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Understanding the Diffusion and Adoption of Improved Cookstove Technologies in Uganda Through the Technological Innovation System Perspective

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Doctor of Philosophy in International Development

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ACKNOWLEDGMENT

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DEDICATION

To my children Love, Darren, Divine and Deborah.
LAY SUMMARY

As many as 80% of people in sub-Saharan Africa still rely on traditional biomass energy to meet their cooking needs. Traditional biomass energy is associated with a myriad of health, environmental and socio-economic challenges. Cooking with cleaner cooking technologies could substantially reduce pollution and its associated health risks, deforestation and generally improve especially women’s welfare, but diffusion and adoption of these technologies is not only low but also their sustained use remains a challenge. This research seeks to contribute to the understanding of why adoption remains slow despite decades of research and development. My investigation is aided by the Technological Innovation Theory, which looks at innovation generation, dissemination and use as a collective activity, which is undertaken through systematic processes by a heterogeneous group of actors. I employ a multi case study research design and use multiple methods to collect data, and analyse it thematically.

Results reveal a strong influence of external factors, which restructured not only the structure but also the key processes, causing superficial growth in the system. The innovation system trajectory largely excludes local manufacturers and users needs and preferences. The voice of formal networks is weakened by limited autonomy caused by donor dependence for survival, and this inhibits learning and knowledge exchange. Informal mechanisms such as social media are used to overcome the interaction challenges, albeit with challenges. Results also reveal a big role of indigenous knowledge in some stove making and use processes but with no mechanism to blend it with scientific knowledge to generate more appropriate technologies. The sector lacks a supporting policy, yet the standard, which is the main institutional framework is detached from local innovators’ focus and user habits and preferences, thus raising questions on the usefulness of standardised stove testing processes. There are divergent perceptions on what constitutes a stove innovation, which causes tension and confusion on what a quality stove innovation is or should be in Uganda’s context. The system is currently experiencing change of context in terms of government priority and declining external funding. The study recommends a change in the way the structure is organised especially networks in order to deal with the changing context.
ABSTRACT

About 2.5 billion people in the world rely on the traditional use of solid bioenergy to cook their meals, and in Sub-Saharan Africa almost 80% of the population still cooks with solid bioenergy. Despite the multifaceted promises associated with improved cookstoves to overcome the inefficient use of bioenergy, their diffusion and adoption remains slow. In making a contribution towards understanding this problem, this thesis departs from the extensive studies that explain it from the users’ and technology attributes’ perspective, and interrogates the role of systemic factors. The thesis draws from the Technological Innovation Systems (TIS) theory, and employs an interpretive multiple case research design. Data was collected using a multi-method approach including semi-structured interviews, document analysis, Focus Group Discussions and direct observation, and it was thematically analysed.

The improved cookstove TIS in Uganda is at a critical stage of going through what I have called structural thinning resulting from change of context in terms of national policy direction and reduced external funding, which brings in the critical question of ability of the system to cope with, and overcome these structural shocks. Structural thinning refers to premature disengagement of key structural elements from the TIS. This change in context comes at a time when the system, which started in the 1980s is working under a largely misaligned structure and the key processes (functions) are largely externally induced, exposing the system at all levels (firm, network and national) to the vagaries of the changing needs and priorities of the external dominant actors especially development partners and carbon finance projects. Although entry of firms is perceived in literature as an inducement to systems in the formative stages, in Uganda’s case it portends a barrier because of firms’ capability and motivation issues. Stove dissemination is largely limited to urban areas and the quality of locally manufactured stoves is generally poor mainly because of the proliferation of counterfeit stoves on the market.

The system is largely unregulated and the household biomass stoves standard, which is currently the main supporting institution is detached from local innovators’ focus and user habits and preferences, thus raising questions on the usefulness of standardised stove testing processes. Results also reveal how indigenous knowledge (informal structures) applied in some of the stove making and use processes (at firm and user levels respectively) is excluded from knowledge generation and exchange mechanisms at network and system levels, and how this exclusion impedes the generation of appropriate technologies. Relatedly, results show how actors perceive innovation and stove quality differently, and how the divergent perceptions (technological frames) work to slow progress of improved cookstove generation, diffusion and adoption in Uganda.
Further, limited autonomy caused by donor dependence for survival coupled with weak legitimacy among local manufacturers weaken the voice of formal networks, which inhibits learning and knowledge exchange. In an effort to address the interaction gaps, some actors like networks use social media for research and information dissemination, albeit with challenges. R&D financing schemes boosted stove generation and dissemination in the short run but caused retrogression in the long term especially at firm level and are largely not adapted to the needs of the system.

