the local behavioural factors determining flame-based cookstove use. The material factors in the local context relate to the cooking appliances, fuels and food ingredients. These factors include the level of available household income; the time available for performing the cooking sequences; the taste, size and frequency of meals; and the dietary rules, recipes and cooking methods.

Formulation of a behavioural framework for an intervention

Formulating the prospective behavioural components provides a powerful heuristic tool to synthesise the pertinent behavioural aspects found in the formative assessment of the behavioural challenge under investigation into a coherent theory of change for an intervention. The behavioural components provide the foundation for designing an intervention. In practice, the components for an intervention frequently include a clear behavioural goal, prospective behavioural sequences and linked motivations.

Co-creative design of an intervention

The development of an intervention is frequently facilitated by a series of co-creative methods guided by behavioural components. It is suggested that the critical elements of an intervention should include an appropriate intervention concept delivering a relevant narrative for the group of beneficiaries selected from the targeted population; a behavioural sequence accommodating a series of touchpoints linked to the identified motivations; a selection of the most appropriate and cost-effective communication channels, specifically the inclusion of analogue demonstrations of cookstove-related aspects; a selection of desirable, affordable and available intervention materials that includes the stoves, fuels and cooking ingredients; and a support infrastructure required for interventions with a focus on trained facilitators and credible partnerships with local communities.

Intervention implementation

Implementing a BCD intervention in a real-world environment is guided by the proposed strategy to reach the targeted population. Constrained by the cost and level of engagement during an intervention,

implementations can take the form of one-on-one demonstrations or community events facilitated by change agents and assisted by outdoor, mass or social media. The implementation procedure includes producing intervention materials and providing support infrastructure for a specific setting. The implementation is assessed to gauge the success of engagement with the selected criteria articulated in the intervention. The evaluations primarily focused on whether the behavioural goal and cookstove-linked motivations have shifted.

Evaluation of the BCD intervention design process and outcome

The final aspect involves assessing the BCD intervention and outcomes. Evidence and outcome are evaluated to determine what aspects were successful and might improve future interventions. Ideally, the sustainability of the behaviour change over the longer term should be measured. Including appropriate research methods and instruments is of paramount importance for the reliable assessment of the development and implementation of behavioural interventions. These methods can include behavioural observations and discrete evaluations of actual behavioural outcomes. However, measuring improvements can be complicated, expensive and frequently unnecessary if the relationship between the behavioural goal and behavioural challenge is already well established.

6.1.2   BCD aspects in South African improved cookstove interventions

The consensus in the literature is that most improved cookstove interventions in South Africa over the last thirty years have failed. No successful improved cookstove dissemination initiative underpinned by a coherent behavioural approach has been found in South Africa, despite many efforts to alleviate the adverse health and safety effects related to the use of flame-based cookstoves. A behaviour-focused approach is critical to ensuring greater accuracy in designing cookstove-related interventions to assist impoverished communities. The following BCD aspects present in successful interventions, even if unintentional, have contributed to a measure of success in a select group of interventions in a South African context.

Theoretical approaches to successful stove projects

The theoretical behavioural approaches largely follow hybrid behavioural approaches spanning cognitive psychology, behavioural economics, and social marketing. Only a limited presence of social counselling models has been found.

Formative assessment of the behavioural challenge

A formative assessment of the behavioural challenge related to unimproved cookstoves is frequently present yet serves a secondary role in adopting a specific cookstove technology.

Identification of the targeted population

A robust understanding of the targeted population is present in successful interventions, drawing from available data sources. Sometimes, a form of segmentation is present to identify the affected groups.

Exploration of the cookstove-related South African context

An in-depth understanding of the local behavioural context is foundational in formulating a BCD intervention. Most projects have performed basic formative research on cookstove-related behaviour using exploratory qualitative methods. The exploratory methods appear to serve as a secondary function in most projects. The KayaGAS and KCJ interventions are exceptions, which incorporated a structured formative research phase, including focus groups and in-depth field studies. Exploration of the local context is recommended before formulating a behavioural goal.

Formulation of clear behavioural focus for an intervention

The lack of a coherent behavioural focus in the design of interventions is frequently cited for failure. Despite the difficulties in obtaining reliable information, framing the selected behavioural aspects to achieve a specific goal is recommended – beyond the objective of cookstove dissemination. The behavioural aspects include a description of the material cookstoves and fuels and prospective sequences in future interventions.

Participatory design of an intervention

An iterative participatory process is recommended to design a behavioural intervention. The design of behavioural interventions frequently employs co-creative methods that seek to include local participants affected by the specific challenge under investigation. The acknowledgement and integration of local communities drawn from the targeted population are considered vital to the success of an intervention. Iterative design methods were present in all the reviewed cases, albeit often unintentionally and incompletely. The KCJ project stands out with an iterative process for designing an intervention. The intervention is recommended to include desirable, financially viable and locally available intervention materials encompassing local cooking appliances, fuels and training programmes. Support infrastructure is essential for sustainable intervention over the long term. Integrating informal community networks in capacity building and training programmes are recommended.

Evaluation of behaviour-focused cookstove-related intervention processes and outcomes

Structured assessments of the design processes and outcomes of behavioural interventions aimed at disseminating improved cookstoves are rare. However, the inclusion of behaviour-focused research methods sourced from social marketing-related disciplines are found frequently in successful interventions (i.e., KayaGAS, *basa njengo magogo* and the KCJ project are prime examples). The Jiko project, in particular, stands out for the level and depth of research undertaken throughout the project's lifespan.

6.1.3 The design of a research framework for designing a BCD intervention

The multiphase case study-based research framework successfully combined sequential and concurrent research and design approaches in addressing the research objectives as suggested by the BCD approach (Aunger & Curtis, 2016). The framework incorporates aspects adapted from the multiphase processes to design complex interventions developed by the London School of Hygiene and Tropical Medicine (Aunger & Curtis, 2016).

The phase-based research framework facilitated the exploratory case study methodology, applying qualitative and quantitative methods in a systematic research process. The research design successfully combined deductive, inductive and abductive research approaches to systematically collect and analyse the primary and secondary data, culminating in disseminating the results. The study employed a deductive approach to assess a behaviour-focused intervention's emerging aspects in a representative South African community and deduce whether a proposed BCD intervention has been successful. An inductive approach was employed in exploring and describing behavioural challenges related to the low diffusion of improved flame-based cookstoves and establishing a preliminary categorisation of selected aspects of the behavioural context under investigation. An abductive approach was employed during the co-creative phase.

The procedural steps reviewed in Section 2.1 and Section 2.2 and described in detail in Chapter 3.2 facilitated the exploration, development, implementation and evaluation of a behaviour centred design intervention. The research framework successfully supported the application of mixed quantitative and qualitative methods, depending on the changing research foci during the research phases.

The research framework engaged the final beneficiaries as early as possible in the design process. The phase-based process facilitated the collection and analysis of data before, during and after the iterative design of the intervention. The triangulation to assess the success of the approach's results increased the validity of the research results.

6.1.4 The development of selected aspects in a BCD intervention

Behavioural challenges related to flame-based cookstoves

The formative assessment of the behavioural challenge was grounded in the review of relevant literature suggested by Section 2.1.4 and Section 2.2.9. The central challenge was the mounting human morbidity and mortality associated with using inefficient flame-based cookstoves in South Africa and the inherent urgency of finding a viable, sustainable solution. The formative research documented the health hazards associated with flame-based cooking, the history and context of culinary behaviours, the currently available cooking alternatives, the broader material and socio-institutional factors affecting cookstove use, and possible motivations underlying existing flame-based cookstove use.

Targeted population

A clear delineation of the people using unimproved flame-based appliances is considered critical. The segmentation of the targeted population provides a deeper understanding of the demographic factors pertinent to using unimproved flame-based appliances in South Africa. The segmentation analysis identified the prospective group of people cooking with unimproved flame-based cookstoves assisted by the SEM living standards instrument. The segmentation identifies a clear difference in cookstove use between the impoverished, mainly rural households (i.e., SEM1 and SEM2) and households beginning to emerge from poverty (i.e., SEM3 and SEM4).

6.1.5 Exploration of the South African cookstove-related context

The exploratory observational study in Dunoon confirmed the prospective South African target population. It provided critical insights into a representative context of cooking with unimproved cookstoves. Households use a variety of flame-based cooking appliances with the stacking of fuels and appliances observed. Cooking with electricity is intermittent due to unreliable supply and high cost. Cast-iron ovens are considered desirable but too expensive. Unpressurised paraffin stoves are ubiquitous. Awareness of LPG stoves does not translate into a level of dissemination when compared to other energy carriers. Precarious income levels influenced the observed flame-based cooking sequences. The Western culinary infrastructure determines the ingredients, utensils, and fuels. Large-scale national and international retailers and distribution networks are dominant. Blends of rural and urban culinary practices influence the flame-based cookstove-related behavioural sequences. The households prepare between two and three meals daily during the week, each in less than an hour. The meals are cooked with paraffin stoves, imbaulas or electric kettles. Leftovers or ready-to-eat meals are prepared over paraffin stoves, imbaulas, open fires or electric hob stoves—simplified and flexible cooking sequences with few ingredients. Starches and vegetables are predominantly boiled, and meat is often braised over imbaulas or open fires. Frying food in vegetable oil is rising in popularity, while the baking of steamed bread is rare.

6.1.6 Critical components of a behavioural framework to guide an intervention

The case study results provide a guiding behavioural framework for designing and assessing a cookstove dissemination intervention that comprises a clear two-tier behavioural goal to reduce the use of unimproved flame-based appliances.

The behavioural goal proposes a targeted shift to cooking with LPG gas stoves for South Africans living in the *SEM3* and *SEM4* categories because it appears to be the most efficient, safe cooking solution, delivering a safer, cheaper, and convenient cooking stove experience. For South Africans living in the *SEM1 and SEM2* categories, a targeted shift to cooking with improved biomass stoves appears to be the most efficient, safe, cheap and convenient option.

Two distinct settings emerge for using flame-based cooking stoves in a South African context: SEM1–SEM2 households accommodate cooking sequences in traditional dwellings and newly urbanised informal homes constructed of sheet metal and wood with bare floors. SEM3–SEM4 settings include a cement floor, cement brick walls and often enclosed kitchens. SEM1–SEM2 households cook with fuelwood over open fires or self-constructed stoves. Paraffin and biomass are still used concurrently. SEM3–SEM4 households cook with electricity, paraffin and biomass. The primary players in cookstove dissemination interventions are female caregivers cooking with flame-based stoves. Many households still follow traditional roles and norms related to cooking. The norms and values they have become accustomed to are a hybrid mixture in urban settings.

The framework proposes the spatial and temporal motivations of hunger, comfort, fear and disgust related to the daily grind of poverty. In addition, the negative and unfounded motivation of the fear of gas explosions is a powerful barrier to cooking with an LPG stove. Hoarding motivations strongly influence decisions concerning cooking a family meal. Affiliation motivations to maintain social relationships, form alliances and conform to group norms are essential. Status motivations are associated with the odours emanating from unimproved paraffin appliances. The play motivation can be targeted in simulated demonstrations of the dangers of stoves without the risks of injury.

6.1.7 Co-creative design of an intervention

As part of the case study, the co-creative workshop-based mapping resulted in a testable intervention consisting of an intervention concept and a selected set of intervention elements. The non-participant workshop-based observations of the amended emotional demonstration developed by a South African behaviour change agency in partnership with local community members resulted in a robust intervention concept for South African conditions. The intervention mapping proposes a blended two-tier intervention concept of baking demonstrations with an improved biomass oven aimed at South Africans living in the *SEM1–SEM2* category and demonstrations of an LPG single hob and cylinder combination aimed at South Africans living in the *SEM3–SEM4* category. Critical to the intervention are the selected touchpoints resulting from the co-creative workshop activities linked to the motivations proposed by the behavioural framework. Additional intervention elements to facilitate the intervention include a succinct description of the intervention sequences, the communication channels, the facilitating intervention stage, the required props and the supporting infrastructure.

6.1.8 Implementation of an intervention at pilot scale

The assessment of a pilot implementation facilitated by the stated preference (SP) survey, household questionnaire and structured household observations indicates that the proposed intervention positively influenced the flame-based cookstove-related behaviour of impoverished South Africans living in two representative sample areas, leading to a significant decrease in the use of unimproved flame-based cookstoves. The short household questionnaire results corroborate the representivity of the targeted

population identified in the behavioural framework. The structured observations facilitated by a checklist of available cooking appliances confirmed a change in the stove ownership patterns in both areas at baseline and endline to more efficient options when exposed to the intervention. The card-based SP survey results indicate that the inclusion of the selected motivational touchpoints achieved a revaluation of the cookstove-related motivations of the prospective targeted population in South Africa (represented by the respondents chosen in the two study areas).

6.1.9 Triangulation of results of the BCD approach

The triangulation assessing the process and outcome of the development and implementation strengthened the reliability and validity of the results proposed by the intervention, indicating that a BCD approach is necessary to achieve a significant positive uptake of improved flame-based cookstoves in South Africa. The SP survey results assessing the pilot implementation in two sample areas verified the components of the behavioural framework emerging from the segmentation, observational study, and the selected intervention elements. The targeted population identified in the segmentation and confirmed by the observational study matched the results of the pilot implementation survey. The structured observations of the pilot implementation confirmed the achievement of the behavioural goal articulated in the behavioural framework. The SP analysis indicated a shift in cookstove-related motivations linked to the selected touchpoints incorporated in the intervention mapping.

6.2 Conclusions

The main aim of this thesis is to establish the effectiveness of a BCD approach as an intervention strategy to positively influence the dissemination of improved flame-based cooking technologies among a representative sample of impoverished South African households.

As part of a full BCD intervention, applying the research methods and techniques as outlined in the research design is key to the successful dissemination of improved flame-based cooking technologies. A systematic phase-based intervention design incorporating these aspects will significantly contribute to an accurate and sustained dissemination among a targeted population.

The aim is achieved based on the results of the literature review of crucial BCD aspects, an exploratory research design framework, a case study-based design and assessment at a pilot scale of a behaviour centred cookstove dissemination intervention assisted by an SP survey and the triangulation of the case study results.

The research objectives articulated in the first chapter (Section 1.4) were answered in the following manner:

6.2.1 Literature review (Research objective [i])

The first objective was answered in the literature review, which provided the background of the theoretical underpinnings and distinguishing aspects of BCD approaches for designing, implementing and evaluating behavioural interventions seeking to increase the diffusion of improved cooking technologies in impoverished contexts similar to South Africa.

i. A brief description of the theoretical underpinnings of the BCD approach is provided, followed by a delineation of the critical elements of a BCD approach for preparing, exploring, creating, implementing and evaluating behavioural interventions.

ii. The behaviour-focused aspects appropriate for a South African cookstove-related intervention resulting from a literature-based case study analysis of selected improved cookstove dissemination interventions employing aspects of a BCD approach are identified.

The overview of theoretical and practice-based aspects considered pertinent to a successful BCD approach provided the blueprint for the behavioural intervention. A pragmatic phase-based design process is necessary to achieve a positive shift in cookstove-related behaviour. Various suitable approaches, methods and instruments are highlighted, gleaned from the BCD literature and improved cookstove dissemination practice.

The literature-based case study analysis of improved cookstove-related interventions indicated which aspects of a BCD approach had positively contributed to the intervention's success and confirmed the main aspects identified in the previous objective. The analysis of selected South African and contextually similar initiatives pertaining to cookstove efforts with behavioural foci provided a valuable insight into what aspects are required to design an effective BCD intervention.

A common thread that emerged was understanding the critical behavioural factors determining the use of unimproved flame-based cookstoves.

6.2.2 Design of a research framework for evaluating a BCD Approach to disseminating improved cookstoves (Research objective [ii])

The exploratory case study framework applied multiple methods to each situational aspect to investigate the main research objectives. Each phase of the framework facilitates data collection and analysis using quantitative and qualitative methods, instruments and techniques, thereby generating diverse findings.

6.2.3 Case study-based development of a BCD intervention (Research objective [iii])

The third objective was facilitated by a phase-based sequential case study-based methodology accommodating the development of a BCD intervention to improve the dissemination of clean and safe flame-based cookstoves in South Africa. Aspects common to successful BCD interventions were

incorporated. The objective was addressed along with the phases in the case study in the following manner.

i. A literature-based assessment of South Africa's cookstove-related behavioural challenge.
ii. A population segmentation of South Africans affected by the hazards of unimproved cookstoves.
iii. An observational study exploring local behavioural factors related to flame-based cookstoves.
iv. The framing of selected behavioural factors to guide the creation of an intervention.
v. The co-creation of intervention appropriate for South African pilot implementation.

The case study proceeded with a literature-based assessment of South Africa's cookstove-related behavioural challenge. The preliminary assessment provided a background for developing a formative understanding of the underlying cookstove-related needs. The review demonstrated the link between the hazards associated with flame-based cooking among indigent South African households and the persistent use of inefficient flame-based cookstoves. The review of the flame-based cookstove-related behaviour of indigent South African households provided valuable insight into ways to influence current and future interventions. A common thread was understanding the critical behavioural challenges of using unimproved flame-based cookstoves. Informed by the formative literature-based assessment of the behavioural challenge, the case study proceeded with the population segmentation and successfully identified the segments in South Africa affected by the hazards of unimproved flame-based appliances.

The observational study's exploration of the behavioural context provided a deeper understanding of the local behavioural factors related to flame-based cookstoves. The exploration provided a clear behavioural focus for a flame-based cookstove-related intervention. The segmentation results and the insights from the observational study assisted in constructing an intervention framework with a clear behavioural goal and related motivations.

The creation of an intervention emerged from the intervention mapping incorporating the findings of the co-creative workshop sessions and preceding behavioural framework. The strategy proposes a flexible intervention concept, accommodating two sequences facilitating touchpoints linked to corresponding motivations. Short CBC experiments strengthened the selection of touchpoint-linked motivations observed during the workshop sessions.

6.2.4   Pilot implementation and evaluation (Research objective [iv])

The fourth objective was achieved by assessing a pilot implementation of the testable intervention emerging from the previous objective, facilitated by an SP survey accompanied by a short household questionnaire and structured household observations in two representative sample areas. The household questionnaire verified the targeted population for the two sample areas. The structured observations of

cookstove ownership at baseline and endline successfully confirmed that the pilot implementation met the behavioural goal articulated in the proposed behavioural framework, namely, the overall reduction of unimproved flame-based appliances and, specifically, a reduction in the ownership of small paraffin stoves in both sample areas and the increased ownership of LPG stoves as articulated by the SEM3–SEM4 behavioural goal. However, no significant change was observed in the ownership of biomass stoves. The card-based SP survey administered at baseline and endline in the two sample areas provided an assessment of the reach of the exposure to the pilot implementation in linking the selected touchpoints to the motivations mooted in the intervention.

When exposed to the key touchpoints, the change in observed cookstove ownership and differences in motivations confirmed the intervention's efficacy in shifting flame-based cookstove-related behaviour, thereby responding to the research objective and the main research aim of this thesis.

6.2.5 Evaluation of the thesis outcomes (Research objective [v])

The triangulation successfully addressed the fifth and final objective of the study. The development of an intervention followed by a pilot implementation provided sufficient evidence to suggest that the application of BCD approaches can trigger the revaluation of cookstove-linked motivations and increase the ownership of improved flame-cookstoves. Triangulation of the results confirmed the thread of evidence strengthening reliability and validity in answering the objectives. In turn, the main argument is that a BCD approach can contribute to any intervention to improve the dissemination of improved flame-based cookstoves among impoverished South African households.

6.2.6 Limitations

This section focuses on the limitations of the case study-based research and supplements the information provided in Section [X]. To properly reflect on the reliability of this thesis, it is necessary to highlight the potential limitations of the study design and the limitations that occurred during the study. The research was conducted cons could not spend unlimited amounts of time on the area of research due to the inherent study limitations of time and budget. The limitations require narrowing the research focus, inevitably leaving some areas of study in danger of not being adequately addressed. Despite these limitations, the research results of the thesis can contribute to the improved design, implementation and evaluation of behaviour-focused interventions in the diffusion of clean cooking technologies.

Limitations in sampling methodology

The short timeframe for data collection necessitated a largely qualitative research approach. The sampling method employed in the short time frame may have affected the results. To mitigate the short time frame, an explicit focus was put on recruiting participants with different socio-economic backgrounds, as indicated by the South African household survey []. In addition, a second sampling arm for a pilot implementation was conducted in a relatively geographically distant sample area. The

sampling of workshop participants was particularly challenging to reflect the general population due to the small sample size. In mitigation, the researcher balanced the use of recorded insights between all participants in the results.

Limitations to the role of researcher

Another limitation was the varying set of roles the researcher assumed. While the researcher was a non-participant observer for the majority of the study, the co-creative workshop section necessitated participation in the workshop activities at times. The researcher assumed the limited role of facilitator during activities focused on the demonstration of cookstoves unfamiliar to the lead workshop facilitator. Continuous open dialogue with the facilitating team and external experts was maintained to mitigate the limitation. Furthermore, the researcher's bias may have affected the information given and received from the data collection and analysis. Finally, the researcher sought feedback on the results from outside experts at points of triangulation between the multiple collection methods sought to assuage the limitation.

Limitations linked to language translations

The pilot implementation was conducted in English, isiXhosa in Dunoon and English, and Pedi in Mamelodi, as it seemed fitting for the study sample areas. The method allowed the participants to express themselves freely. However, this required the data sources needed to be translated into English at a later stage. Some of the meanings could have been altered or lost in translation during this process.

6.2.7 Final conclusions

Based on the literature review, the research design framework, the case study-based development of an intervention, the implementation of the intervention at a pilot scale, and the triangulation of the results confirm the main thesis aim. The application of BCD approaches can contribute as an effective intervention in positively influencing the dissemination of improved flame-based cooking technologies among a representative sample of impoverished South African households dependent on unimproved cooking technologies. The application of the selected research methods and instruments outlined in the research design furthermore appears vital for a successful BCD approach as part of a nationwide implementation.

A phase-based BCD approach incorporating the selected aspects ensured a measurable change in the ownership and use of flame-based cookstoves among a sample area representative of South African low-income households.

A key finding indicates that an intervention design linking cookstove-related motivations to selected touchpoints in a co-created intervention could significantly influence the targeted motivations and, in turn, achieve the designated behavioural goal included in the guiding behavioural framework.

The following research objectives have been achieved:

- The literature-based review of the critical aspects of a BCD approach seeking to increase the diffusion of improved technologies in impoverished contexts similar to South Africa succeeded in providing the basis for developing an intervention.

- The research framework for evaluating a BCD approach incorporated behavioural theory and design practice employing a phase-based case study methodology.

- The case study-based provided evidence of selected aspects of a BCD approach in preparing, contextualising and designing an intervention for a South African context.

- The assessment of the pilot implementation of BCD intervention found that a revaluation of motivations linked to targeted cookstoves was achieved. There was a positive dissemination in cookstove ownership; specifically, the increased use of LPG stoves in the two sampled South African communities.

- In conclusion, the BCD approach significantly facilitated the diffusion of improved flame-based cookstoves in a representative South African context.

6.3   Recommendations and implications for future interventions

A wide variety of recommendations are suggested for behavioural interventions that disseminate flame-based cookstoves to succeed. The implications for the future of cookstove-related interventions are discussed first, followed by general recommendations for the design and evaluation of multiple behaviour change interventions.

6.3.1   Implications for design research and practice

The case-based evaluation underscores the challenges associated with changing behaviours and the need for continued research to support the development and testing of novel behaviour-focused interventions. Behavioural interventions must be thoughtfully designed using a BCD approach, considering the behavioural settings and comprehending the motivational factors influencing the targeted behavioural sequence. A prospective intervention must address the pertinent motivations in the setting where the targeted behaviours are performed. The widespread replication of a co-created intervention strategy incorporating a set of pertinent motivations for revaluing a behavioural sequence is strongly recommended. Although a behaviour-focused approach is fundamental for the development of operational tools for designers of interventions, the design discipline has not yet defined an operational paradigm (i.e. a set of standard tools and methods to design and develop BCD interventions). This thesis contributes to closing this gap by proposing methods and tools that have been effectively used in a South African context. The conceptual methods and techniques can be operationalised, enabling designers to create a set of illustrated guides and maps, enabling intervention designers to create, frame and evaluate behavioural components.

BCD approaches in the design of interventions

Intervention designers are advised to formulate a context-specific behavioural approach drawing on existing research and contextually relevant evidence to guide the anticipated achievement of outputs and outcomes in a targeted population. Policymakers, managers, and researchers are strongly encouraged to consider incorporating strategies, methods, tools and activities based on a BCD approach in designing interventions. The operational tools applied in this thesis can guide the implementation of the intervention in prospective interventions. Using a BCD approach may require the iterative replication of similar interventions in similar contexts. In weighing the different strands of gathered evidence, it is essential to explicitly articulate the intervention's main behavioural objectives at the outset.

Accommodation of complexity

Accommodating the inherent complexity is critical to the success of a behaviour-focused intervention. Behavioural interventions are recommended to accommodate activities operating in multiple areas as part of the intervention design process. This includes the local contextual factors and the more extensive nationwide social, political and economic factors, the local social and material, and the individual and interpersonal factors in the behaviour setting.

Comprehensive co-created conceptual narratives

A comprehensive conceptual narrative can provide a powerful signal to differentiate the intervention and assist in emotionally communicating the improvements from clean cooking. Policymakers and researchers should consider including the strategic use of branded narratives to build the connections and affinities between people and the targeted motivations and outcomes associated with a prospective surrounding infrastructure. A cogent conceptual narrative can group a plethora of behavioural determinants. An integrated conceptual narrative can harness a collection of motivational touchpoints as part of an intervention design.

Recommended areas of further investigation

Further research is recommended in the following areas:

- to accentuate a focus on gathering behavioural insights on the relationship between the behavioural factors in the specific context during the early exploratory phases of an intervention design process
- to refine and assess the validity of different motivations and sequences, assisted by co-creative workshops and in-field prototypes
- to include a rigorous assessment of the intervention design process and implementation outcomes when including a BCD approach

- to foster an interdisciplinary research approach between the practitioners and policymakers in the clean cooking environment and the behavioural design specialists
- to build a standardised behavioural framework, incorporating the behavioural challenges, targeted behaviours, pertinent motivations and possible culinary sequences
- to assess the role of a BCD approach can play in supporting significant transformative shifts in related fields of research

6.3.2 Implications for future cookstove interventions

A wide variety of recommendations are suggested for behavioural interventions that disseminate flame-based cookstoves to succeed. Given the lack of previous focus on the role of cookstove-related motivations in adopting novel improved cookstoves, tailored South African interventions to motivate a significant number of users to switch to an improved alternative are recommended. Additional research is needed to assess the efficacy of BCD approaches on a larger scale and ascertain whether the positive results can be reproduced in the diverse contexts a behaviour-focused cookstove-related intervention may encounter beyond South Africa. Further work is required to optimise the implementation of intervention strategies in both peri-urban and rural settings. Well-funded interventions are needed to operationalise and assess country-wide interventions. An inquiry into the plethora of BCD methods and instruments currently used by practitioners, perhaps under different names in cookstove-related interventions, could shed light on their efficacy. This could enable design researchers and practitioners to understand which methods and instruments could contribute positively.

A BCD intervention focused on the mass uptake of clean cooking appliances in SSA could be similar to the South African experience. The strong economic, political, and socio-institutional parallels indicate that the form and sequence of changes in the continent's cookstove-related behaviour will continue to follow a path similar to the South African experience. The current global focus on electricity as a strategy for reducing energy-related poverty could follow the same pattern as in South Africa, where dirty and dangerous flame-based appliances persist, despite a successful electrification intervention. A profound transformation in the well-being of indigent households requires the involvement of local, and, in particular, female African participation in novel ways. Intervention design strategies cognisant of an African perspective can avoid the pitfalls of cookstove interventions of the past and improve, if not wholly transform, their communities beyond cooking with efficient cookstoves, extending the female cooks' well-being and that of their families and the larger community. A sustainable culinary infrastructure co-created with the cooks, entrepreneurs, manufacturers, vendors, suppliers, distributors and governments through partnerships and networks facilitated by analogue and digital media is recommended.

A critical insight from the thesis is that the motivations for using a stove may not translate into the repeated purchase of a targeted candidate stove. The cooking sequences need to reinforce the purchasing

decision—the props and supporting infrastructure need to reinforce the motivations. Providing a desirable, available, affordable biomass cookstove or oven is critical to translating the positive motivations of biomass-powered appliances into large-scale diffusion. Repeated exposure to the intervention sequences through digital communication channels is also recommended due to the rapid diffusion of mobile phones and social media among the targeted population. In addition, the provision of comprehensible cooking manuals, with clear instructions and supporting pictures illustrating culinary sequences employing improved cookstoves, is recommended. Establishing local relationships and community networks to support improved cookstove interventions is recommended as early in an intervention's development as feasibly possible. Institutional stakeholders, including government and academia, can assist in collecting, assessing and disseminating local cookstove-related factors to address the gaps in knowledge on culinary sequences. The co-creative participatory mapping of intervention sequences and motivational touchpoints could provide a cost-effective tool for designing behavioural interventions addressing the needs of impoverished communities beyond the scope of improved cookstove diffusion. Crucially, well-financed, long-term intervention development and assessment strategies are recommended for the long-term emancipation of the women caregivers currently bearing the culinary burden.

In conclusion, a carefully crafted Behaviour Centred Design intervention targeting pertinent motivations in collaboration with the final beneficiaries can change cookstove-related behaviour well beyond the South African context.

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APPENDICES

Appendix I   Executive Summary

A transition to clean and safe flame-based cookstoves among the global energy-poor could significantly advance the attainment of the Sustainable Development Goals (SDGs) adopted in 2015 by the United Nations (United Nations, 2016). Despite broad support for finding solutions to inefficient and dangerous cookstove-related practices, only a limited number of interventions have shown success at scale (Urmee & Gyamfi, 2014; Lindgren, 2020). The failure to transition to improved cooking alternatives in response to large-scale interventions in South Africa has followed the same trajectory (Kimemia & van Niekerk, 2017). Using unimproved biomass, coal, or paraffin-fuelled household stoves persists among energy-impoverished South African households (Kimemia & van Niekerk, 2017). Women and young children are most exposed to hazardous emissions (Kimemia & van Niekerk, 2017). Further negative health implications associated with the continued use of paraffin cookstoves include burns, scalds and poisonings (Kimemia & van Niekerk, 2017). South Africa records 1.6 million burn victims annually, with mortality linked to cookstove-related burn injuries considered one of the highest globally (Allorto *et al.*, 2018). The rising burden has become a public health priority (van Niekerk *et al.*, 2022).

Despite many efforts to alleviate the adverse effects of flame-based cookstoves among energy-poor South Africans, rigorous statistical confirmation of successful interventions is rare to non-existent (Makonese *et al.*, 2012; Kimemia & van Niekerk, 2017; Makonese & Bradnum, 2018). A limited number of localised South African studies have included behavioural approaches for assessing how households are affected by the harmful effects of flame-based cooking appliances (Barnes, 2014). A significant shortcoming in cookstove dissemination efforts has been the absence of appropriate behavioural design-led approaches (Barnes *et al.*, 1994; Shafer, 2019; Abdelnour *et al.*, 2020; Lindgren, 2020), prompting the current exploration of behavioural design approaches in understanding the motives for adopting new cooking appliances by an array of international agencies and partner organizations (Hallsworth, 2017; Rosenthal *et al.*, 2018; Lambe *et al.*, 2020). This specific attention is furthermore attributable to behavioural design approaches' success in the related water and sanitation fields (Greenland *et al.*, 2016; Niedderer *et al.*, 2016). Of the behavioural design approaches, the Behaviour Centred Design (BCD) approach of Aunger and Curtis (2016), in particular, has been successfully applied in interventions aimed at influencing motives leading to the dissemination of desired behaviours in low-income contexts similar to South Africa (Biran *et al.*, 2014; Greenland *et al.*, 2016; White *et al.*, 2016; Gautam *et al.*, 2017; Burns *et al.*, 2018; Tidwell *et al.*, 2019; Morton *et al.*, 2020).

The main aim is to evaluate a BCD approach when seeking to influence motives linked to the dissemination of improved flame-based cookstoves in a representative South African community. The

scope of the research is limited to the field of behavioural design, specifically the aspects required for an improved cookstove intervention, applicable to South African households living in poverty. Detailed technical cookstove-related aspects are excluded.

Background Summary

A BCD approach employs an iterative phase-based intervention design process incorporating human-centred design methods into the design, delivery and evaluation of behavioural interventions (Aunger & Curtis, 2016). The prominent steps during the phase-based design process are firstly, setting a clear behavioural goal in meeting the behavioural challenge; secondly, building an understanding of the behavioural determinants, specifically the underlying human motives; thirdly, designing an intervention linking the goal-related motives to touchpoints in a proposed campaign sequence; fourthly, implementing the proposed intervention in a real-world environment; and, finally, evaluating the intervention process and outcome (Aunger & Curtis, 2016).

Setting a clear behavioural goal in meeting a specific challenge

Aunger and Curtis (2016) propose setting a clear behavioural goal to guide the design and delivery of an intervention. The behavioural goal is formulated as a synthesised response to the behavioural challenge under investigation. Central to the assessment are the intertwined material and socio-institutional factors that powerfully shape human behaviour, influencing the distribution of wealth, income, knowledge and competencies in society (Aunger & Curtis, 2016).

Understanding human motives linked to the behavioural goal

Unique to the BCD approach is successfully incorporating the complex motives directing nearly all human behaviour (Aunger & Curtis, 2016). The fifteen preeminent motives are categorised according to biophysical, emotional and learning motives arising primarily from evolutionary adaptations (Aunger & Curtis, 2016). The biophysical motives shared with other vertebrates and invertebrates are satisfied by passing resources from the environment into the body (e.g., food for hunger and heat for comfort) or avoiding the loss of internal resources (e.g., the disgust of rotting food or fear of fire) (Aunger & Curtis, 2016).

Creative mapping of touchpoints to underlying goal-linked motives

The BCD approach recommends the creative mapping of key motives to a series of touchpoints to achieve the overriding behavioural goal in an intervention (Aunger & Curtis, 2015; 2016). Drawing on design literature and practice, the BCD approach describes touchpoints as the points of contact or interaction between people in an intervention (Clatworthy, 2011). Unique to a BCD approach is linking the distinct human motives determining behaviour to points of interaction (i.e., touchpoints) in an intervention (Aunger & Curtis, 2015; 2016).

Evaluation of the design and delivery of interventions

The final key aspect of a BCD approach outlines the inclusion of appropriate research methods and instruments for a reliable assessment of the design and delivery of behavioural interventions (Aunger & Curtis, 2015; 2016). The BCD literature provides a comprehensive set of analytical methodologies for increasing the validity and reproducibility of a BCD implementation (Aunger & Curtis, 2015; Aunger, White, Greenland *et al.*, 2017). These methods can include observations of behaviour and discrete evaluations of actual behavioural outcomes (Aunger, 2003; Aunger & Curtis, 2015; Aunger, White, Huberts *et al.*, 2017).

Research Methodology

A case study methodology is employed in the study to assess the success of a BCD approach in influencing motives linked to the adoption of improved cooking technologies in a representative South African sample area (Yin, 2017; Creswell & Creswell, 2018).

The study proceeded with the design and delivery of a behaviour-focused intervention following the BCD approach. The insights gained from the immersion of the researcher in Dunoon, are distilled within an abridged framework articulating a behavioural goal and a summary of goal-linked motives. A clear behavioural goal is set in response to the behavioural challenge. Critical aspects of a testable intervention were then created using a co-creative workshop method around a set of motive-linked touchpoints. The case study then proceeds to outline the pilot implementation in the representative sample area. The case study culminates in the evaluation of the pilot implementation outcomes, specifically the motives targeted by the touchpoints linked to the adoption of improved cookstoves.

Data collection during the case-based intervention design process took place from February to December 2017. The case study was conducted in the representative sample area of Dunoon, Western Cape, South Africa. Mamelodi was added for the pilot implementation. The data collection instruments included structured observations of cookstove ownership and card-based choice (CBC) questionnaires before and after the interventions. The participants of the intervention campaign were envisaged to be the female caregivers and children living in the representative settings.

Setting of a clear cookstove-related behavioural goal

The behavioural goal for the specific South African intervention addressed in the study, is proposed to increase the adoption of an improved biomass stove, similar to a *Stovetec EcoZoom* and a single hob LPG stove (similar to the *KayaGAS Combo*). The deleterious health hazards associated with flame-based cooking are particularly amplified by the overcrowded living arrangements, the poorly designed and manufactured appliances and weakening social support structures, with the brunt of these effects falling on the female cooks and their children. The female cooks prepare meals with portable and cheap paraffin cookstoves or self-constructed metal barrel stoves, leading to injury and disease resulting from

hazardous emissions, burns and fires (Lloyd, 2014). A recent increase in paraffin-based cooking is further attributed to the escalating cost and unreliability of electricity supply (Tait *et al.*, 2012; Buthelezi *et al.*, 2019), despite the recent introduction of improved methanol stove alternatives. Inefficient, self-constructed biomass stoves are linked to severe respiratory problems (Matsika *et al.*, 2013; Makonese & Bradnum, 2018). Many improved biomass stoves have been introduced over the years without success (De Chastonay *et al.*, 2012). South Africa's use of LPG among low-income households remains conspicuously low globally, compared to similar emerging countries (Kojima *et al.*, 2011). Price controls and subsidies have been introduced in response (Buthelezi *et al.*, 2019). Many LPG stoves are available in stores with a negligible localised focus on low-income households (Tatham, 2013).

Explorative framing of cookstove-related motives

Immersive nonparticipant observations by the researcher in the Dunoon study area were undertaken to develop a broad understanding of the motives related to under-resourced South African households using flame-based cooking appliances—as described and applied by Suri (2006) and Aunger and Curtis (2016). A framing is employed to synthesise insights in a guiding framework for the design of an intervention comprising contextually-related motives drawing on primary and secondary data (Aunger & Curtis, 2015; Kar & Zerriffi, 2018).

Guided by the categories suggested by Aunger and Curtis (2016), the motives associated with using flame-based cookstoves, summarised and tabulated in Table A1 12, and most frequently addressed in the literature, include hoarding stoves and fuels as scarce resources and the motives of social affiliation and status. The reasons for switching to a better cookstove are primarily unrelated to gains in long-term respiratory health (Goodwin *et al.*, 2015; Lambe & Senyagwa, 2015). The motives for reappraising particular flame-based cooking sequences are commonly linked to financial incentives paired with social support or status expression (Goodwin *et al.*, 2015). The motives of hunger, comfort, fear and disgust related to the daily grind of poverty are proposed for inclusion in a prospective intervention. The motives categorised by hoarding, creativity, affiliation and status are included. Motives for learning linked to curiosity and play are included, which could act as possible touchpoints in an intervention. Motives of lust, love and attraction are excluded from further investigation due to the complexity and rapidity of changes observed in gender roles at home and in the workplace in South Africa.

Table A1 12. Individual motives linked to flame-based cookstoves

Motive	Description of Behavioural Motives
Hunger	Food is primarily cooked to still hunger in impoverished settings, rather than luxury (Maré & Annegarn, 2017). Exposure to aromas is frequently targeted in triggering hunger to sell food (Ramaekers *et al.*, 2014).
Comfort	Comfort is frequently targeted by tailored stove features (i.e., portability or stability when used on untiled and uneven surfaces) (Evans *et al.*, 2017). Comfort is furthermore derived from heating homes with flame-based stoves in the colder winter months (Makonese *et al.*, 2016).