Results above represent a nascent system in formative stage. However, the improved cookstove TIS has been growing for about 35 years now, which points more to the system being stunted than young. The factors responsible for this stunted growth are embedded in the weak and misaligned structure, which affects fulfilment of the key processes. The study recommends restructuring of both the institutions and networks in order to absorb the current shocks and also create better structuration for progressive development of improved cookstove TIS in Uganda. This restructuring is specifically about aligning the improved cookstove standard to the needs of the system as well as building new necessary institutions such as supporting policy, and integrating the dominant informal institutions with formal ones to generate appropriate technologies. The restructuring also speaks about the reorganisation of networks to overcome dependency and legitimacy challenges.
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ACRONYMS

BEETA  Biomass Energy Efficiency Technologies Association
BEST  Bioenergy Energy Strategy
CCT  Controlled Cooking Test
CIRCODU  Centre for Integrated Research and Community Development Uganda
CDM  Clean Development Mechanism
CREEC  Centre for Research in Energy Efficiency and Conservation
GACC  Global Alliance for Clean Cookstoves
GWP  Global Warming Potential
IEA  International Energy Agency
IIED  International Institute for Environment and Development
IPCC  Intergovernmental Panel on Climate Change
KCCA  Kampala City Council Authority
KPT  Kitchen Performance Test
MEMD  Ministry of Energy and Mineral Development
MFPED  Ministry of Finance Planning and Economic Development
MWE  Ministry of Water and Environment
NDP  National Development Plan
NGOs  Non-governmental Organisations
PREEEP  Promotion of Renewable Energy and Energy Efficiency Programme
REDD+  Reducing Emissions from Deforestation and Forest Degradation
SDGs  Sustainable Development Goals
TIS  Technological Innovation System
UBOS  Uganda Bureau of Statistics
UNACC  Uganda National Alliance for Clean Cooking
UNBS  Uganda National Bureau of Standards
UNFCC  United Nations Framework Convention on Climate Change
UNREEEA  Uganda National Renewable Energy and Energy Efficiency Alliance
URA  Uganda Revenue Authority
WBT  Water Boiling Test
CHAPTER ONE: BACKGROUND TO THE STUDY

1.0 Motivation

This thesis seeks to interrogate the institutional context of improved cookstoves and how it influences diffusion and adoption of these technologies in Uganda. The study was inspired by the growing interest in renewable energy as the best and possibly only choice for achieving sustainable development on one hand, and the concern over slow diffusion and adoption of renewable energy technologies on the other, especially in developing countries. Much of the international political and scientific debate on climate change mitigation is focused on fossil fuel production and consumption and the critical need to transition to renewable energy. In most developing countries however, the predominant source of energy and emission is not fossil fuel but bioenergy. For example, the Uganda National Charcoal Survey of 2016 revealed that 9 out of 10 households use either firewood or charcoal for cooking (MEMD, 2016), and the use of clean fuels, such as liquefied petroleum gas (LPG), biogas, and ethanol also remain under 1 per cent (GACC, 2017). This means that the focus on the search for sustainable development pathways in developing countries in general and Uganda in particular must include biomass production and consumption at least for the foreseeable future.
1.1 Overview of Uganda’s Energy Sector

Out of the total area of 241,551 sq. km, about 37,000 sq. km of Uganda is open water and trees, forests and woodlands cover about 14% of Uganda’s land surface (Obua et al., 2010). Uganda’s forests meet 88% of the country’s energy needs and it is estimated that the country loses about 120,000 hectares of forest cover annually, of which 60% (72,000 hectares) is due to charcoal and firewood production and consumption (NDP III, 2020). Uganda is among the countries with highest population growth and in 2014, the annual rates of population growth stood at 3.0 per cent (UBOS, 2017). This therefore means that demand for energy and energy services to meet the growing population is going to place more pressure on the already dwindling energy resources.

Uganda’s primary source of energy is predominantly bioenergy. As presented in Figure 1, the National Development Plan 2020/21-2024/25 puts bioenergy contribution to the country’s energy mix at 88%, followed by oil products (10%) and lastly electricity (2%). Bioenergy predominantly meets all the basic energy needs of cooking and water heating in rural areas and for most urban households.

Figure 1: Uganda’s Energy Mix
It is also the main source of energy for many institutions such as schools, hospitals, prisons, small and medium enterprises. The use of alternative sources of energy for cooking is still very low. Less than 1% of the people in Uganda have access to clean fuels such as LPG and electricity for cooking (UNDP and WHO, 2009).

According to the national energy survey of 2014, 0.5% of the population utilises electricity and approximately 3.7% of the households use fuels such as Kerosene, LPG and biogas for their cooking needs (UNBOS, 2014). The low electricity use is mainly due to low levels of electrification on one hand and high electricity tariffs on the other. The country’s access to electricity stands at 24% and the rate is lower in rural areas. In many instances houses connected to the electricity grid rarely use electricity for cooking due to its higher cost compared to the use of biomass fuels. Energy assessments by the World Bank reveal that the share of household expenditure on solid fuels for cooking in Uganda is one of the highest in sub-Saharan Africa (World Bank, 2011).