Fear	Fear of injury from gas and paraffin stove explosions or fire is observed (Barnes *et al.*, 2009). The fear of accidents with LPG stoves is attributed to the inferior quality of stoves and a lack of knowledge on how to cook with gas safely (Tatham, 2013).
Disgust	Disgust is frequently linked to flame-based cookstoves. Disgust motives are linked to the taste of food cooked over paraffin stoves (Lloyd, 2014). Disgust is attributed to the pungent smell of paraffin or smoke associated with dirty homes and clothes (Lloyd, 2014).
Nurture	The maternal nurture motives are linked to the hazards of unimproved flame-based stoves (Harold *et al.*, 2013). Nurture motives can be targeted as the women cook, nurture and care for their children close to where the meals are being prepared in cramped settings (Lusinga & de Groot, 2019).
Hoard	Resource scarcities are strongly linked to hoarding motives. The level of poverty strengthens the motive to hoard multiple cookstove types and fuels to meet the many competing household needs and hedge against the unpredictable socio-economic circumstances (van der Kroon *et al.*, 2014).
Create	Creative motives are observed in the wide variety of culinary routines and recipes observed in preparing meals under severe constraints (Bikombo, 2014) as exemplified by the creative adaptations in preparing steam bread (Chirwa *et al.*, 2010).
Affiliation	Affiliation motives to build trust and strengthen social cohesion is observed through the sharing of food or cooking together (Viljoen, 2010). Cooking with family and friends maintains social relationships, forms alliances and establishes norms (Kar & Zerriffi, 2018). Social pressure to adopt novel cooking appliances has found success (Lambe *et al.*, 2018).
Status	Status is frequently recommended in cookstove interventions (Lloyd, 2014; Hamerman, 2016). An improved stove could be linked to the perception of a higher standard of living. Low status is associated with the odours emanating from poorly constructed wood and paraffin stoves (Lloyd, 2014).
Justice	Justice is frequently and ineffectively targeted by regulatory means in South Africa to trigger shame followed by sanctions or fines associated with using unimproved cookstoves (Kimemia *et al.*, 2018). Illegal electric connections and unsafe paraffin stoves proliferate despite the regulations and standards (Kimemia *et al.*, 2018).
Curiosity	Curiosity could be linked to cooking luxurious foods with a novel, improved stove (Beltramo *et al.*, 2015). In a Malawian case study, a novel stove piqued curiosity, leading to the transgression of social norms (Ardrey, 2016).
Play	Play motives can be linked to learning how to use an improved stove in simulated activities, demonstrating the dangers without the risks of injury (Altarriba Bertran *et al.*, 2019). Improved cookstove interventions are frequently accompanied by the physical controlled demonstration of candidate cookstoves (Nuwarinda, 2010; Evans *et al.*, 2017).
Love and Attraction	The ability to cook, linked to the collection of firewood and food preparation to attract a partner in a South African context, is still observed yet has diminished in importance (Matinga & Clancy, 2020). The preparation of romantic meals is less common to all genders and orientations in low-income contexts (Ojong & Ndlovu, 2016).

Co-creative mapping of campaign touchpoints and motives for an intervention

A series of collaborative workshop-based activities served to map out the pertinent touchpoints and motives for an intervention campaign guided by the framework (Mor *et al.*, 2012; Lockton *et al.*, 2013; Kwon, 2016). The co-creative mapping of intervention sequences and touchpoints were facilitated by BREADrev, a local change agency with experience in the design and implementation of local community interventions, in partnership with participants drawn from Dunoon (Figure A1 53).

Figure A1 53. Facilitated baking sequence with improved biomass oven at a community bakery training school (July 2017)

The mapping of the workshop-based activities proposed a community bread-baking intervention adapted from similar BREADrev initiatives. Two sequences were suggested following existing local recipes. The first sequence is intended to trigger the increased adoption of improved biomass stoves (similar to the Stovetec EcoZoom). It proposes an amended baking demonstration, centred around an improved biomass oven, performed by trained change agents drawn from the local community. The touchpoints for the first sequence of baking bread with an improved biomass oven and the second sequence of serving tea with an LPG stove comprise the following:

T01:   Showing the lighting of the novel, improved biomass oven to instil the motive of curiosity.

T02:   Exposing beneficiaries to the warmth of an improved biomass oven linked to the comfort usually provided by imbaula stoves.

T03:   Spreading the appealing aroma of freshly baked scones emerging from the improved biomass oven to spark hunger motives.

T04:   Baking a variety of local scone recipes together during the first biomass sequence triggers the motive for playful learning.

T05:   Showing the fuel savings associated with the improved biomass oven to revalue motives related to hoarding household resources.

T06:   Accentuating a clean cooking stage where clothes remain smoke- and odour-free during the biomass sequence, targeting status motives.

T07:   Sharing scones triggers motives for affiliation associated with cooking together in shared settings.

The second sequence is intended to trigger the increased adoption of LPG double hob stoves (similar to the KayaGAS offering) through the demonstration of serving snacks and tea prepared with an LPG stove by trained change agents. The intervention touchpoints included in the second sequence are:

T08: Lighting an LPG stove repeatedly to reduce the fear associated with LPG appliances.

T09: Demonstrating an auto-ignition switch on a high-quality LPG stove during the LPG sequence to target status motives.

T10: Releasing a briefly lit paraffin stove's pungent smell to spark disgust.

T11: Exhibiting the warmth emanating from an LPG heater linked to the comfort usually provided by paraffin heaters.

T12: Viewing an uncontrolled paraffin conflagration triggers the motive of fear linked to paraffin appliances.

T13: Serving tea and scones with the participating beneficiaries and facilitating light-hearted banter while preparing the tea together during the LPG sequence ensures a safe and relaxed atmosphere to facilitate the affiliation motive.

Delivery of the intervention campaign

The case study proceeded with the pilot delivery of the intervention campaign in the representative sample area of Dunoon as depicted in Figure A1 54 and Figure A1 55. The second pilot implementation in Mamelodi is described in the thesis. The pilot implementation was facilitated by BREADrev with a team of three trained facilitators guided by the mapped campaign sequences and touchpoints.

Figure A1 54. Baking of scones with the improved biomass oven by trained Breadrev facilitators in Dunoon

Figure A1 55. Sharing of scones baked with the improved biomass targeting affiliation motives

Evaluation of the case-based intervention design and delivery

The case study concluded with a survey of changes in cookstove-related motives linked to the intervention touchpoints assisted by a CBC questionnaire in the sample area before and after the pilot implementation (Segelström, 2010; Dziegielewski, 2011; Yin, 2017). Structured observations of cookstove ownership complemented the questionnaire.

The CBC section of the questionnaire consisted of a set of 36 cards to assess the touchpoints by targeted motive (i.e., hunger, fear, disgust) linked to locally available and affordable improved flame-based appliances categorised by the three fuel types (i.e., biomass, LPG and paraffin). The survey employed a visual CBC design with choice sets depicting photos of real stoves linked to visualisations of each motive reflecting the stove attributes under investigation (Figure A1 56).

Figure A1 56. Pre-coded list of illustrated cookstove-related motives

Each card-based question collected ordinal data assessing each motive's perceived positive or negative connotation to the three stove types rated as binary choices of *agree* and *disagree* with the added option of *neutral/don't know*. Each level was visually represented with a "thumbs up", "neutral" and "thumbs down" icon below each stove image on each card (Figure A1 57). A short pre-coded descriptive narrative of each depicted motive was prepared. Similarly to the assessment of motives, the structured observations of stove ownership were characterised as nominal data (i.e., yes, no, and other/don't know) for each stove type categorised by fuel type. The assessment is augmented by statistical analyses of the collected survey data.

Figure A1 57. Sample cards depicting the pre-coded list of behavioural motives targeted by the selected intervention touchpoints

The evaluative survey was administered before the pilot implementation in Dunoon to provide a control group for assessing the intervention. The intervention campaign was then piloted in the sample area. Six months later, the survey was repeated. The respondents were asked to react to the illustrated cards. The responses were recorded, with the choices marked and filed with each consent form.

A control group of 100 respondents were selected in Dunoon from a larger-screened sample of residents in cooperation with the local council office. For the post-intervention sample group, 100 respondents were again randomly selected from households sourced from Dunoon.

The responses were then scanned for completeness. One response set was rejected for the control group and three for the post-intervention group. The observed stove ownership was compared in the control group before and after the intervention to assess for changes in stove ownership patterns and motive levels between the respondents exposed to the intervention (endline) and those not exposed to the intervention (baseline). The effect of the exposure to the intervention was assessed by calculating the difference in the differences of the changes (i.e., difference-in-differences approach) in stove ownership between the exposed and unexposed respondents adjusted for the control group as suggested by Gautam *et al.* (2017). A non-parametric two-sample Wilcoxon rank-sum test was applied (i.e., Mann-Whitney U) to compare the difference in the differences and to estimate statistical support.

The mean proportions of the observed stove ownership for the selected stove categories were compared in the control group before and after the intervention to assess whether an increase in improved flame-based cookstove ownership was achieved as a result of the intervention exposure. The data were separated by the sample groups exposed and unexposed to the intervention, and then assessed by calculating the difference in the differences of the changes adjusted for the control group.

The CBC results of the groups were then screened and collated according to a baseline of respondents exposed or not exposed to the intervention. Statistical support for exposure to the intervention leading to a revaluation of the selected motivations targeted by the linked touchpoints was assessed by comparing the mean differences in the stove-related motivations between the control and post-intervention groups at baseline and endline collected through the SP survey. The intra-group correlation coefficient was again calculated to compare the means and estimate statistical support.

The results were finally tabulated and arranged by the change in ownership of cookstoves differentiated by fuel type, and changes in the revaluation of the targeted touchpoint-related motives in response to the pilot implementation.

Results

The results of the survey conducted before and after the abridged BCD intervention implementation in Dunoon indicate the majority of touchpoints achieved significant success in influencing the selected cookstove-related motives of the sampled households. The CBC results were further corroborated by an observed shift in household cookstove ownership patterns targeted by the intervention. The results record an increase in the adoption of LPG stoves and improved biomass stoves. Nevertheless, no significant reduction in paraffin stove ownership levels has been recorded.

Changes in observed stove ownership levels

The structured observations recorded during the household survey indicate a successful shift in the ownership patterns of flame-based cooking appliances after interventions, as depicted in Table 2. A key result was the significant increase in LPG stove ownership of 23.9% (P = 0.044). A significant increase of 18.0% in biomass stove ownership (P = 0.049) was observed. The differences in observed cookstove ownership patterns for paraffin stove types between the control and post-intervention populations were not large enough to be statistically significant.

Table A1 13. Change in flame-based stove ownership patterns for Dunoon (direct comparison of difference-in-differences adjusted for control)

Stove Ownership by Energy Carrier	Control			Post-Campaign Unexposed				Post-Campaign Exposed				Effect Size (difference in differences)[a]			
	n=99	%	SD	n=53	%	SD	P-val.	n=44	%	SD	P-val.	% exp.	% unexp.	% DID	P-val.

Biomass stove	58	58.6	0.5	23	43.4	0.5	0.161	27	61.4	0.5	0.009	2.8	-15.2	18.0	0.049
Paraffin stove	37	37.4	0.5	12	22.6	0.5	0.235	13	29.5	0.5	0.360	-7.8	-14.7	6.9	0.538
LPG stove	16	16.2	0.4	3	5.7	0.2	0.009	13	29.5	0.3	0.243	13.4	-10.5	23.9	0.044

[a] Significant differences at α=0.05.

Changes in touchpoint-linked motives

The difference-in-differences (DID) statistical analysis (Table A1 14) indicates significant changes in touchpoint-linked motives between households surveyed in the control and post-intervention sample at baseline (i.e., not exposed to the intervention) and endline (i.e., exposed to the intervention).

Curiosity motives linked to biomass stoves targeted by the first touchpoint (T01 in Table A1 14) showed an unreliable result. Comfort motives linked to improved biomass stoves (T02 in Table A1 14) showed an insignificant result. Hunger motives linked to improved biomass stoves (T03 inTable A1 14) showed an insignificant response to the intervention. The implementation showed an increase in play motives linked to biomass stoves (T04 in Table A1 14) by 21.4% (P = 0.003). After adjusting for the baseline prevalence, the intervention increased hoarding motives (T05 in Table A1 14) linked to biomass stoves by 34.3% (P = 0.003). After adjusting for the baseline prevalence, the status motives linked to biomass stoves (T06 in Table A1 14) result was unreliable. Affiliation motives linked to biomass stoves (T07 in Table A1 14) increased significantly by 28.5% (P = 0.005). The intervention campaign decreased fear motives linked to LPG stoves (T08 in Table A1 14) by 31.2% (P = 0.008). Status motives linked to LPG stoves (T09 in Table A1 14) increased significantly by 15.8% (P = 0.004). The intervention significantly increased disgust motives linked to paraffin stoves (T10 in Table A1 14) by 27.5% (P = 0.005). No significant changes in comfort motives linked to LPG stoves (T11 in Table A1 14) were recorded. The implementation achieved a significant increase in fear linked to paraffin stoves (T12 in Table A1 14) of 12.8% (P = 0.005). Changes to motives of affiliation linked to LPG stoves (T13 in Table A1 14) showed a significant increase of 48.6% (P = 0.008) post-campaign.

Table A1 14. Changes in cookstove-related motives for Dunoon (direct comparison of difference-in-differences adjusted for control)

Touchpoint-linked Stove Motives	Control			Post-Campaign Unexposed				Post-Campaign Exposed				Effect Size (difference in differences)[a]			
	n = 99	%	SD	n = 53	%	SD	P-val.	n = 44	%	SD	P-val.	% exp.	% unexp.	% DID	P-val.
T01 Curiosity (biomass)	72	72.7	0.9	41	77.4	0.8	0.441	34	77.3	0.8	0.562	4.6	4.6	-0.1	0.564
T02 Comfort (biomass)	41	41.4	1	28	52.8	1	0.147	25	56.8	1	0.092	15.4	11.4	4.0	0.098
T03 Hunger (biomass)	11	11.1	0.3	5	9.4	0.3	0.745	6	13.6	0.3	0.681	2.5	-1.7	4.2	0.684
T04 Play (biomass)	42	42.4	1	26	49.1	1	0.439	31	70.5	0.9	0.002	28.0	6.6	21.4	0.003
T05 Hoard (biomass)	49	49.5	1	30	56.6	1	0.44	40	90.9	0.6	<0.001	41.4	7.1	34.3	0.003
T06 Status (biomass)	56	56.6	1	19	35.9	1	0.012	23	52.3	1	0.686	-4.3	-20.7	16.4	0.694
T07 Affiliate (biomass)	19	19.2	0.8	9	17.0	0.8	0.737	20	45.5	1	0.003	26.3	-2.2	28.5	0.006
T08 Fear (LPG)	85	85.9	0.7	37	69.8	0.9	0.038	17	38.6	1	<0.001	-47.2	-16.1	-31.2	0.008
T09 Status (LPG)	47	47.5	1	35	66.0	0.9	0.022	36	81.8	0.7	<0.001	34.3	18.6	15.8	0.004
T10 Disgust (paraffin)	75	75.8	0.4	36	67.9	0.5	0.317	42	95.5	0.2	<0.001	19.7	-7.8	27.5	0.005
T11 Comfort (LPG)	78	78.8	0.8	39	73.6	0.9	0.559	37	84.1	0.7	0.447	5.3	-5.2	10.5	0.449
T12 Fear (paraffin)	78	78.8	0.4	45	84.9	0.4	0.345	43	97.7	0.2	<0.001	18.9	6.1	12.8	0.005
T13 Affiliation (LPG)	47	47.5	0.5	20	37.7	0.5	0.249	38	86.4	0.3	<0.001	38.9	-9.7	48.6	0.008

[a] Significant differences at α=0.05.

Conclusions

There is growing evidence to suggest that behavioural design approaches are critical components in disseminating improved flame-based cookstoves at scale. The results of this study indicate that the application of a BCD approach could assist in understanding and influencing the critical cookstove-related motives of South African households leading to increased adoption of improved cookstove alternatives.

A key finding indicates that intervention campaigns accommodating motive-linked touchpoints could significantly increase the use of improved stoves. Respondents changed their stove-linked motives to improved stove options when exposed to the piloted intervention.

The structured observations of cookstove ownership in the sample area confirmed that exposure to the pilot implementation achieved the increased adoption of improved flame-based cookstoves, specifically, an increase in the ownership of biomass stoves and LPG stoves. The card-based survey administered in the sample area indicated a revaluation of cookstove-related motives targeted in the co-created intervention. When exposed to the selected touchpoints, the change in observed cookstove ownership and differences in motive-linked stove preferences confirmed the intervention's efficacy in influencing the adoption of flame-based cookstoves.

Despite the study being limited to the South African sample area, the sample selection criteria were based on the main factors that households using inefficient cookstoves exhibit, implying a broader relevance of the findings. The study may have important implications beyond disseminating clean and efficient cookstoves. Behavioural design approaches could significantly assist the development of behaviour change programmes in addressing the complex challenges affecting low and middle-income households. The centrality of a primary behavioural goal informed by a deep understanding of the stove-linked motives and their inclusion in co-created interventions has far-reaching implications. This more profound understanding of the cookstove-related motives is predicated on using integrated behavioural design approaches at the outset of SDG-focused interventions. The study demonstrates that the valuable role of a well-structured BCD approach can enhance the success of interventions aimed at behavioural change.

Appendix II   Behavioural Design Theories, Approaches, Models and Frameworks

Appendix II provides an alphabetical list of the main behaviour change design frameworks, models and theories. In each case the name of the theory and a brief description is provided.

Action Theory Model of Consumption

The Action Theory Model of Consumption is a micro model of consumption that aims to explain the processes involved in purchasing an item or a service (Bagozzi, 1974). The theory considers rational cognitive processes and the influence of habitual, non-conscious, emotional and social processes (Bagozzi, 1974).

Affective Events Theory

Affective Events Theory aims to explain how compelling experiences (i.e., experiences relating to moods, emotions and attitudes) affect job satisfaction and performance (Weiss *et al.*, 1999). It focuses on the structure, causes and consequences of affective experiences at work and explores their direct effects on attitudes and behaviours (Weiss *et al.*, 1999).

Aids Risk Reduction Model

The AIDS risk reduction model attempts to explain and facilitate the study of HIV-protective behaviours (Catania *et al.*, 1990). The model conceptualises the behaviour change process in three stages (labelling, commitment and enactment) and outlines social, psychological and emotional factors that influence progress through these stages (Catania *et al.*, 1990).

Assisting Behaviour Change

The Assisting Behaviour Change (ABC) approach assists awareness-raising and education interventions to encourage behaviour change (Gallagher *et al.*, 2018). The ABC process utilises ten steps, with a strong focus on formative research (Gallagher *et al.*, 2018).

Behaviour Centred Design

The BCD approach developed by the London School of Hygiene and Tropical Medicine emerged from WASH approaches and applied to other nutrition and health-related sectors, including food hygiene, particularly for infants and young children (Aunger & Curtis, 2015b).

Behavioural Motivations Model

The behaviour motivations model informing the BCD approach has achieved behaviour change in large-scale public health interventions in real-world low-income contexts (Aunger & Curtis, 2015a). It emphasises behaviour as a complex, dynamic interaction between bodies and environments (Aunger & Curtis, 2015a).

Behaviour Grid Model

The Behaviour Grid Model guides on achieving successful behaviour change (Fogg, 2009). Fogg describes the Behaviour Grid as 15 ways to change behaviour (Fogg, 2009). Fogg contends that behaviour is systematic and only occurs when three elements converge simultaneously: motivation, ability, and a trigger (Fogg, 2009). Therefore, to achieve behaviour change, it is necessary to select the correct target behaviour, make the target behaviour easy to do and ensure a trigger will prompt behaviour (Fogg, 2009).

Behavioural Change Wheel Model

Michie, van Stralen and West (2011) developed a behaviour change wheel to help identify and develop behaviour change primarily for health reasons (Michie *et al.*, 2011). The behaviour change wheel model seeks to capture behavioural factors and the different interventions used to change behaviours (Michie *et al.*, 2011). The centre of the wheel articulates the motivations, capabilities and opportunities for behaviour change (Michie *et al.*, 2011). The centre is surrounded by nine possible intervention types: education, persuasion, incentive, coercion, training, enablement, modelling, environmental restructuring, and restrictions (Michie *et al.*, 2011). The outer circle of the wheel sets out policy characteristics which could enable the interventions (Michie *et al.*, 2011).

Behavioural Economic Theory

Behavioural economic theory unifies psychology and economics and is concerned with decision-making that ranges from small to significant decisions (Thaler, 2016). Behavioural economics deals with how such everyday decisions can be influenced, providing a set of principles that can lead to the design of better products and services (Thaler, 2016). Essentially the approach is about understanding and overcoming (or exploiting) cognitive biases through restructuring choice environments (Thaler, 2016). The failure of the neoclassical model of behavioural economics that assumes that people behave with a rational self-interest has led to the development of more realistic behavioural economic theories (Thaler, 2016).

Behavioural Infrastructure Model

Behavioural infrastructures are designed to make the performance of a specific behaviour possible (e.g., Enable recycling by making recycling facilities available) (Christmas *et al.*, 2009). The primary focus is to enable Individuals to overcome barriers preventing the performance of the desired behaviour (Christmas *et al.*, 2009). Changing a behavioural infrastructure is usually beyond the individual's ability (Christmas *et al.*, 2009). due to the plethora and complexity of behavioural factors (Christmas *et al.*, 2009). The model was conceived to support and structure behaviour by gathering evidence, listening to different viewpoints, and evaluating the tailormade behaviour change policy or intervention and interventions structured around nine questions (Christmas *et al.*, 2009).

Behavioural-Ecological Model of Adolescent Aids Prevention

The Behavioural-Ecological model of Adolescent AIDS Prevention aims to guide effective strategies to change adolescent sexual risk behaviour (Hovell *et al.*, 1994). The model blends learning theories within a socio-ecological model of behaviour and proposes that experiences of reward and punishment for sexual behaviours play a central role in determining safe or unsafe sexual behaviours (Hovell *et al.*, 1994).

Change Theory

Change theory describes a three-stage process of social change (i.e., unfreezing, movement and freezing (Lewin, 1952). Change or lack of change occurs due to the balance between opposing driving and restraining forces (Lewin, 1952).

Choice Architecture Approach

Originating from behavioural economic theory, the choice architecture approach of Thaler and Sunstein (2008a) considers how people make choices and intentionally defines and predetermines a default option that requires individuals to take active steps to select another option (Johnson & Goldstein, 2003; Thaler & Sunstein, 2008b). The choice architecture approach draws on social and psychological theories to nudge behaviour (Tversky & Kahneman, 1981; Gawronski & Keith Payne, 2011). The choice architecture approach assumes that the design of a product or service can shape choices (Thaler *et al.*, 2014; Niedderer *et al.*, 2017).

Classical Conditioning

According to Pavlov's original formulation, classical conditioning theory describes how innate responses to stimuli can become elicited by a previously 'irrelevant' stimulus through repeated presenting the irrelevant stimulus after the original stimulus (Pavlov, 1927). It also proposes factors that can influence this process (Pavlov, 1927).

COM-B System

The COM-B model conceptualises behaviour as a part of a system of interacting elements involving capability, opportunity and motivation (Michie *et al.*, 2011). For any behaviour to occur at a given moment, there must be the capability and opportunity to engage in the behaviour, and the strength of motivation to engage in it must be greater than any competing behaviours (Michie *et al.*, 2011).

Community-Based Social Marketing Framework

The Community-Based Social Marketing (CBSM) framework applies the psychological principles of behavioural change (McKenzie-Mohr, 2011). CBSM has been developed to execute effective socially based marketing campaigns (McKenzie-Mohr, 2011). To facilitate change, CBSM incorporates norms, incentives, prompts, communication, commitments and removing barriers (McKenzie-Mohr, 2011). The model incorporates aspects of industrial design in the four steps of the CBSM process (McKenzie-Mohr, 2011).

Consumption as Social Practices

Consumption as Social Practices theory aims to explain consumer behaviour, focusing on pro-environmental domestic behaviour (Spaargaren & Van Vliet, 2000). It describes a mutual dependency between domestic consumers and external systems that provide domestic goods, where consumers cannot engage in environmentally sustainable lifestyles unless external systems provide facilitative goods and consider consumers' domestic practices (Spaargaren & Van Vliet, 2000).

Containment Theory

Containment Theory is a theory of deviant behaviour (Reckless, 1961). It proposes that people are subject to an internal and external control system, each regulating the conduct and preventing deviant behaviour (Reckless, 1961).

Control Theory

Control Theory is a theory of the processes underlying the regulation of human behaviour (Carver & Scheier, 1982). It proposes that behaviour is regulated by a negative feedback loop, in which a person's perception of their current state is compared to a goal state (Carver & Scheier, 1982). According to the theory, people strive to reduce perceived discrepancies between the two states by modifying their behaviour (Carver & Scheier, 1982).

Design for Healthy Behaviour Model

The Design for Healthy Behaviour Model proposes four design strategies that spread over multiple stages: 'raising awareness', 'enabling', 'motivating' and 'fading out' (Ludden & Hekkert, 2014). The model suggests that designers must consider the different stages people go through to change their behaviour (Ludden & Hekkert, 2014).

Design for Sustainable Behaviour Model

The Loughborough Model aligns closely with behavioural economics, drawing on feedback, constraints and affordances, and persuasive technology (Lilley, 2009). Most examples cited in the Loughborough model relate to providing feedback to energy and water users, especially concerning feedback devices for energy and water-saving (Lilley, 2009). It predominantly addresses product designers (Lilley, 2009). Lilley (2009) posits that designs should respond to the users' level of compliance, the gravity of the consequences of actions taken and the context in which the interactions take place (Lilley, 2009). In real-life design contexts, the way a client or other stakeholders frame the brief, and assumptions about what the 'problem' is, can influence the extent to which a designer can 'intervene' and where interventions can be positioned (Lilley, 2009). It is acknowledged that knowing where to position interventions is complex, and this is a challenge for designers (Lilley, 2009).

Designing for Behaviour Change

DfBC grew out of AED's BEHAVE Framework, the CORE Group's Social and Behaviour Change Working Group, Food Security and Nutrition Network Social and Behaviour Change Task Force, Food for the Hungry and TOP, among others. (Wendel, 2013). origins in 2000 (Wendel, 2013). WASH, Food Security, Agriculture, Nutrition, Natural Resource Management, Gender (Wendel, 2013). Analysis and design include identifying monitoring indicators but do not include implementation of BC activities or detail on choosing activities or developing communications (Wendel, 2013).

Designing Moralised Products

Jelsma's (2006) Designing Moralised Products sees products as actors, driving routine actions (Jelsma, 2006). Jemma's design process incorporates user logic and "scripts" to encourage the desired interaction with products (Jelsma, 2006). This process aims to first understand the "folk logic" of everyday routines (or cognitive models) prior to designing scripts into artefacts that may direct the user towards the desired use (Jelsma, 2006). The model parallels Lockton's use of mental models introduced above and the architectural choice model (2013) (Jelsma, 2006). Specific material features of the artefacts are involved (Jelsma, 2006). those of cup, saucer and spoon in coffee drinking) support and guide the actions of the user (Jelsma, 2006). Realising this, we perceive artefacts differently (Jelsma,

2006). The changes in perception imply that the artefacts are co-responsible for how the action develops and for what results (Jelsma, 2006). If we waste energy or produce waste in routine actions, such as household practices, this depends on how artefacts guide us (Jelsma, 2006).

Differential Association Theory

Differential Association Theory is a theory of criminal behaviour which proposes that people engage in criminal behaviour due to their life experiences, the presence of situations that facilitate criminal behaviour and the degree to which they associate with criminal and non-criminal individuals (Sutherland, 1947).

Diffusion of Innovations

Diffusion of Innovations Theory explains how people or social groups adopt or reject a new idea, behaviour, or object (Rogers, 1983). It specifies numerous mechanisms for achieving adoption or rejection and factors that facilitate adoption (Rogers, 1983).

Dimensions of Behaviour Change Model

The Dimensions of Behaviour Change framework, developed by Daae and Boks (2014), provides a toolkit of behavioural methods disseminated through a deck of cards (Daae & Boks, 2014). The framework guides the facilitator through the process of specifying techniques for influencing behaviour focusing on sustainability (Daae & Boks, 2014). The tool was developed based on existing literature and five workshops with design practitioners, which were used to identify multiple behavioural techniques, categorised into nine dimensions (Daae & Boks, 2014). The framework appears to build on the framework developed by Lidman & Renström (2011), which approaches a design problem in the field of sustainability through the lenses of enlighten, spur, steer, force and match (Daae & Boks, 2014).

Ecological Model for Preventing Type 2 Diabetes in Minority Youth

The Ecological Model for Preventing Type 2 Diabetes in Minority Youth emphasises the need to target individual-level cognitive and environmental-level institutional and social factors to promote behaviour change (Burnet et al., 2002).

Extended Information Processing Model

The Extended Information Processing Model aims to explain the processes underlying attitude and behaviour change resulting from mass media campaigns (e (Flay et al., 1980).g (Flay et al., 1980). public health campaigns) (Flay et al., 1980). It proposes five communication factors relating to the message's source, the message content and style, the channel used to transmit the message, the message audience, and the targeted issues (Flay et al., 1980). It proposes 12 steps from exposure through retention to maintenance (Flay et al., 1980).

Extended Parallel Processing Model

The Extended Parallel Processing Model aims to explain the cognitive processes and behavioural outcomes that occur in response to fear appeals and identify the factors determining whether responses to a perceived threat will be adaptive or maladaptive (Witte, 1992).

Feedback Intervention Theory

Feedback Intervention Theory explains how feedback on performance can influence behaviour and describes how the factors determining whether feedback has a positive or negative influence on performance (Kluger & DeNisi, 1996).

Focus Theory of Normative Conduct

The Focus Theory of Normative Conduct aims to explain how norms (i (Cialdini et al., 1991).e (Cialdini et al., 1991). what is most commonly done and what is most acceptable in a culture) influence behaviour (Cialdini et al., 1991). Four types of norms are described: descriptive (beliefs about what is typically done), injunctive (beliefs about what is approved or disapproved of), personal (personal beliefs and values about behaviour) and provincial (beliefs about what is typically done within a specific environment) (Cialdini et al., 1991).

General Theory of Crime

The General Theory of Crime explains what causes people to engage in criminal behaviour (Gottfredson & Hirschi, 1990). Its central tenet is that those with low self-control are more likely to engage in criminal acts than those with high self-control and that low self-control is a function of child-rearing practices (Gottfredson & Hirschi, 1990).

General Theory of Deviant Behaviour

The General Theory of Deviant Behaviour explains why people engage in deviant behaviour (Kaplan, 1972). The theory proposes that negative self- attitudes (the emotions resulting from people's evaluations of their attributes or behaviours) are the primary motivation for deviant behaviours, as engaging in such behaviours can enhance people's self-attitudes (Kaplan, 1972).

Goal-Directed Theory

The Goal-Directed theory describes the factors that influence the performance of goal-directed behaviours (Bagozzi, 1992). People form intentions to try and reach a goal based on appraisals of the means available to help them reach that goal (Bagozzi, 1992). The number of factors determines whether or not these intentions are translated into goal achievement (Bagozzi, 1992).

Goal-Setting Theory

Goal-setting theory explains the mechanisms by which goals (defined as the object or aim of an action) affect the level of task performance and how performance can be moderated by several factors, including the level of commitment, the importance of the goal, levels of self-efficacy, feedback and task complexity (Locke & Latham, 1968).

Goal-Framing Theory

Goal-framing theory proposes that goals direct the information and cognitions that people attend to (Lindenberg & Steg, 2007). The theory proposes three types of goals (hedonic, gain and normative) and states that activation of each type directs people's attention to different sub-goals, cognitions and information (Lindenberg & Steg, 2007).

Health Action Process Approach

The Health Action Process Approach is proposed as a causal model for initiating and maintaining health-related

behaviours (Schwarzer, 1992). The model incorporates a temporal perspective, making an explicit distinction between a motivation (or decision-making) phase and an action (or maintenance) phase (Schwarzer, 1992).

Health Behaviour Goal Model

The Health Behaviour Goal Model is a stage model proposing that behaviour change is most likely to occur if the target change is compatible with what is essential to a person and what they want to achieve in life (Maes & Gebhardt, 2000).

Health Behaviour Internalisation Model

The Health Behaviour Internalisation Model is a model of behavioural regulation (Bellg, 2003). It proposes that the regulation of behaviour lies along a continuum from external regulation (i (Bellg, 2003).e (Bellg, 2003). behaviour is regulated by an external source) to integrated self-regulation (Bellg, 2003). behaviour is regulated by the self and is consistent with a person's values and identity) (Bellg, 2003). A person's position on this continuum determines the likelihood of behaviour maintenance (Bellg, 2003).

Health Belief Model

The Health Belief Model explains health-risk reducing behaviours (Rosenstock, 1974). Its core proposal is that people are most likely to take preventative action if they perceive the threat of the health risk to be serious, that they are personally susceptible and if they feel there are fewer costs than benefits to engaging in protective action (Rosenstock, 1974). The Health Belief Model (HBM) was developed in the early 1950s by social scientists at the U (Rosenstock, 1974).S (Rosenstock, 1974). Public Health Service to understand people's failure to adopt disease prevention strategies or screening tests for the early detection of disease (Rosenstock, 1974). Besides, the relationships between perceived susceptibility and severity as well as perceived benefits and barriers are not well-defined in this model, which limits the applicability of the HBM and weakens the power of meta-analyses of the HBM (Rosenstock, 1974). The model focuses on the attitudes and beliefs of individuals (Rosenstock, 1974). The HBM is commonly used in many health actions, such as sexual health actions (condom use) (Rosenstock, 1974). When mapping this model to an application, the most commonly used behaviour change techniques are individual knowledge, plan social support or social change, and educational information through behaviour (Rosenstock, 1974).

Health Promotion Model

The Health Promotion Model explains the factors underlying motivation to engage in health-promoting behaviours (Pender *et al.*, 2002). The model emphasises the role of person-environment interactions in motivating health-promoting behaviour (Pender *et al.*, 2002). It describes eight behaviour-specific beliefs proposed to determine the health-promoting behaviour and to be modifiable targets for behaviour change interventions (Pender *et al.*, 2002).

Human-centred design

The approach was developed by IDEO (IDEO, 2015).org, launched by IDEO, a global design and innovation company, in 2011 (IDEO, 2015). The approach has solid

philosophical ties with social marketing in developing attractive, feasible, affordable products, services, and behaviour options (IDEO, 2015). The Stanford d.school at Stanford University (IDEO, 2015) also promotes the approach. Any intervention sector, not limited to products, also includes designing programme approaches, services and behaviour options (IDEO, 2015). For example, human-centred design has been used to design messages to motivate and enable parents to take more opportunities to encourage their young children's development or to develop a mobile app that helps young people track, share and manage their financial behaviour (IDEO, 2015). Analysis, design and implementation, though the implementation phase of the process, primarily concerns piloting and improving solutions before going full scale (IDEO, 2015).

I-Change Model

The I-Change Model integrates several behaviour change models and aims to identify psychological and social determinants of behaviour (De Vries *et al.*, 2005). It was developed from the Attitude-Social Influence-Efficacy model, which proposes that attitudes, social influences and self-efficacy are the primary determinants of behaviour and that behaviour change or initiation occurs in several stages (De Vries *et al.*, 2005).

Information-Motivation-Behavioural Skills Model of Adherence

The three main factors that affect adherence are information, motivation and behavioural skills (Fisher *et al.*, 2006). The three factors must be specific to the situation and the population in which the behaviour occurs (Fisher *et al.*, 2006). The Information-Motivation-Behavioural skills model of adherence aims to explain and predict adherence to highly active antiretroviral therapy (HAART) to inform how it can best be promoted (Fisher *et al.*, 2006).

Integrated Behavioural Model for Water, Sanitation and Hygiene (IBM-WASH)

The IBM-WASH framework applied in Kenyan, and Zimbabwean health interventions follow a flexible multi-factor behaviour change approach proposing that behaviour is influenced by the contextual, psycho-social and technological factors across differing levels of proximity spanning from the larger society to the habits of an individual (Hulland *et al.*, 2013). The contextual factors include determinants related to the individual, the setting, and the immediate environment (Hulland *et al.*, 2013). The contextual factors include social, physical and biological influences that shape behaviour (Hulland *et al.*, 2013). The psycho-social factors comprise the behavioural, social, or psychological determinants that influence behavioural outcomes and technology adoption (Hulland *et al.*, 2013). The technological factors consist of the attributes of a technology, product, or device that influence the adoption of a specific behaviour or set of behaviours (Hulland *et al.* 2013). The three factors are considered to operate at five levels of proximity, ranging from the habitual, individual, and community to the infrastructural level of society, as depicted in the figure above (Hulland *et al.*, 2013).

Integrated Theoretical Model for Alcohol and Other Drug Abuse Prevention

The Integrated Theoretical Model for Alcohol and Other Drug Abuse Prevention combines the Health Belief Model, Social Learning Theory and Problem Behaviour Theory to provide a framework for preventing alcohol and drug abuse

on university campuses (Gonzalez, 1989). The model emphasises the importance of both intrapersonal and environmental factors in facilitating behaviour change (Gonzalez, 1989).

Integrated Theory of Drinking Behaviour

The Integrated Theory of Drinking Behaviour is a 'meta-theory' that integrates ideas from a range of other theories of drinking and aims to identify the factors that determine alcohol consumption in young people (Wagenaar & Perry, 1994). The model emphasises the role of social interactions in determining drinking behaviour and the importance of changing socio-environmental conditions to facilitate long-term reductions in alcohol consumption (Wagenaar & Perry, 1994).

Integrated Theory of Health Behaviour Change

The Integrated Theory of Health Behaviour Change aims to explain the adoption of self-management behaviours (Ryan, 2009). Three main factors are proposed to facilitate behaviour change: knowledge and beliefs, self-regulatory skills and abilities, and social facilitation (Ryan, 2009).

Integrative Model of Behavioural Prediction

The Integrative Model of Behavioural Prediction is a development of the Theory of Planned Behaviour (Fishbein, 2000). The model emphasises the importance of two additional factors, environmental constraints and skills/ability, which influence behaviour over and above the effect of behavioural intentions (Fishbein, 2000).

Integrative Model of Factors Influencing Smoking Behaviours

The Integrative Model of Factors Influencing Smoking Behaviour aims to identify the determinants of smoking behaviour during adolescence and to describe the developmental stages in which smoking behaviour occurs (Flay et al., 1983). It proposes four stages in the acquisition of smoking behaviour: preparation and anticipation, initiation, experimentation, and regular smoking (Flay et al., 1983). It proposes different types of influence in transition between the different stages (Flay et al., 1983).

Integrative Model of Health Attitude and Behaviour Change

The Integrative Model of Health Attitude and Behaviour Change integrates several social and behavioural psychology theories and describes how mass media health promotion campaigns can lead to changes in health-related attitudes and behaviours (Flay, 1981). Change occurs in sequential stages: messages influence knowledge, beliefs and attitudes, leading to changes in behavioural intentions and finally behaviour change (Flay, 1981).