It estimated that approximately 69% of the population utilize the traditional “three stone fire stoves” for cooking, predominantly in rural areas, and that almost 19% use the traditional charcoal stoves (UBOS, 2014). It is called a three stone fireplace/stove because three sturdy stones of the same height are placed triangularly and fuel is fed into the middle of the stones (fire chamber) through the three outlets between the stones (Picture 1). The cooking vessel is placed on top of the stones.
Bioenergy is consumed in the form of charcoal and firewood, and the main burden of bioenergy collection and use is on women who are the major domestic caretakers and employees in the informal food industry (MFPED, 2015). Uganda is experiencing high rates of increase in demand for bioenergy, which is estimated at 3% and 6% for firewood and charcoal per annum, respectively (Okello et al., 2014). Increasing demand, coupled with agricultural land expansion, is leading to accelerated deforestation and forest degradation, which is one of the drivers of anthropogenic climate change and fuelwood deficit experienced in many parts of the country.
Figure 2 shows that households consume the biggest percentage of energy (64%) in Uganda, followed by industry (20%) and other sectors such as transportation, commercial and others. These figures demonstrated the importance and urgency of ensuring efficient and clean energy access and use at the household level in Uganda.

The Ugandan government has acknowledged the importance of the bioenergy sector through different policy documents. Uganda developed the Renewable Energy Policy in 2007 with the aim of increasing access to and use of modern energy technologies that are clean and more sustainable than existing practices. The policy also aims at increasing the use of improved cookstoves with higher efficiency and the use of domestic biogas systems for household cooking and lighting. Renewable energy policy was undergoing review at the time of research. To further underscore the bioenergy sector’s importance, in 2013, the government developed a Bioenergy Energy Strategy whose main aim is to provide a balanced view of all the options available for managing the country’s all-important bioenergy resources.

Uganda’s long-term energy strategy is described in the policy document “Vision 2040”. The document recognizes the threat of climate change and outlines how the government envisages increasing access to modern sources of energy especially wind, solar and biogas. The policy anticipated that wood fuel will remain the most important energy source, but the objective is to increase efficiency with which it is used. The other important policy document that emphasises the importance of bioenergy is the National Development Plan II (2015/16 – 2019/20), whose target was to promote and facilitate the use of renewable energy technologies like biofuels, wind, solar, energy saving stoves and LPG at household and institutional levels during the plan period. The latest National Development Plan III (2020/21 – 2024/25), however, shifted focus to domestic and institutional biogas and LPG infrastructure development. The current plan aims at increasing access to sustainable energy and transitioning from bioenergy
to more efficient energy sources, but improved cookstoves are not listed among the priority interventions.

From around the late 1980s, a number of targets were set, more investments done and more actors brought on board to develop and promote improved and modern bioenergy energy technologies in the country. Examples of technologies promoted include energy saving stoves (for both firewood and charcoal), domestic biogas systems, bioenergy briquettes, and plant oil based systems (Okello et al. 2014). The Ministry of Energy and Mineral development clearly highlights the significance of the bioenergy sector in Uganda. For example, it has been argued that the improved household rocket stoves have efficiencies\(^1\) of 30\% (average) compared to the traditional (open) 3-stone fire stove’s 15.6\%. Improved bioenergy stoves help the users to have firewood savings of 50 – 60 \% when compared to the traditional (open) 3-stone stove (MEMD, 2013). This implies that the amount of firewood used by a family in one day with a traditional 3-stone fire can be used for two–three days with the rocket stove (MEMD/PREEEP, 2008). This wood saving reduces deforestation, and forest degradation by lowering bioenergy energy demand.

Improved cookstove activities were boosted by the international efforts on climate change mitigation and reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) in the late 2000s. Stove generation, dissemination and promotion activities received more institutional support in form of standards and financing (carbon financing).

\(^1\) How efficiency is determined is explained in empirical chapter five.
1.1.1 The Ugandan Improved Bioenergy Cookstove Landscape

The improved cookstove sector has registered exponential growth in the last two decades, bringing various players on board. This growth is a response to deforestation and forest degradation caused by the high demand for wood fuel\(^2\) the threat of climate change and the health effects of reliance on traditional bioenergy. Bioenergy is Uganda’s predominant cooking fuel, with 85% of the population using firewood and 13% using charcoal, the latter mainly in urban and peri urban areas (NDP III, 2020).

Alternatives to fuelwood, charcoal, and crop residues as cooking fuel are expensive and, in some cases, hardly available in some resource-poor communities. R&D in the sector therefore prioritises investments in development and promotion of technologies which save fuel but do not alter cooking habits, in order to overcome the problem of unsustainable exploitation of forests for wood and charcoal (Dresen et al., 2014). According to a World Bank report (2014), the cookstove sector in Uganda is mainly made up of different actors and each of these actors performs differentiated roles in the sector, although some actors like NGOs engage in various roles as shown in Table 1.