Mental Models Approach

Designers often use the mental models' approach to deepen their understanding of human behaviour (Gentner & Stevens, 2014). Mental models can be broadly described as understanding a system and its constituent parts (Gentner & Stevens, 2014). The mental models' approach allows designers to develop focused actions and explain the results of the sequence of actions (Gentner & Stevens, 2014). Within a human-centred design process, understanding the user's behaviour in context is critical (Gentner & Stevens, 2014). Mental models attempt to systematise the user's model underpinning their decisions (Gentner & Stevens, 2014).

MINDSPACE Model

The MINDSPACE Model (Dolan et al., 2009) was one of the models used by private and public sector stakeholders (Dolan et al., 2012). It presents guidance and a checklist of influences on behaviour for use in policy making (Dolan et al., 2012). It was developed by the UK Cabinet Office to help inform policy design to achieve effective behaviour change (Dolan et al., 2012). MINDSPACE presents the nine effects that influence our behaviour in mostly automatic (rather than deliberate) ways (Dolan et al., 2012). Dolan et al. (2012) position this in neuroscience terms as influencing 'System 1' of our brain that guides automatic, uncontrolled, effortless, associative, fast, unconscious and affective responses (Dolan et al., 2012). This model is based on the Choice Architecture model, referencing Thaler and Sunstein (2008) and Ariely (2008), and therefore is also situated in the context section of approaches (Dolan et al., 2012). It is not strictly a design model (more a straight behaviour change model) (Dolan et al., 2012).

Model of Pro-Environmental Behaviour

The Model of Pro-Environmental Behaviour proposes several intrapersonal and external factors that can contribute to environmentally friendly behaviour, alongside some intrapersonal and external barriers to pro-environmental behaviour (Kollmuss & Agyeman, 2002).

Modes of Transitions Model

The Modes of Transitions Model (Kursat Ozenc, 2014) offers designers a way to understand people going through a change process (Ozenc, 2014). The framework structures human-centred design methods to analyse and comprehend transitions combine them with scenario-based design to provide a means of action, and suggests using research-through design methods in the prototyping phase (Ozenc, 2014).

Motivation Opportunity and Ability Model

The MOA (motivation, opportunity and ability) model combines individual and contextual factors in articulating a process for behaviour change (Rothschild, 1999). The model holds that motivation, ability and opportunity are the critical behavioural determinants influencing behaviour change (Rothschild, 1999). The first determinant related to motivation is affected by our identity and attitudes rooted in the expected positive or negative outcomes of the existing behaviour (Rothschild, 1999). The second determinant of opportunity covers the environmental context at the micro and macro level (Rothschild, 1999). The micro-level refers to the personal living spaces, while the macro-level includes the marketing of foods and tax systems (Rothschild, 1999). The third determinant of the ability refers to the belief and self-efficacy to change to a specific behaviour (Rothschild, 1999). A confident person is likelier to perform a specified behaviour (Rothschild, 1999).

Needs-Opportunities-Abilities Model

Based on the Motivation-Opportunities-Abilities Model, the Needs- Opportunities-Abilities model aims to identify the factors that determine consumer behaviour (Gatersleben & Vlek, 1998). The model recognises the importance of a wide range of internal and external factors and their interactions (Gatersleben & Vlek, 1998). It proposes that consumption is determined by the needs, opportunities and abilities of a person or a household (Gatersleben & Vlek, 1998).

Norm Activation Theory

Norm Activation Theory aims to explain the decision-making process underlying altruistic behaviours (Schwartz, 1975). The central proposal of the theory is that when people perceive others to be in need, their responses are guided by the activation of personal norms, which elicit a sense of responsibility to act in a certain way (Schwartz, 1975).

Operant Learning Theory

Operant Conditioning Theory is a learning theory that describes how the frequency of behaviours can be modified through schedules of reinforcement involving reward or punishment (Skinner, 1938). The theory also details how behaviour can be 'shaped' using these processes (Skinner, 1938).

Persuasive Technology Theory

Persuasive technology has been defined as 'any interactive computing system to design people's attitudes or behaviours' (Fogg, 2009). Persuasive technology has investigated different ways in which people respond to computing technologies and how these, in turn, can be used to influence or change the performance of target behaviours or social responses (Fogg, 2009). Fogg's (2014) persuasive technology model focuses on motivation, ability, and triggers (prompts) to encourage or discourage users from acting in desired ways (Fogg, 2009).

Practice Orientated Design Models

The practice-orientated design of products and services is an emerging area that is attempting to apply the understanding of Social Practice Theory to the design of products and services to influence the trajectory of practices and behaviours (Kuijer, 2017). The human practice-oriented design model seeks to stabilise specific social practices while fundamentally changing others (Kuijer, 2017; Lackner, 2014). From a product design perspective, a change in physical artefacts is utilised to shift specifically targeted social practices (Kuijer, 2017).

Precaution Adoption Process Model

The Precaution Adoption Process Model proposes that the decision-making and behaviour change process to adopt health-protective behaviours occurs in seven distinct stages (Weinstein & Sandman, 1992). The stages range from being unaware of the threat to maintaining the newly adopted behaviour (Weinstein & Sandman, 1992). People at each stage vary in their beliefs and knowledge (Weinstein & Sandman, 1992).

Pressure System Model

The Pressure System Model is a theory of behaviour change which proposes that behaviour change is determined by opposing forces of motivation and resistance (Katz, 2001). It aims to guide behaviour change counselling in primary care and classifies five categories of people in the behaviour change process, with suggested counselling strategies for each (Katz, 2001).

PRIME Theory

The PRIME Theory of Motivation is a general theory of motivation, which provides a framework in which more specific theories of choice, self-control, habits, emotions and drives can be integrated (West, 2013). It proposes that five sub-systems make up the human motivational system

(West, 2013). These interact with each other and are influenced by the immediate internal and external environment (West, 2013). Going from close to most far in terms of moment-to-moment influence on behaviour, these involve response coordination, impulses/inhibition, motives (wants and needs), evaluations (beliefs about what is good or bad), and plans (self-conscious intentions) (West, 2013).

Problem Behaviour Theory

Problem Behaviour Theory aims to identify the underlying factors explaining the problem behaviour during adolescence (Jessor, 1987). The theory proposes that three 'systems' interact to determine a person's 'proneness' to problem behaviour: personality, behavioural, and social-environmental factors (Jessor, 1987). Each system comprises variables that act as either instigators or controls against problem behaviour (Jessor, 1987).

Product-Impact Tool

Dorrestijn's Product-Impact Tool (2012) assesses the impact of technical products on user behaviour (Dorrestijn, 2012). It assessed the Dutch RFID public transport e-payment mechanisms (Dorrestijn, 2012). The product impact tool structures the exploration of user guiding and changing effects (Dorrestijn, 2012). The person is placed in the middle of four influences: the abstract, the cognitive, the environment and the physical (Dorrestijn, 2012). The tool is one of few that seek to understand how technology (products and visions) has driven change through history (Dorrestijn, 2012).

Prospect Theory

Prospect theory is a theory of how people make decisions under uncertainty (Kahneman & Tversky, 1979). It is a development from Subjective Expected Utility Theory and proposes that people weigh the expected positive and negative outcomes of the options and compare them (Kahneman & Tversky, 1979).

Protection Motivation Theory

Protection Motivation Theory provides a model of the cognitive processes that occur in reaction to messages designed to instil fear ("fear appeals") or health threats (Rogers, 1975). Specifically, it proposes a theoretical account of the cognitive appraisal of maladaptive and adaptive responses to threats and their influence on behaviour (Rogers, 1975).

Prototype Willingness Model

The Prototype Willingness Model provides a theoretical account of the decision-making processes involved in adolescent risk behaviour (Gerrard *et al.*, 2008). It is a dual-process model, proposing a 'reasoned path' and a heuristically-based 'social reaction' path to risk behaviour (Gerrard *et al.*, 2008). In the social reaction path, a risk behaviour does not result from intention but behavioural willingness, which is influenced by social identity (Gerrard *et al.*, 2008).

Rational Addiction Model

The Rational Addiction Model is an economic model of addiction based on the idea of stable rational preferences (Becker & Murphy, 1988). It makes assumptions common to classical economics, including the idea that people behave rationally and have all the relevant information at their disposal (Becker & Murphy, 1988). Rationality is

defined as 'a consistent plan to maximise utility over time' where utility is a measure of the benefits (or losses) as the person concerned sees them (Becker & Murphy, 1988). Although addiction may seem irrational, the model's central premise is that addictions are rational in that the person maximises utility consistently over time. A good is potentially addictive if increases in past consumption raise current consumption (Becker & Murphy, 1988).

Reflective Impulsive Model

The Reflective-Impulsive Model is a dual-process model that explains behaviour as a function of two different, interacting cognitive processes: the reflective and impulsive systems (Strack & Deutsch, 2004). The reflective system involves reasoning and decision-making, whilst the impulsive system directs behaviour based on associations between stimuli and behavioural schemata (Strack & Deutsch, 2004).

Regulatory Fit Theory

Regulatory Fit Theory states that if a person's motivational orientation directing goal pursuit is congruent with the methods they are using to achieve the goal, they will be more motivated in their efforts towards goal achievement and assign more value to goal pursuit than if they are incongruent (Higgins, 2000).

Relapse Prevention Model

The Relapse Prevention Model provides a theoretical account of factors that increase or decrease the risk of relapse during abstinence from an addictive substance or behaviour, focusing on factors determining how people will react to high-risk situations for relapse (Marlatt & Gordon, 1984). It proposes explanations for the 'abstinence violation effect' in which lapses commonly lead to full relapse (Marlatt & Gordon, 1984).

Risk as Feelings Theory

Risk as Feelings Theory aims to explain decision-making and behaviour in risky situations, proposing that responses in risky situations are determined by the interaction between emotional reactions to the risk and cognitive evaluations of potential responses to that risk (Lowenstein *et al.*, 2001).

Risk Attitude Norms Ability Self-regulation Model

The Risk Attitude Norms Ability Self-regulation (RANAS) model shares similarities with other approaches such as DBC and SaniFOAM (Contzen *et al.*, 2012). RANAS was initially developed for behaviour change in the WASH sector but could be applied to other sectors and behaviour types using the same logic and methodology (Contzen *et al.*, 2012). All phases identify potential behavioural factors; measure the behavioural factors identified and determine those steering the behaviour; select corresponding behaviour change techniques (BCTs) and develop appropriate behaviour change strategies; and implement and evaluate the behaviour change strategies (Contzen *et al.*, 2012).

SaniFOAM Framework

The SaniFOAM framework has successfully been implemented in community-led hygiene improvement interventions in under-resourced contexts of Tanzania, Indonesia and India (Devine, 2009). The framework takes a multi-factor approach (Devine 2009), suggesting that behaviour change can be categorised through the following

four behavioural determinants: Focus, Ability, Opportunity and Motivation (Devine, 2009). Focus refers to the need for a clear focus and definition of the targeted behaviours, and the targeted segment of the population is critical in the commencement of a behavioural change intervention (Devine, 2009). Opportunity refers to whether the individual has the chance to perform the targeted behaviour (Devine, 2009). Ability refers to the targeted individual's capability to perform the behaviour (Devine, 2009). Motivation states that the individual must be motivated to perform the behaviour (Devine, 2009). The framework emphasises the importance of focusing on the specific segment the behavioural intervention wants to change (Devine, 2009). The category comprises the behavioural determinants of attitudes and beliefs, values, emotional/physical/social drivers, competing priorities, intention, and the willingness to pay (Devine, 2009).

Self-Determination Theory

Self-determination theory is a meta-theory (comprising five mini- theories) which aims to provide a broad framework to study motivation, personality and behaviour (Deci & Ryan, 1985). Central to the theory's explanation of behaviour is the distinction between motivation due to inherent interest or enjoyment and motivation due to external factors or controls, and people's basic need for autonomy, competence and relatedness (Deci & Ryan, 1985).

Self-Efficacy Theory

The self-efficacy theory proposes that a significant psychological mechanism underpinning behaviour change is people's beliefs that they are capable of that change (Bandura, 1977). Perceptions of self-efficacy are based on four sources of information: personal experience of success, vicarious experience of success, verbal persuasion about capability and emotional arousal (Bandura, 1977).

Self-Regulation Theory

Self-Regulation Theory outlines the cognitive processes by which people regulate or control their behaviour (Kanfer & Gaelick, 1991). The theory proposes that self-regulation depends upon people monitoring their behaviour and comparing it to a desired or acceptable standard, which determines the behavioural outcome of these self-regulatory processes (Kanfer & Gaelick, 1991).

Six Staged Model of Communication Effects

The Six Staged Model of Communication Effects synthesises four existing theories (the hierarchy of effects model, the stages of change model, social learning theory and diffusion of innovations theory) (Vaughan & Everett, 2000). The model hypothesises that mass media messages influence behaviour through identification with media characters who serve as role models and through the interpersonal communication (Vaughan & Everett, 2000).

Social Action Theory

Social Action Theory provides a framework for guiding efforts to promote behaviour change at the population level (Ewart, 1991). The theory emphasises the influence of social and environmental factors upon behaviour and outlines cognitive processes proposed to be instrumental in behaviour change (Ewart, 1991). Social Action Theory states that whilst much action might be carried out unconsciously and distinctions between types of action may not always be clear, it is conceptually essential to

distinguish social action from other types of action (Ewart, 1991). Social action may be oriented in one of four ways: instrumentally rational, value-rational, effectual or traditional (Ewart, 1991).

Social Change Theory

Social Change Theory proposes that the external environment influences community goals, norms, values and organisations, which influence social norms (shared rules and expectations) regarding health behaviours, which bring about behavioural change at an individual level (Thompson & Kinne, 1990).

Social Cognitive Theory

Social Cognitive Theory provides a framework for studying and understanding human thought and behaviour (Bandura, 1986). The central proposal of the theory is that behaviour, the environment and personal factors all interact to determine each other (Bandura, 1986). In addition, the theory proposes that human functioning can be best understood in terms of five basic capabilities for symbolic thought, forethought, observational learning, self-regulation and self-reflection (Bandura, 1986).

Social Consensus Model of Health Education

The Social Consensus Model proposes that health education aimed at individuals alone is insufficient as it fails to target potentially inaccurate but socially-supported beliefs and norms (Romer & Hornik, 1992). According to the model, health education at the broader societal level is needed to ensure that the behaviour is adopted and maintained over time (Romer & Hornik, 1992).

Social Development Model

The Social Development Model explains how delinquency and crime among young people can be prevented (Hawkins & Weis, 1985). The core tenet of the theory is that social bonding within units of socialisation such as family, peers, and school is the most influential factor in preventing delinquent behaviour (Hawkins & Weis, 1985).

Social-Ecological Model of Behaviour Change

The Social-Ecological Model of Behaviour Change emphasises the importance of embedding interventions in the social and ecological settings that contextualise human behaviour provides a theoretical account of the determinants of behaviour change, and provides a framework for the design and evaluation of behaviour change interventions (Panter-Brick *et al.*, 2006).

Social-Ecological Model of Walking

The Social-Ecological Model of Walking proposes a model of the decision-making process underlying walking behaviour, with fulfilment of a hierarchy of walking needs being requisite antecedents to walking (Alfonzo, 2005). This hierarchy is placed within a social-ecological framework, which outlines the factors determining whether the fulfilment of needs will translate into walking behaviour (Alfonzo, 2005).

Social Identity Theory

Social Identity Theory aims to explain intergroup behaviour and intergroup conflict (Tajfel & Turner, 1986). Social group behaviour is related to group members' desire to differentiate themselves positively from other groups and to form positive evaluations of their group (Tajfel & Turner, 1986).

Social Influence Model of Consumer Participation

The Social Influence Model of Consumer Participation explains why consumers participate in virtual communities: network-based and small-group-based (Dholakia *et al.*, 2004). It identifies individual motives and desires and social identity and group norms as explanatory factors (Dholakia *et al.*, 2004).

Social Learning Theory

Miller and Dollard's Social Learning Theory primarily aims to explain how people learn by imitating others and outlines four factors instrumental to learning (drive, cue, response and reward) (Miller & Dollard, 1945).

Social Marketing Theory

Social marketing grew from commercial marketing in the 1970s (Lee & Kotler, 2011). Social Marketing theory concludes that behavioural change requires shifting the foci of initiatives away from individual consumer decisions and toward shaping and intervening in the shared behaviours of social groups (Lee & Kotler, 2011). Strongly promoted by USAID and the World Bank Water and Sanitation Program (WSP), the FOAM and SaniFOAM frameworks were developed by the World Bank WSP in collaboration with Population Services International (PSI), UNICEF, LSHTM and the Hygiene Improvement Program (HIP) of USAID (Lee & Kotler, 2011). Strong focus on hygiene and sanitation (Lee & Kotler, 2011). Social marketing involves the complete analysis, design and implementation process (Lee & Kotler, 2011).

Social Norms Theory

Social Norms Theory is a theory of human behaviour which proposes that behaviour is influenced by inaccurate perceptions of the thoughts and behaviours of other people within their social group (Perkins & Berkowitz, 1986).

Social Practice Theory

Social practices can be described as interrelated behaviours between people and objects (Shove *et al.*, 2012). Most practices emerge and change randomly by the people performing the practice (Shove *et al.*, 2012). The repetition and modification of these sets of behaviours influence the development of practice (Shove *et al.*, 2012). SPT uses a holistic approach, first identifying the material infrastructure that facilitates the practices to be performed in specific ways (Shove *et al.*, 2012). Secondly, the mental infrastructure comprising the symbols, images, interpretations or concepts associated with a set of activities determines how and when they might be performed; and the skills or competencies that lead to activities being undertaken in a specific way (Shove *et al.*, 2012).

Stage Models of Behaviour Change

Stage models of behaviour change mainly focus on understanding readiness to make a change, appreciating barriers to change, and helping to anticipate relapses to improve patient satisfaction and lower frustration during the change process (Sniehotta & Aunger 2010). The models in this category follow a specific pattern by dividing the behaviour change process into discrete stages (Sniehotta & Aunger 2010). A central assumption of those models is that the different stages are characterised by different

combinations of determinants, which are unique for each stage (Sniehotta & Aunger 2010).

Systems Model of Health Behaviour Change

The Systems Model of Health Behaviour Change integrates social, environmental, psychological and physiological factors into a theoretical account of the health behaviour change process (and its antecedents) to provide a framework for developing health education curricula (Kersell & Milsum, 1985).

Technology Acceptance Model 1, 2 & 3

The Technology Acceptance Model describes the factors that influence the acceptance and usage of technology and the mechanisms underlying these influences (Venkatesh & Bala, 1989). Central to the model is the proposal that two factors primarily determine technology: perceptions of 'ease of use' and perceptions of usefulness (Venkatesh & Bala, 1989).

Temporal Self-Regulation Theory

Temporal Self-Regulation Theory is a framework for understanding human behaviour that can be considered irrational (Hall & Fong, 2007). The model emphasises the role of the temporal proximity and value of anticipated benefits and the costs and outcomes of behaviours in influencing whether the behaviour is determined by rational decision-making processes or self-regulatory ability and behavioural pre-potency (Hall & Fong, 2007). likelihood the behaviour will be performed) (Hall & Fong, 2007).

Terror Management Health Model

The Terror Management Health Model postulates that conscious and non-conscious thoughts about mortality play an essential role in determining the factors that motivate decisions about health and health behaviour (Goldenberg & Arndt, 2008).

Terror Management Theory

Terror Management Theory aims to explain why humans require self-esteem and how that need influences their behaviour (Greenberg *et al.*, 1986). Self-esteem is a buffer against our inherent terror of inevitable mortality (Greenberg *et al.*, 1986). Most social behaviour aims to maintain individual self-esteem (Greenberg *et al.*, 1986).

Theory of Interpersonal Behaviour

The Theory of Interpersonal Behaviour aims to explain and predict the likelihood of people engaging in social behaviours or 'acts' (Triandis, 1977). According to the theory, the probability of a behaviour being carried out is determined primarily by habit strength, behavioural intentions and facilitative conditions (Triandis, 1977).

Theory of Normative Social Behaviour

The Theory of Normative Social Behaviour aims to provide a theoretical account of the mechanisms by which normative beliefs influence behaviour, developed with a specific focus on alcohol consumption (Rimal & Real, 2005). It proposes that normative beliefs influence behaviour through the mechanisms of social approval, group identity and beliefs about the benefits of the behaviour (Rimal & Real, 2005).

Theory of Planned Behaviour

The Theory of Planned Behaviour is a model of purposeful human behaviour (Ajzen, 1985). The model asserts that attitudes are determined by behavioural beliefs, subjective norms by normative beliefs and perceived behavioural control by control beliefs (Ajzen, 1985). Intentions are the direct precursors of behaviour and are, in turn, again influenced by the linked attitudes (Ajzen, 1985).

Theory of Triadic Influence

The Theory of Triadic Influence is a synthesis of several micro-level theories of health behaviour in which three streams of influence (attitudinal, social and intrapersonal) flow through five levels of causation to explain health-related behaviour (ultimate causes, personal social nexus, expectancy-value, cognitive, decisions) (Flay & Petraitis, 1994).

Transcontextual Model of Motivation

The Transcontextual Model of Motivation explains how perceived support for behavioural autonomy and motivational orientations in educational contexts can influence motivation and behaviour in other contexts (Hagger *et al.*, 2003).

Transtheoretical Model of Behaviour Change

The Transtheoretical Model holds that behaviour change occurs in five sequential stages. It identifies processes of change that lead to transition between the stages and proposes different processes linked to different stage transitions (Prochaska & DiClemente, 1982). The stages range from pre-contemplation (not planning to change within the next six months), contemplations (thinking about changing within six months but within the next month), preparation (taking steps towards changing within the next month), action (attempting the change), and maintenance (having changed for at least six months) (Prochaska & DiClemente, 1982).

Trials of Improved Practices

Trials of Improved Practices (TIPs) were developed by the Manoff Group and were first used in nutrition programming in the late 1970s and early 1980s (Harvey *et al.*, 2013). TIPs can be used to define new behaviours/practices/products/services and test whether they are acceptable and feasible, as well as to adapt them based on research / piloting at the household level before promoting them (Harvey *et al.*, 2013). The TIPs approach is similar to product research in social marketing (Harvey *et al.*, 2013). It is unsuitable for behaviours that: stretch over a long time (Harvey *et al.*, 2013).

Value Belief Norm Theory

Value Belief Norm Theory aims to explain support for social movements, particularly pro-environmental movements (Stern *et al.*, 1999). People who accept the values of a movement and hold a belief that things they value are endangered (and that their actions can mitigate that danger) will experience a sense of responsibility to act in support of that movement (Stern *et al.*, 1999).

Appendix III   Review of Bread-Baking in a South African Context

Baking bread constitutes an essential set of culinary behaviours to prepare food from primary staple crops. Traditional varieties of bread and pastry are prepared with fire in Africa and beyond. The consumption of bread and other wheat products is increasing rapidly in South Africa. This rise is attributed to rapid urbanisation and the changing role of women in African society. African women are still traditionally responsible for preparing meals. It appears that increasing pressures (i.e. employment away from home and wood fuel collection) on women have contributed to the increased consumption of prepared foods such as bread to reduce time spent cooking. The traditional bread-baking practices in South Africa have emerged through the interplay of geographical, biological, cultural, social, technological and institutional factors. Bread is a dietary staple in South African households. Traditional African bread is made from the flours of various starches (i.e., maize, cassava or grain) baked, steamed, and sometimes fried to produce pancakes, flatbreads, and leavened or slightly leavened loaves, or cakes using ovens, hearths, griddles, pots, and moulds. The main factors determining the baking sequences are the locally preferred and available cooking materials (i.e. ovens, pots and baking ingredients), individual motivations, and the local community's surrounding environment.

Traditional bread-baking in South Africa

The practice of traditional African forms of bread-baking still survives in rural parts of South Africa. Iron pots have replaced traditional clay pots as the preferred method of preparing bread over the fire. Baking in traditional clay ovens is rare but can still be observed in isolated rural areas of the Eastern Cape and Qwa Qwa. The loaves of bread are steamed, baked or pot-roasted, prepared from wheat, maize, sorghum, sourdough or commercial yeast, salt and warm water (Modi, 2009). Steaming is the preferred cooking method for most traditional bread, except wheat bread, where the bread is baked in a clay oven or roasted in a pot (Modi, 2009). Traditional steam bread is made from flour (ground cereal grains comprising wheat, rye, sorghum or maize, depending on availability) (Modi, 2009). Variations of steamed bread (translated as *ujeqe* in Zulu and *isonka sombhako* in Xhosa) can be found among rural Zulu, Xhosa and Southern Sotho-speaking communities in South Africa (Modi, 2009). While traditional baking methods are still practised, a large amount of creativity in recipes, ingredients and cooking technologies can be observed (Modi, 2009). The methods range from adding previously unavailable ingredients (dry yeast, sugar and spices) to variations in baking practice (Modi, 2009). Innovations in traditional bread baking practice can mainly be observed in steamed bread's iterations (Modi, 2009). The traditional Zulu version of steamed bread commonly referred to as *ujeqe* is a case in point (Modi, 2009). Despite significant modifications in the preparation methods, it is still regarded as a traditional baking method and is still called *ujeqe* (Modi, 2009). *Ujeqe*, in its original form, is made by boiling crushed green maize or sorghum and adding traditional beer as a raising agent (Modi, 2009). The raised dough is covered in maize husks and steamed in clay pots (Modi, 2009). Current variations are made with wheat flour, salt, sugar, yeast, water, eggs, and melted butter (Modi, 2009). Baking powder is used

as an alternative leavening agent. The dough is left in a warm place to rise, wrapped with maize leaves and steamed in a metal pot (Modi, 2009).

Traditional South African Baking Sequences

The wide variety of baking sequences in an indigenous South African context can be linked to the cultural and religious narratives integrating and continuously adapting the underlying food systems, preparation methods and baking technologies. Traditional African baking sequences include the baking of pancakes, flatbreads or slightly leavened loaves made in ovens, griddles, and pots (Lyons & D'Andrea, 2003). This separation of baking into the oven, griddle, and pot technologies gloss over the complexity and variety of Africa's baking culture (Lyons & D'Andrea, 2003). An example can be found in many of Africa's porridge-based cultures, where baking bread incorporates the boiling of fermented dough into a thick porridge before baking the bread. This process causes the dough to become elastic and starches to gelatinize, trapping gas that lightly leavens the bread as it bakes (Lyons & D'Andrea, 2003).

The traditional baking infrastructure required to produce bread is strongly interlinked with culinary sequences, socio-institutional factors, and its associated cultural meaning (Lyons & D'Andrea, 2003). The origins of baking bread in South Africa differ markedly from the Middle Eastern and later European context. A distinct sSA bread-baking infrastructure has emerged from two contrasting origins: the oven and griddle infrastructure and the pot infrastructure. In the Maghreb and Horn of Africa, ovens and griddles have historically been used for baking bread. Baking bread in ovens appears to have originated in Ancient Egypt and Sudan, where bread was produced with the Near Eastern cereals wheat or barley, which had spread from the Levant presumably with the concept of bread-baking (Haaland, 2006). Sub-Saharan porridge-based cultures incorporated baking bread in clay pots, disseminating the practise across Africa.

The ethnographic evidence indicates that the importance of bread in religious practices and institutions is confirmed widely. The biblical metaphor, central to Christianity of bread supplanting the body of God, is an example (Chevalier & Gheerbrant, 2009). The active ingredient of yeast in the baking process is metaphorically associated with spiritual transformation. Dietary rules regard the absence of yeast as a sign of purity and sacrifice. The hearth is frequently considered the centre of the household where male and female meet with traditions of an *ingoqo* with the symbolic display of firewood. Of interest is the meaning of a hearth in an African context extending beyond the individual household to include a group of families and a clan (Haaland, 2006).

Industrial Bread-Baking in South Africa

South Africa is the biggest bread producer in SSA., with bread forming a large part of the daily diet of black South Africans. The pre-dominant bread-baking industry differs significantly from traditional SSA pot bread baking sequences still surviving in parts of South Africa. The shift from traditional

bread-baking can be traced back to South Africa's colonial history and Apartheid. There has been a marked increase in bread consumption despite an increase in the price of bread relative to maize or rice over the corresponding period (Stanwix, 2012; Van der Walt, 2016).

Bread is the second-largest source of calories in what South Africans eat after maize, with over 2,800 million (1,500 million white loaves and 1,300 million brown loaves) produced in 2003 (Van der Walt, 2016). Most of South Africa's bread is baked in factories by four large companies, using industrial production and distribution systems and sold through supermarkets and local retailers (Van der Walt, 2016). In-store and stand-alone bakeries have grown in importance since the end of Apartheid (Stanwix, 2012; Van der Walt, 2016). South African industrial bread production is dominated by a cartel of four companies that produce 1.4 billion loaves per year (Stanwix, 2012; Van der Walt, 2016).

Small-Scale Commercial Bread-Baking in the South African Region

The small-scale commercial baking of bread with flame-based ovens serving impoverished South African communities is rare to non-existent in South Africa. Informal small-scale enterprises predominantly use unimproved biomass-fuelled cooking appliances to prepare ready-to-eat meals spanning braised meat and fried bread (Steyn *et al.*, 2011; Kimemia & Annegarn, 2013). Beyond South Africa's borders, using biomass-fuelled ovens is critical in small-scale and commercial bakeries. In Zimbabwe alone, 1,200 bakeries are estimated to consume around 218,000 tonnes of fuelwood annually (Nyabeze *et al.*, 1996; Nyabeze, 2001). The most significant obstacle for entrepreneurs to start a bakery is the availability and affordability of the energy carrier and improved wood-fuelled ovens designed for commercial purposes. (Fellows & Axtell, 2012; Aneke, 2017).

In response to the lack of small-scale bread-baking enterprises serving impoverished households, several small-scale baking interventions have been attempted in South Africa in recent years without much success. Common to the interventions is the use of expensive electric-powered ovens and seemingly unsustainable business models with an over-reliance on Corporate Social Responsibility (CSR) funding or state subsidies. The interventions' continued viability depends on sizable capital investments, with continuous financial assistance required (Erasmus & Cownie, 2002).

Examples of small-scale bakeries and bakery schools include *Sasko Sally*, *Snowflake Bake for Profit*, *Borotho Ba Rena* and the *Butterfield Village Bakery* project (Erasmus & Cownie, 2002). *Sasko Sally* is a community baking intervention to teach unemployed women how to bake bread with electric ovens (Erasmus & Cownie, 2002). The *Snowflake Bake for Profit* intervention is focused on establishing a small baking business facilitated by training programmes in baking and entrepreneurial skills (Erasmus & Cownie, 2002). The *Borotho Ba Rena* intervention aims to establish a series of bakery franchises providing fresh, quality bread at affordable prices to local impoverished communities, alleviating hunger, creating jobs and empowering local caregivers (Erasmus & Cownie, 2002). The first of ten planned rural bakeries owned and managed by local black women was opened in May 2014 in

KwaMhlanga, north of Pretoria, yet the continued rollout was hampered by the high cost and unreliability of electricity required for the running of the electric ovens (Erasmus & Cownie, 2002). An additional intervention is the *Butterfield Village Bakery* intervention adapted to low-income rural and urban African communities (Erasmus & Cownie, 2002). The product range includes large white loaves, rolls and sweet confectionery items with traditional baking sequences incorporated (Erasmus & Cownie, 2002).

Appendix IV   Observational Survey Notes and Interview Transcripts

This appendix contains the selected field notes of observations and transcribed interviews of the six households drawn from Dunoon participating in the survey. The observations and interviews are presented for each household. The time stamped details remain largely unedited. To reduce the length, repetitive section are removed focussing instead on the cooking activities in each household. The names of participants are removed.

Observational Survey Notes by Household Group (HH1-HH6)

HH1: SEM1–SEM2 Supergroup

Summary

- informal shack made from sheet metal
- backyarder
- no sealed floor
- no built-in kitchen sink & no electric connection
- social grant
- shares the dwelling with daughter
- sister visits sometimes
- mainly cooks with imbaula mainly
- sometimes cooks on open fire
- rarely cooks with paraffin stove

General

- headed by 28-year-old mother and her son
- married but husband in Johannesburg job-hunting
- last saw him six months ago
- they moved from Eastern Cape two years ago after husband found work in Cape Town
- he has been unemployed for a year
- he sometimes sends money
- her sister sometimes visits from E Cape
- child grant only regular source of income

Household Related

- informal shack made from cardboard, corrugated iron and wood
- located in backyard of another resident
- most stands have backyard structures
- sites rented out by owner taking advantage of lack of stands available
- shack has unprepared earthen floor, swept daily
- the single room has no windows
- door used to regulate airflow, bricks used to keep it ajar
- there are a lot of flies
- strong smell of refuse in the air
- dwelling adjacent to midden used by approx. 10 households

Cooking Related

- most meals cooked outside on derelict *imbaula* got from a neighbour
- *imbaula* used to heat water for washing
- she has two worn aluminium pots
- larger pot handles missing
- wire contraption made by neighbour used to manipulate the pot when placed over fire

- larger pot used to boil vegetables, stews and maize porridge
- smaller pot used to boil water for tea and eggs in the mornings on paraffin stove
- says that paraffin has become expensive and has spoken to her landlord about extending an electric cable from her light fitting for an electric kettle
- paraffin stove used to heat the home
- sometimes in winter after cooking outside, she takes the *imbaula* stove inside to stay warm
- uses wood to cook
- electricity is expensive (has to pay her landlord if she uses more than a single electric light)
- she collects firewood for 2 to 3 hours a week on the surrounding smallholdings and farms
- occasionally she gets wooden pallets from nearby industrial area
- prefers wood as it heats quickly
- like most backyarders, the electric connection is illegal
- implying she does not get Free Basic Electricity allowance
- pays a nominal R100 every month for the electric light
- negotiating with landlord for installation of more cables for kettle, tv etc
- charges phone at neighbour's place as they have corrected phone cable connection
- collecting firewood takes a lot of time out of her day
- complains but shrugs her shoulders saying: "what can we do"
- has to wake up early to do it
- her son does not help
- after preparing her son for school she goes to collect with three other women
- it is safer together
- good to talk with others about what is happening
- she does not know many people in the area as her family is in Eastern Cape

HH2: SEM1–SEM2 Supergroup

Summary

- grandmother-headed household, with daughter and three grandchildren
- social grants main source of income, supplemented by old-age pension
- dwelling had no sealed floor and no kitchen sink
- An old electric stove occasionally used
- open fireplace was predominant cooking technology

General

- three generations: grandmother (56), unmarried daughter (24) & three grandchildren (3, 5 & 10)
- head of second household is the grandmother who cooks
- daughter refers to her as *makoti* (woman of high standing)
- she moved to the city to join her husband who died 3 years ago
- Her nephews grill meat on the outdoor fireplace that she sells to passing people in the late afternoons and evenings as an income
- when we arrived, she was busy cutting and cleaning sheep offal for the day's cooking
- daughter's child support grant stabilises household income

Household Related

- home has separate bedroom & living space with kitchen area inside and traditional fireplace outside
- home has earthen floor, but bedroom has cement floor
- home does not get a lot of natural light
- home not well lit
- separate bedroom contains large mattress that all three sleep on
- bedroom contains an old flat screen television set
- no toilet or running water
- ablutions done outside the house in a municipal chemical toilet
- large bucket used for washing
- kitchen situated next to brick wall at the entrance
- kitchen area has large window-like opening in the brick wall with metal bars to prevent crime
- opening provides limited ventilation while cooking
- large door provides light and air
- door remains open for most of the day depending on weather
- according to the cook it is always ajar
- cardboard barrier used to keep out neighbourhood dogs
- two tables in the room draped with plastic cloth
- two large 50 litre plastic water buckets stored under largest table
- a third bucket contains plates and cutlery
- paraffin stove on second table next to a bucket filled with onions she purchased the previous day
- outside the kitchen is a traditional fire place (an *iziko*)
- roof to protect against the rain has been fitted
- there are no walls so ventilation is ample
- large cast-iron stove next to the central fireplace
- two conical metal water canisters are close to the fireplace
- rusted, disused *imbaula* stoves on the ground in back of dwelling

Cooking Related

- HH2 cooks food using multiple different stoves
- often use Panda paraffin stove, *imbaula* stove and traditional open fire
- in addition, there is a recently acquired electric kettle
- cooking decisions depend on time and money available
- collects fuelwood with daughter two to three times a week
- makes the family tea with electric kettle in the mornings

- tea is served with bread
- often reheats leftover porridge from previous evening on paraffin stove
- prepares sandwiches with locally purchased, commercial white bread, with generous helping of thick apricot jam and margarine
- loves the electric kettle as it switches off automatically
- sometimes boils eggs in the kettle
- considering purchasing single electric hotplate
- *imbaula* used occasionally in afternoons for cooking porridge and barbecuing meat, especially when paraffin runs out and her money runs out
- paraffin stove is used to heat the dwelling in winter
- once a month, her nearby relatives assist her, cooking over an open fire for family and church gatherings

HH3: SEM1–SEM2 Supergroup

Summary

- illegal electric connection
- illegal backyard connection
- household consists of 1 woman, four children
- no sealed floor
- no kitchen sink
- sole source of income = social grant + remittances from the woman's family

General

- single-parent household
- mother and four children
- unemployed
- dependent on social grant and daughter's income
- daughter (22) is cleaner at container storage warehouse (5km away)

Household Related

- family live in a tin shack with an illegal electric connection
- access to outside tap shared with neighbour
- interior immaculately clean with living and cooking area and two bedrooms
- she uses one bedroom while the children sleep in the other
- has a television set in her room
- the shack has no running water
- shares her neighbour's electricity
- living area has couch with three chairs around low coffee table
- supper is eaten at the table
- her children are watching a television programme in her bedroom

Cooking Related

- cooks an old pressurised Primus paraffin stove and electric stove every day
- paraffin stove mainly used for making tea, reheating food and making gravies
- single hob electric hotplate used for cooking vegetables and boiling water for tea when no electricity
- she has started boiling tea on the electric hob due to her electric kettle breaking
- electric stove used in the mornings to save time getting the children ready for school (boiling tea and eggs)
- prefers old Primus stove to unpressurised paraffin stove as other stoves do not last longer than 6 months
- another broke on the first day of use
- third unpressurised stove lasted three months
- daughter said that odours emanating from paraffin stove make her clothes smell bad
- has not heard of the *Protostar* methanol stove nor ever used a gel stove
- when has little money, cooks stew on an *imbaula* or over an open fire using neighbour's cast-iron pot
- wood is free and close by
- family uses paraffin stove and occasionally an *imbaula* to warm the home in winter

Summary

- family of three
- headed by single mother
- informal dwelling constructed from wood, sheet metal & cement bricks
- main cooking devices used = paraffin stove & electric hotplate
- main stable source of income was social grant
- HH4: consists of a family of three
- widowed mother, son & daughter
- income from child grant, money from her brother & her mother's pension
- both children are finishing primary school
- family of three in self-constructed face-brick house
- household consists of husband (36), wife (28), son (14)
- husband is wage earner
- works as delivery driver for local car part supplier
- he is away most of the day
- household income supplemented by social grant

General

- HH4 consists of a family of three
- A mother her son and daughter
- She is a widow
- she receives a child grant, money from her brother, and her mother's pension
- Both children are finishing primary school

Household Related

- their state-provided RDP house has two bedrooms, a separate bathroom lounge/television room and a kitchen with a dining room table
- the has had numerous structural improvements made to it
- when she has money she pays for improvements such as a glass window and front door
- happy with her home and takes great pride in it
- feels comfortable and safe living in it
- the plastered walls are painted white and floor is tiled
- kitchen includes a countertop and built-in cupboards
- outside the kitchen door a tiled path leads to an outside courtyard with a fireplace where on weekends the family sit together on two wooden benches
- kitchen table has a protective plastic covering
- plates, pots and kitchen utensils are stored in kitchen cupboards
- paraffin stove used in front of the electric stove with a pot of mealie meal steaming
- electricity has been off due to local power cuts

Cooking Related

- the cook prefers her four-plate electric stove
- occasionally reverts to paraffin stove when the electricity runs out
- uses electric kettle or paraffin stove to make tea before the children go to school
- cooks large family meals with electric stove over weekends when she has enough money
- on special occasions she will cook stews in a large cast iron pot on a three-stone fire
- does not like using the paraffin stove
- it is badly made and she is scared of burning herself
- it feels unstable when putting on a big pot
- she likes the heat it gives off and uses it to heat the children's room before they go to bed
- has used an *imbaula* on occasion in winter, but doesn't like the smoke or having to clean it

HH5: SEM3–SEM4 Supergroup

Summary

- family of three in small self-constructed cement brick house
- adjoining informal shack of sheet metal rented additional source of income
- house had sealed floor
- access to electricity with electric hot plate
- equipped with television
- primary source of income = social grant with occasional part-time work

General

- the family live in a self-constructed face-brick house
- household consists of a husband (36) and wife (28) and their 14-year-old son
- husband is wage earner working as delivery driver for local car part supplier
- he leaves early in the morning and only arrives back late at night
- household income supplemented by a child grant

Household Related

- house consists of living room, kitchen, bathroom and two bedrooms
- tiled and well-constructed with windows and doors
- gardens in the front and back
- back garden occasionally is used to cook outside
- building materials stored in small tool shed outside
- modern kitchen includes refrigerator, chest freezer & four-plate electric stove
- cellphone is charged in kitchen from same plug as the electric kettle
- microwave oven is broken
- two paraffin stoves, one big 3-legged pot stored outside the kitchen door

Cooking Related

- the mother cooks both indoors and outdoors
- she cook loves her electric stove (four-plate hob and oven)
- it is a 20-year-old Defy used for most cooking tasks and occasionally for baking
- it is used frequently but she says electricity is excessively expensive
- paraffin stove infrequently used as backup for power cuts or when pre-paid runs out
- *imbaula* for heating and occasional cooking due to cost of electricity
- purchases firewood locally as needed, due to physical effort required to collect

HH6: SEM3–SEM4 Supergroup

Summary

- main source of income = husband's wage labour (absent for long periods)
- main cooking device = electric stove
- paraffin stove occasionally used when prepaid electricity ran out
- LPG double hob recently purchased
- other durable assets included television set and refrigerator

General

- family of four in self-constructed brick house
- traditional family structure consists of a husband (38), wife (24), son (6) and daughter (4)
- children go to a local faith-based low-fee private school
- household caregiver and cook run a cooking business from home
- husband is wage earner working for a construction firm, often away during the week
- his wages provide stability in the household budget, making it easier to plan purchases

Household Related

- the small house is on an erf, protected by a prefabricated cement wall and welded iron gate
- The stove and fridge stand out in the kitchen as spotless and clean.
- the kitchen adjoins a large living room and three bedrooms and bathroom connected by a long corridor
- the large living room contains lounge furniture and a large television.
- kitchen is well lit with windows and a separate wooden door
- floors are tiled
- kitchen has a sink with running hot and cold water

Cooking Related

- primary stove is a standard four-plated electric stove and recently a LPG two hob stove
- two hob LPG stove stands on top of the electric stove
- she is happy with her current electric stove
- still uses the electric stove for baking
- husband bought LPG stove for use during electricity blackouts
- at first, she was apprehensive but has since changed her mind, especially when electricity is running low
- she has switched the cooking for her business over to her LPG stove to accommodate the volumes of meat
- she commented on the LPG stove saying that it 'feels expensive' referring to its high quality finish
- it cooks 'very fast'
- not afraid of using it
- has not used a paraffin stove for more than two years
- cooking decisions are made weekly, depending on how much gas or electricity remains and what quantities are required to be sold locally as ready-to-eat meals
- she cooks chicken and pork offal on an *imbaula* and sells at the local taxi rank
- does not collect fuelwood but purchases it every month from local entrepreneur
- wood is delivered by a small pickup at the cost of R500 per delivery
- food not sold during the day, is reheated and consumed at home
- happy with the electric stove
- her daughters agree
- would switch to new stove if it was cheaper to run or heat the home
- says the high cost of electricity is primary factor affecting cooking decisions
- on being showed the image of a high-end BOSCH 4-plate gas stove and oven, she said that she liked it, but thought it was too expensive

Field Study Interview Transcripts

Table A1: Household One Interview Transcript

Interview Question	Reply
When Last Did Make The Following? [Samp]	On Special Occasions
When Last Did Make The Following? [Mealie Meal]	This Week
When Last Did Make The Following? [Bread]	Today
When Last Did Make The Following? [Rice]	This Week
When Last Did Make The Following? [Greens (Pumpkin, Cabbage Etc)]	This Week
When Last Did Make The Following? [Street Food (Maginya Kota Etc)]	This Week
When Last Did Make The Following? [Beef]	Last Weekend
When Last Did Make The Following? [Chicken]	This Week
When Last Did Make The Following? [Goat]	On Special Occasions
When Last Did Make The Following? [Relish (Chaka Laka)]	Seldom
When Last Did Make The Following? [Tea]	This Week
When Last Did Make The Following? [Coffee]	Today
Location Of The Kitchen (Where Is The Stove In The Home?)	In A Separate Room Used As Kitchen
What Of The Following Do You Think Is Dangerous?	LPG Gas Exploding
Which Single One Do You Think Is The Most Dangerous?	LPG Gas Exploding
What Do You Cook With?	Electric Stove, Paraffin Stove
How Do You Heat Your Home In Winter?	Paraffin Stove
How Do You Light Your Home?	Electric Light
Have You Seen A Wood Oven With A Chimney?	Yes
Do You Ever Cook To Earn Additional Money?	No
Do You Ever Bake?	Maginya, Isonka Sombhako
Is Any Member Of Household Currently Being Treated For Any Medical Problems?	No
If Anybody Has Been Coughing In The Last Two Weeks, How Often Does That Happen?	Not Applicable
Do You Belong To A Women's Group Or Self-Help Group, Cooperative?	No
What Is The Primary Function Of This/These Group(s)?	N/A
In What Ways Does This Membership Influence Your Decisions About Managing Or Spending Money, If Any? [Do Not Read From The List]	N/A
How Has It Been Using The New Oven? What Do You Think Of It?	Difficult To Start The Fire, Its Good For A Small Business, Looks Attractive
Tell Me More About Your Experience? [Record Any Additional Details]	N/A
How Satisfied Are You With The Oven So Far?	Satisfied
What Do You Think Are The Most Important Qualities To Have In A Stove?	Uses Less Firewood/Fuel, Emits Less Smoke, Cooks Quickly
Is The Amount Of Smoke More, Less Or The Same With The Oven As With Other Stoves?	Less
Is The Taste Of The Food Baked In The Oven Better Than, Worse Than Or The Same As The Food Baked In Your Own Oven?	Better
Does This New Oven Use More Fuel, Less Fuel Or The Same Amount Of Fuel As Your Other Ovens?	Less
What Problems, If Any, Have You Had Baking With The Oven?	Food Doesn't Cook Well, It Takes Longer To Cook
What Changes Would You Make To The Oven?	N/A
This Oven Is Worth R10,000. At Discount It Is R8,500. Would You Buy It?	Yes
We Can Offer Instalment Payments If Easier. Are You Interested In The Stove If You Could Buy It For 12 Payments Of R800?	N/A
If The Price Is Still Too High, Tell Me What You Are Willing To Pay.	N/A
Thank You Very Much For Your Contribution. Do You Have Any Questions Or Comments Of Your Own?	No
Do You Think That It Was Easy For The Respondent To Answer The Questions?	Yes
Are You Certain That The Interviewee Was Answering The Questions Honestly And Truly?	Moderately Certain
Have You Noticed Or Came To Know Anything Irregular/Abnormal About The Household?	No
If Yes, Please Briefly Explain	N/A

Table A2:   Household Two Interview Transcript

Interview Question	Reply
When Last Did Make The Following? [Samp]	Seldom
When Last Did Make The Following? [Mealie Meal]	Today
When Last Did Make The Following? [Bread]	Today
When Last Did Make The Following? [Rice]	
When Last Did Make The Following? [Greens (Pumpkin, Cabbage Etc)]	Today
When Last Did Make The Following? [Street Food (Maginya Kota Etc)]	This Week
When Last Did Make The Following? [Beef]	This Week
When Last Did Make The Following? [Chicken]	This Week
When Last Did Make The Following? [Goat]	Seldom
When Last Did Make The Following? [Relish (Chaka Laka)]	On Special Occasions
When Last Did Make The Following? [Tea]	Today
When Last Did Make The Following? [Coffee]	This Week
Location Of The Kitchen (Where Is The Stove In The Home?)	In A Separate Room Used As Kitchen
What Of The Following Do You Think Is Dangerous?	Paraffin Stove Fire, Candle Fire
Which Single One Do You Think Is The Most Dangerous?	LPG Gas Exploding
What Do You Cook With?	Electric Stove, LPG Gas Stove
How Do You Heat Your Home In Winter?	Paraffin Stove, Paraffin Heater
How Do You Light Your Home?	Electric Light
Have You Seen A Wood Oven With A Chimney?	Yes
Do You Ever Cook To Earn Additional Money?	Sometimes
Do You Ever Bake?	Bread, Scones, Maginya, Isonka Sombhako
Is Any Member Of Household Currently Being Treated For Any Medical Problems?	Yes
If Anybody Has Been Coughing In The Last Two Weeks, How Often Does That Happen?	Sometimes
Do You Belong To A Women'S Group Or Self-Help Group, Cooperative?	Yes
What Is The Primary Function Of This/These Group(S)?	Savings, Religious, Civic Based Organisation
In What Ways Does This Membership Influence Your Decisions About Managing Or Spending Money, If Any? [Do Not Read From The List]	They Make Me Feel More Confident, They Help Me Learn New Skills
How Has It Been Using The New Oven? What Do You Think Of It?	Saves Fire Wood, I Like The Chimney, It's Easy To Prepare Food, It's Healthier, Looks Attractive
Tell Me More About Your Experience? [Record Any Additional Details]	
How Satisfied Are You With The Oven So Far?	Extremely Satisfied
What Do You Think Are The Most Important Qualities To Have In A Stove?	Easy To Light, Easy To Cook, Uses Less Firewood/Fuel, Emits Less Smoke, Cooks Quickly
Is The Amount Of Smoke More, Less Or The Same With The Oven As With Other Stoves?	Less
Is The Taste Of The Food Baked In The Oven Better Than, Worse Than Or The Same As The Food Baked In Your Own Oven?	Better
Does This New Oven Use More Fuel, Less Fuel Or The Same Amount Of Fuel As Your Other Ovens?	Less
What Problems, If Any, Have You Had Baking With The Oven?	None
What Changes Would You Make To The Oven?	
This Oven Is Worth R10,000. At Discount It Is R8,500. Would You Buy It?	Yes
We Can Offer Instalment Payments If Easier. Are You Interested In The Stove If You Could Buy It For 12 Payments Of R800?	
If The Price Is Still Too High, Tell Me What You Are Willing To Pay.	
Thank You Very Much For Your Contribution. Do You Have Any Questions Or Comments Of Your Own?	No
Do You Think That It Was Easy For The Respondent To Answer The Questions?	Yes
Are You Certain That The Interviewee Was Answering The Questions Honestly And Truly?	Moderately Certain
Have You Noticed Or Came To Know Anything Irregular/Abnormal About The Household?	Yes
If Yes, Please Briefly Explain	The Household Uses Paraffin, Gas And Electrical Stoves

Table A3:   **Household Three Interview Transcript**

Interview Question	Reply
When Last Did Make The Following? [Samp]	On Special Occasions
When Last Did Make The Following? [Mealie Meal]	Last Weekend
When Last Did Make The Following? [Bread]	This Week
When Last Did Make The Following? [Rice]	This Week
When Last Did Make The Following? [Greens (Pumpkin, Cabbage Etc)]	This Week
When Last Did Make The Following? [Street Food (Maginya Kota Etc)]	This Week
When Last Did Make The Following? [Beef]	Last Weekend
When Last Did Make The Following? [Chicken]	This Week
When Last Did Make The Following? [Goat]	On Special Occasions
When Last Did Make The Following? [Relish (Chaka Laka)]	Last Weekend
When Last Did Make The Following? [Tea]	This Week
When Last Did Make The Following? [Coffee]	This Week
Location Of The Kitchen (Where Is The Stove In The Home?)	In The Same Room Used For Living/Sleeping
What Of The Following Do You Think Is Dangerous?	Paraffin Stove Fire
Which Single One Do You Think Is The Most Dangerous?	Paraffin Stove Fire
What Do You Cook With?	Electric Stove
How Do You Heat Your Home In Winter?	Open Fire
How Do You Light Your Home?	Electric Light
Have You Seen A Wood Oven With A Chimney?	Yes
Do You Ever Cook To Earn Additional Money?	No
Do You Ever Bake?	Maginya
Is Any Member Of Household Currently Being Treated For Any Medical Problems?	No
If Anybody Has Been Coughing In The Last Two Weeks, How Often Does That Happen?	Not Applicable
Do You Belong To A Women'S Group Or Self-Help Group, Cooperative?	No
What Is The Primary Function Of This/These Group(S)?	
In What Ways Does This Membership Influence Your Decisions About Managing Or Spending Money, If Any? [Do Not Read From The List]	
How Has It Been Using The New Oven? What Do You Think Of It?	Saves Fire Wood, Easy To Start The Fire, Looks Attractive
Tell Me More About Your Experience? [Record Any Additional Details]	
How Satisfied Are You With The Oven So Far?	Satisfied
What Do You Think Are The Most Important Qualities To Have In A Stove?	Easy To Light, Uses Less Firewood/Fuel, Emits Less Smoke, Suitable For My Cooking Pots/Meals, Cooks Quickly
Is The Amount Of Smoke More, Less Or The Same With The Oven As With Other Stoves?	Less
Is The Taste Of The Food Baked In The Oven Better Than, Worse Than Or The Same As The Food Baked In Your Own Oven?	Better
Does This New Oven Use More Fuel, Less Fuel Or The Same Amount Of Fuel As Your Other Ovens?	Less
What Problems, If Any, Have You Had Baking With The Oven?	Risk Of Burning My Hand When Pushing Wood Inside The Stove, Food Doesn't Cook Well, It Takes Longer To Cook
What Changes Would You Make To The Oven?	Not At This Stage
This Oven Is Worth R10,000. At Discount It Is R8,500. Would You Buy It?	Yes
We Can Offer Instalment Payments If Easier. Are You Interested In The Stove If You Could Buy It For 12 Payments Of R800?	
If The Price Is Still Too High, Tell Me What You Are Willing To Pay.	
Thank You Very Much For Your Contribution. Do You Have Any Questions Or Comments Of Your Own?	No
Do You Think That It Was Easy For The Respondent To Answer The Questions?	Yes
Are You Certain That The Interviewee Was Answering The Questions Honestly And Truly?	Neutral
Have You Noticed Or Came To Know Anything Irregular/Abnormal About The Household?	No
If Yes, Please Briefly Explain	

Table A4:   **Household Four Interview Transcript**

Interview Question	Reply
When Last Did Make The Following? [Samp]	Last Weekend
When Last Did Make The Following? [Mealie Meal]	Today
When Last Did Make The Following? [Bread]	Today
When Last Did Make The Following? [Rice]	This Week
When Last Did Make The Following? [Greens (Pumpkin, Cabbage Etc)]	This Week
When Last Did Make The Following? [Street Food (Maginya Kota Etc)]	Last Weekend
When Last Did Make The Following? [Beef]	Last Weekend
When Last Did Make The Following? [Chicken]	Today
When Last Did Make The Following? [Goat]	
When Last Did Make The Following? [Relish (Chaka Laka)]	Last Weekend
When Last Did Make The Following? [Tea]	Today
When Last Did Make The Following? [Coffee]	Last Weekend
Location Of The Kitchen (Where Is The Stove In The Home?)	In The Same Room Used For Living/Sleeping
What Of The Following Do You Think Is Dangerous?	Paraffin Stove Fire, LPG Gas Exploding, Candle Fire
Which Single One Do You Think Is The Most Dangerous?	Electric Shock
What Do You Cook With?	Electric Stove
How Do You Heat Your Home In Winter?	Paraffin Stove
How Do You Light Your Home?	Electric Light
Have You Seen A Wood Oven With A Chimney?	Yes
Do You Ever Cook To Earn Additional Money?	No
Do You Ever Bake?	Bread, Scones, Maginya, Isonka Sombhako
Is Any Member Of Household Currently Being Treated For Any Medical Problems?	No
If Anybody Has Been Coughing In The Last Two Weeks, How Often Does That Happen?	Not Applicable
Do You Belong To A Women'S Group Or Self-Help Group, Cooperative?	No
What Is The Primary Function Of This/These Group(S)?	
In What Ways Does This Membership Influence Your Decisions About Managing Or Spending Money, If Any? [Do Not Read From The List]	
How Has It Been Using The New Oven? What Do You Think Of It?	Food Cooks Faster
Tell Me More About Your Experience? [Record Any Additional Details]	
How Satisfied Are You With The Oven So Far?	
What Do You Think Are The Most Important Qualities To Have In A Stove?	Easy To Light, Emits Less Smoke, Suitable For My Cooking Pots/Meals, Cooks Quickly
Is The Amount Of Smoke More, Less Or The Same With The Oven As With Other Stoves?	Could Not. See The Smoke, It Seems Going Very Well Bcz It's Invisible And Harmless
Is The Taste Of The Food Baked In The Oven Better Than, Worse Than Or The Same As The Food Baked In Your Own Oven?	I Don't Have An Oven At Home
Does This New Oven Use More Fuel, Less Fuel Or The Same Amount Of Fuel As Your Other Ovens?	Less
What Problems, If Any, Have You Had Baking With The Oven?	
What Changes Would You Make To The Oven?	
This Oven Is Worth R10,000. At Discount It Is R8,500. Would You Buy It?	
We Can Offer Instalment Payments If Easier. Are You Interested In The Stove If You Could Buy It For 12 Payments Of R800?	
If The Price Is Still Too High, Tell Me What You Are Willing To Pay.	
Thank You Very Much For Your Contribution. Do You Have Any Questions Or Comments Of Your Own?	
Do You Think That It Was Easy For The Respondent To Answer The Questions?	
Are You Certain That The Interviewee Was Answering The Questions Honestly And Truly?	
Have You Noticed Or Came To Know Anything Irregular/Abnormal About The Household?	
If Yes, Please Briefly Explain	

Table A5: Household Five Interview Transcript

Interview Question	Reply
When Last Did Make The Following? [Samp]	
When Last Did Make The Following? [Mealie Meal]	This Week
When Last Did Make The Following? [Bread]	Today
When Last Did Make The Following? [Rice]	This Week
When Last Did Make The Following? [Greens (Pumpkin, Cabbage Etc)]	Last Weekend
When Last Did Make The Following? [Street Food (Maginya Kota Etc)]	
When Last Did Make The Following? [Beef]	
When Last Did Make The Following? [Chicken]	Today
When Last Did Make The Following? [Goat]	
When Last Did Make The Following? [Relish (Chaka Laka)]	
When Last Did Make The Following? [Tea]	Today
When Last Did Make The Following? [Coffee]	
Location Of The Kitchen (Where Is The Stove In The Home?)	In The Same Room Used For Living/Sleeping
What Of The Following Do You Think Is Dangerous?	Paraffin Stove Fire, LPG Gas Exploding, Candle Fire
Which Single One Do You Think Is The Most Dangerous?	LPG Gas Exploding
What Do You Cook With?	Paraffin Stove
How Do You Heat Your Home In Winter?	Paraffin Stove
How Do You Light Your Home?	Electric Light
Have You Seen A Wood Oven With A Chimney?	Yes
Do You Ever Cook To Earn Additional Money?	No
Do You Ever Bake?	Maginya, Isonka Sombhako
Is Any Member Of Household Currently Being Treated For Any Medical Problems?	No
If Anybody Has Been Coughing In The Last Two Weeks, How Often Does That Happen?	
Do You Belong To A Women'S Group Or Self-Help Group, Cooperative?	No
What Is The Primary Function Of This/These Group(S)?	
In What Ways Does This Membership Influence Your Decisions About Managing Or Spending Money, If Any? [Do Not Read From The List]	
How Has It Been Using The New Oven? What Do You Think Of It?	The Citizen Never Saw It Working But Believes That It Should Be Worth Having It As An Alternative Rather Than Using Gas Stove Or Paraffin Stove
Tell Me More About Your Experience? [Record Any Additional Details]	
How Satisfied Are You With The Oven So Far?	Somewhat Satisfied
What Do You Think Are The Most Important Qualities To Have In A Stove?	Easy To Light, Easy To Cook, Uses Less Firewood/Fuel, Cooks Quickly
Is The Amount Of Smoke More, Less Or The Same With The Oven As With Other Stoves?	In fact U Can't Even Smell The Smoke
Is The Taste Of The Food Baked In The Oven Better Than, Worse Than Or The Same As The Food Baked In Your Own Oven?	I Don't Have An Oven At Home
Does This New Oven Use More Fuel, Less Fuel Or The Same Amount Of Fuel As Your Other Ovens?	By Look Of Things It Should Use Less Consumption
What Problems, If Any, Have You Had Baking With The Oven?	Risk Of Burning My Hand When Pushing Wood Inside The Stove
What Changes Would You Make To The Oven?	
This Oven Is Worth R10,000. At Discount It Is R8,500. Would You Buy It?	Yes
We Can Offer Instalment Payments If Easier. Are You Interested In The Stove If You Could Buy It For 12 Payments Of R800?	
If The Price Is Still Too High, Tell Me What You Are Willing To Pay.	
Thank You Very Much For Your Contribution. Do You Have Any Questions Or Comments Of Your Own?	No
Do You Think That It Was Easy For The Respondent To Answer The Questions?	Yes
Are You Certain That The Interviewee Was Answering The Questions Honestly And Truly?	Moderately Certain
Have You Noticed Or Came To Know Anything Irregular/Abnormal About The Household?	No
If Yes, Please Briefly Explain	

Table A6:   Household Six Interview Transcript

Interview Question	Reply
When Last Did Make The Following? [Samp]	Last Weekend
When Last Did Make The Following? [Mealie Meal]	Today
When Last Did Make The Following? [Bread]	Today
When Last Did Make The Following? [Rice]	This Week
When Last Did Make The Following? [Greens (Pumpkin, Cabbage Etc)]	This Week
When Last Did Make The Following? [Street Food (Maginya Kota Etc)]	This Week
When Last Did Make The Following? [Beef]	Last Weekend
When Last Did Make The Following? [Chicken]	This Week
When Last Did Make The Following? [Goat]	On Special Occasions
When Last Did Make The Following? [Relish (Chaka Laka)]	Never
When Last Did Make The Following? [Tea]	This Week
When Last Did Make The Following? [Coffee]	Today
Location Of The Kitchen (Where Is The Stove In The Home?)	In The Same Room Used For Living/Sleeping
What Of The Following Do You Think Is Dangerous?	LPG Gas Exploding
Which Single One Do You Think Is The Most Dangerous?	Candle Fire
What Do You Cook With?	Electric Stove
How Do You Heat Your Home In Winter?	Imbaula, Paraffin Stove
How Do You Light Your Home?	Electric Light
Have You Seen A Wood Oven With A Chimney?	No
Do You Ever Cook To Earn Additional Money?	No
Do You Ever Bake?	Scones, Maginya, Isonka Sombhako
Is Any Member Of Household Currently Being Treated For Any Medical Problems?	No
If Anybody Has Been Coughing In The Last Two Weeks, How Often Does That Happen?	Not Applicable
Do You Belong To A Women'S Group Or Self-Help Group, Cooperative?	Yes
What Is The Primary Function Of This/These Group(S)?	Burial Society
In What Ways Does This Membership Influence Your Decisions About Managing Or Spending Money, If Any? [Do Not Read From The List]	Assist Me To Be Able To Burry My Family Members
How Has It Been Using The New Oven? What Do You Think Of It?	Saves Fire Wood, The House, Pots, Pans And Clothes Remain Cleaner, I Like The Chimney, It's Healthier, Looks Attractive
Tell Me More About Your Experience? [Record Any Additional Details]	Reliable And Less Risk For Kids
How Satisfied Are You With The Oven So Far?	Extremely Satisfied
What Do You Think Are The Most Important Qualities To Have In A Stove?	Easy To Light, Cooks Quickly
Is The Amount Of Smoke More, Less Or The Same With The Oven As With Other Stoves?	Less
Is The Taste Of The Food Baked In The Oven Better Than, Worse Than Or The Same As The Food Baked In Your Own Oven?	Better
Does This New Oven Use More Fuel, Less Fuel Or The Same Amount Of Fuel As Your Other Ovens?	Less
What Problems, If Any, Have You Had Baking With The Oven?	Food Doesn't Cook Well, Especially Umbhako, The Fire Must Be Slow But Still Be Careful Bcaz The Bread Will Not Be Properly Cooked
What Changes Would You Make To The Oven?	
This Oven Is Worth R10,000. At Discount It Is R8,500. Would You Buy It?	Yes
We Can Offer Instalment Payments If Easier. Are You Interested In The Stove If You Could Buy It For 12 Payments Of R800?	
If The Price Is Still Too High, Tell Me What You Are Willing To Pay.	
Thank You Very Much For Your Contribution. Do You Have Any Questions Or Comments Of Your Own?	
Do You Think That It Was Easy For The Respondent To Answer The Questions?	Yes
Are You Certain That The Interviewee Was Answering The Questions Honestly And Truly?	Neutral
Have You Noticed Or Came To Know Anything Irregular/Abnormal About The Household?	
If Yes, Please Briefly Explain	

Appendix V   Sample of Observed Time-Coded Workshop Sequences

Bread-Baking Sequence with an Improved Biomass Oven | 2017-07-10

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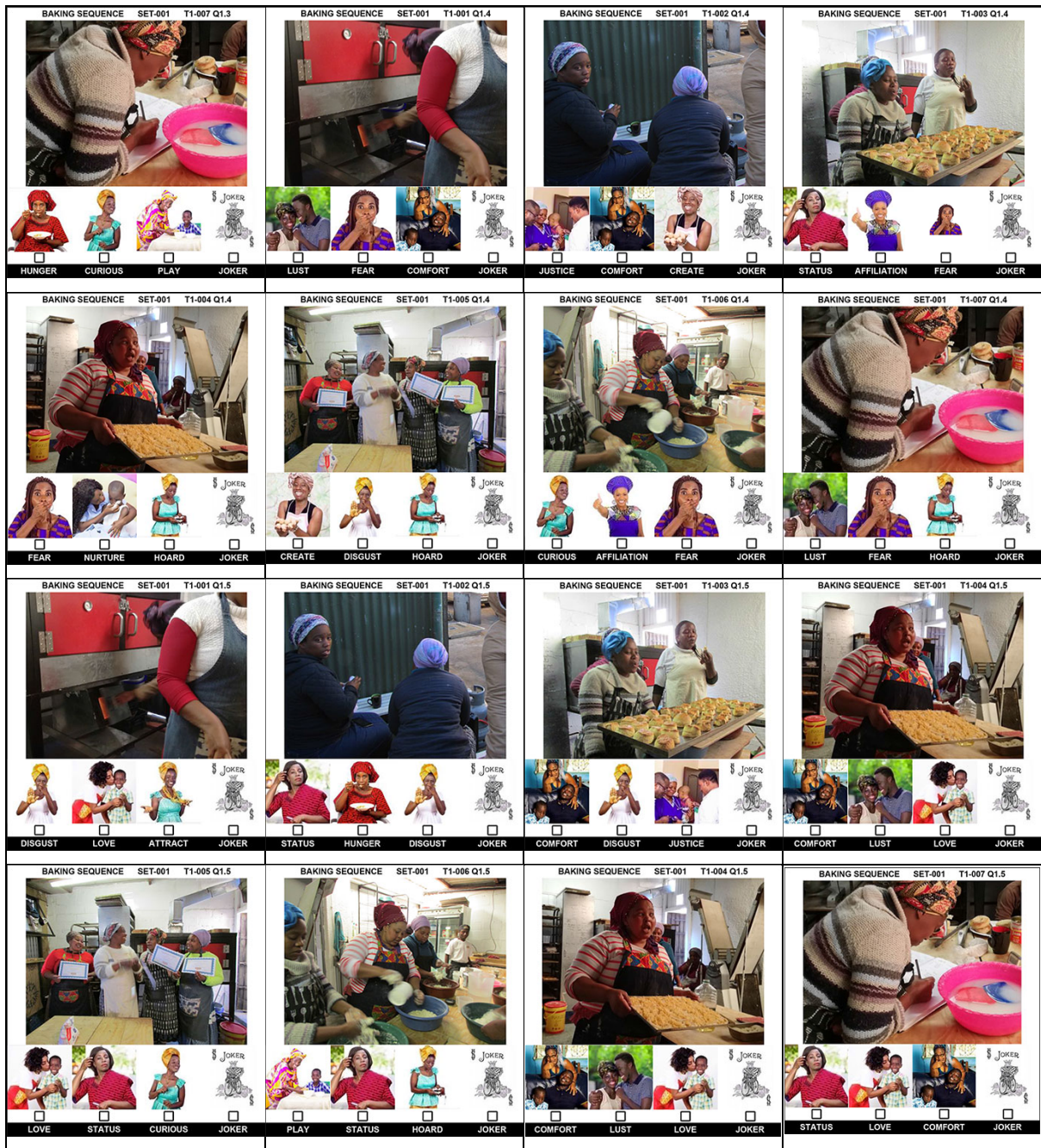2017-07-13 Thu | Chocolate Cr...

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Appendix VI   Sample Workshop Card-Based Question Set

Appendix VII   Pilot Implementation Stated Preference Survey Questionnaire

Interviewer section (interviewer only)

Interviewer Instructions

Good day sir/madam.

My name is (state your name),

I am doing research on cooking. We would like to find out how you live and cook within the area. This information will be treated with the strictest confidence and used for research purposes only. You don't have to answer if you don't want to and we can stop at any time. We want to understand how the community uses cookstoves..

May I ask you a few questions?

Interviewer Information

1.   Sample Area

   Mark only one oval.

   ◯ Mamelodi

   ◯ Dunoon

   ◯ Other: _____

2.   Interviewer's name:

   Mark only one oval.

   ◯ Bulelwa Mayende

   ◯ Billy Zulu

   ◯ Other: _____

Household representivity section

3. Do you live here?

   Mark only one oval.

   ◯ Yes

   ◯ Other: _____

4. Name of respondent
   What is your name?

   _____

5. Cellphone Number

   _____

6. Gender

   Mark only one oval.

   ◯ Male

   ◯ Female

7. Age

   _____

8. Position in household

   Mark only one oval.

   ◯ Grandparent

   ◯ Parent

   ◯ Teenager

   ◯ Child

   ◯ Other: _____

9. How many people live in the home in total?

Mark only one oval.

○ 1
○ 2
○ 3
○ 4
○ 5
○ 6
○ Other: _____

10. Household head

Who is the head of the home?

Mark only one oval.

○ Same person answering the questions

○ Father

○ Mother

○ Grandfather

○ Grandmother

○ Other: _____

11. Monthly Cash Income Sources

What are the income sources in the home? Choose more than one if necessary.

Tick all that apply.

☐ Wage Labour
☐ Farming
☐ Selling/Spaza/Shop
☐ Bartering
☐ Income Grant
☐ Pension
☐ Money Transfers
Other: ☐ _____

Material indicators

12. Is the floor sealed? (choose "Yes" if the floor covered with tiles, brick, wood, concrete or similar; or choose "No" if the floor is ground or unprepared)

Mark only one oval.

◯ Yes

◯ No

13. Is there running hot water? (Yes/No)

Mark only one oval.

◯ Yes

◯ No

14. Is there a flushing toilet? (Yes/No)

Mark only one oval.

◯ Yes

◯ No

15. Do you have a smartphone? (Yes/No)

Mark only one oval.

◯ Yes

◯ No

16. Do you have a microwave? (Yes/No)

Mark only one oval.

◯ Yes

◯ No

17. Do you have a kitchen sink? (Yes/No)

Mark only one oval.

◯ Yes

◯ No

Media channel access

18. Do you use WhatsApp? (Yes/No)

Mark only one oval.

◯ Yes

◯ No

19. Do you use Facebook? (Yes/No)

Mark only one oval.

◯ Yes

◯ No

Observed cookstove ownership section

20. What type of stoves do you see in the home?

    Tick all that apply.

    ☐ LPG stove
    ☐ Biomass stove
    ☐ Paraffin stove
    ☐ Electric stove
    ☐ Other

Intervention exposure

21. Did you hear about the igoqo bakery course?

    Mark only one oval.

    ◯ Yes
    ◯ No

22. Did you see the igoqo bakery course?

    Mark only one oval.

    ◯ Yes
    ◯ No

Interviewer debriefing section (interviewer only)

24. Do you think that it was easy for the respondent to answer the questions?

    Mark only one oval.

    ◯ Yes

    ◯ No

25. Are you certain the respondent was answering the questions honestly and truly?

    Mark only one oval.

    ◯ Very uncertain

    ◯ Moderately uncertain

    ◯ Neutral

    ◯ Moderately certain

    ◯ Very certain

26. Have you noticed or came to know anything irregular/abnormal about the household?

    Mark only one oval.

    ◯ Yes

    ◯ No

27. If yes, please briefly explain

    _____

    _____

    _____

28.   Any other comment?

_____

_____

_____

Sample CBC choice set

Sample card-based choice question set consisting of 36 questions of the 12 motivations and three stove types.

"I can save money and resources when cooking with the stove"

Agree   Neutral   Disagree

"I've made the household better now; I did well!"

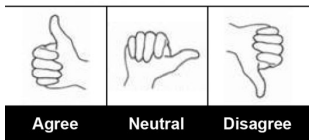**Agree   Neutral   Disagree**

"I like looking beautiful after cooking in the home"

Agree   Neutral   Disagree

"I like being warm and comfortable when cooking with the stove"

Agree   Neutral   Disagree

"I will be less hungry when cooking with the stove"

Agree   Neutral   Disagree

"I really learned a new way of doing things, I did well!"

Agree   Neutral   Disagree

"Now my child will be safe when cooking with the stove"

Agree   Neutral   Disagree

"I am safe from accidents and dangers when cooking with the stove"

Agree   Neutral   Disagree

"I really learned a new way of doing things, I did well!"

Agree   Neutral   Disagree

"The smell is disgusting when cooking with the stove"

Agree   Neutral   Disagree

"I like being warm and comfortable when cooking with the stove"

Agree   Neutral   Disagree

"I've made the household better now; I did well!"

Agree   Neutral   Disagree

M203	DISGUST

"The smell is disgusting when cooking with the stove"

Agree   Neutral   Disagree

M203	STATUS

"I like looking beautiful after cooking in the home"
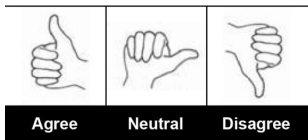
Agree   Neutral   Disagree

M203	AFFILIATION

"You showed you are one of us, well done!"

Agree   Neutral   Disagree

M203	JUSTICE

"That was the right thing to do, well done!"

Agree   Neutral   Disagree

M203	CURIOSITY

"I like being well informed about what is going on in my community"
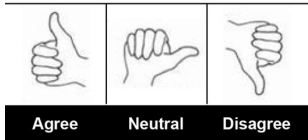
Agree   Neutral   Disagree
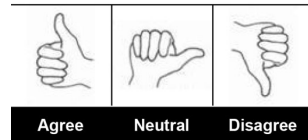
M203	HOARD

"I can save money and resources when cooking with the stove"

Agree   Neutral   Disagree
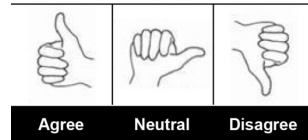
M203	HUNGER

"I will be less hungry when cooking with the stove"

Agree **Neutral** **Disagree**

M203	PLAY

"I really learned a new way of doing things, I did well!"

Agree **Neutral** **Disagree**

M203	CURIOSITY

"I like being well informed about what is going on in my community"

Agree **Neutral** **Disagree**

M203	AFFILIATION

"You showed you are one of us, well done!"

Agree **Neutral** **Disagree**

M203	COMFORT
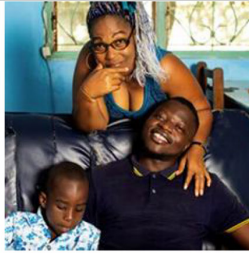
"I like being warm and comfortable when cooking with the stove"

Agree **Neutral** **Disagree**
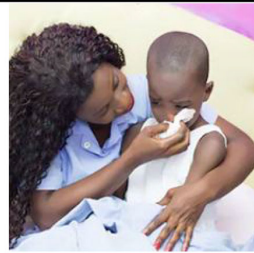
M203	NURTURE

"Now my child will be safe when cooking with the stove"

Agree **Neutral** **Disagree**

"You showed you are one of us, well done!"

| Agree | Neutral | Disagree |

"I like being well informed about what is going on in my community"

| Agree | Neutral | Disagree |

"That was the right thing to do, well done!"

| Agree | Neutral | Disagree |

"Now my child will be safe when cooking with the stove"
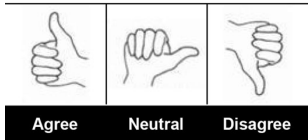

| Agree | Neutral | Disagree |

"That was the right thing to do, well done!"

| Agree | Neutral | Disagree |

"I will be less hungry when cooking with the stove"

| Agree | Neutral | Disagree |

Appendix VIII   Guiding frame for the thematic analysis in the observational study

Themes	Codes
1. Cookstove-related behavioural factors	1. Cooking with wood or pellets
	2. Cooking with paraffin
	3. Cooking with LPG
2. Social and material factors linked to flame-based cooking	4. Traditional culinary sequences adapted to urban settings
	5. Pre-cooked meals displacing home cooking sequences
	6. Deep frying sequences
	7. Summarised weekly cooking sequences
3. Motivations linked to flame-based cooking	8. Hunger motivations
	9. Comfort motivations
	10. Fear motivations
	11. Disgust motivations
	12. Nurture motivations
	13. Hoarding motivations
	14. Creative motivations
	15. Motivations of affiliation
	16. Status motivations
	17. Justice motivations
	18. Curiosity motivations
	19. Play motivations

Appendix IX   Workshop Coding Sample Sheet

Sample workshop data coding sheet of motivations and touchpoints by workshop participant.

No.	Date	Time Code	WP	Sequence	Col. 1: Raw Translation	Col. 2: Prelim Code (Touchpoint)	Col. 3: Prelim Code (Motiv)	Col. 4: Final Code
13847	10/07/2017	08:53:03:34	WP2	Starting Rocket Oven	I remember the Dover stove from my mother in Cutwini (growing up). It was nice	lighting stove	curiosity affiliation	lighting-curiosity