Table 1: Major Actors in the Bioenergy Cookstove Sector in Uganda

<table>
<thead>
<tr>
<th>Actor</th>
<th>Major Roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Government agencies</td>
<td>Policy guidance, regulation, quality control, sensitization</td>
</tr>
<tr>
<td>2. National and international non-government organizations (NGOs)</td>
<td>Advocacy, sensitization, manufacturing, distribution, training of trainers</td>
</tr>
<tr>
<td>3. Donors and international organisations</td>
<td>Funding of stove related projects</td>
</tr>
<tr>
<td>4. National research and testing centres</td>
<td>Training in stove design and testing, testing of manufactured stoves, manufacturing of stoves and research</td>
</tr>
</tbody>
</table>

\(^2\) Wood fuel includes firewood and charcoal
| 5. Private sector and community groups | Manufacturing and distribution |
| 6. Financial intermediaries | Financing acquisition and use of improved cookstoves |

**Source:** World Bank Report, 2014

There are a variety of cookstoves that are being developed and promoted, each with distinct characteristics and a targeted population – rural or urban, based on the energy resources typically available in the community. Different stove types have different levels of efficiency. According to the World Bank Report (2014), about 30,000 improved bioenergy cookstoves are produced every month in Uganda and the estimated demand is 90,000 cookstoves per month.

### 1.2 Problem Statement

Implementation of improved cookstove interventions is typically driven by the desire to reduce deforestation and forest degradation, mitigate climate change, reduce harmful exposure to smoke, and generally improve poor people’s welfare. Although clean renewable energy technologies like LPG, solar, biogas, biofuels and hydropower would be preferred to achieve the intended change, their accessibility, affordability, and availability among other factors have made their diffusion and adoption an even bigger challenge. This is why improved cookstoves, some of which are far less efficient than the above-mentioned renewable energy technologies, still have a big role to play in Uganda’s cooking technology mix.

Widespread diffusion and adoption of improved bioenergy cookstoves is a prerequisite for overcoming the health, environmental, social and economic challenges associated with traditional cooking technology use. Despite decades of their promotion however, over 85% of the population in Uganda, Rwanda, Tanzania

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3 Stove Manufacturers and distributors
4 These include banks, community-based savings and credit cooperatives (SACCOs) and carbon finance agencies
and Burundi still relies on traditional bioenergy stoves to perform their daily tasks like cooking, while in Kenya the percentage is slightly lower - 68%. Yet, in order to achieve health benefits and reduce forest degradation for example, there has to be major reductions in emissions and demand for fuel wood and charcoal respectively, targets which can only be achieved through large scale diffusion, adoption and sustained use of improved bioenergy cookstoves. Therefore, the theory of change of bioenergy technologies stands at crossroads in the face of limited progress in widespread diffusion and adoption of the improved cooking stoves.

There are numerous studies that explain the slow adoption of improved cookstoves and they have majorly focused on individual-blame, rather than system-blame analysis to explain the slow rate of cookstove adoption in the region (Namagembe et al., 2015; Mwaura et al., 2014; IIED, 2013; Boldt et al., 2012; Sovacool, 2012; Levine and Cotterman, 2012; Kaygusuz, 2012; Kaygusuz, 2011; Haselip et al., 2011; Mondal et al, 2010; Karekezi et al., 2008; Balachandra et al 2007; Karekezi and Kithyoma, 2003). According to Rogers’ (2003) diffusion of innovation theory, individual blame is the tendency that holds an individual or community responsible for their problems, rather than the system of which they are a part. Most of the existing literature blames economic and social characteristics of end-users and communities for hampering diffusion and adoption of improved bioenergy cookstoves, yet these are just a part of the bigger complex processes of interaction in the system. Advocates of new technologies have largely focused on technical, scientific, social and economic matters (Tigabu, 2017; Juma, 2016).

On the other hand, system-blame is the tendency to hold systemic factors like institutions, processes, and/or interaction between actors and functions embedded in the technology development process responsible for challenges in the diffusions and adoption of solutions (Hekkert et al., 2007; Rogers, 2003). Rogers’ Diffusion of
Innovation theory specifically constructs determinants of technology adoption at implementation stage. This study built on this theory by constructing the pre-implementation determinants of successful diffusion and adoption of bioenergy technologies. On the other hand, Hekkert et al.’s (2007) theoretical constructions on innovation systems mainly apply to developed country’s experiences. This thesis examines how the innovation system model works in a developing country context.

Although, as expounded by previous studies, end-user characteristics and technology attributes affect diffusion and adoption of technologies to some extent, this research contends that these are not enough to explain the slow trend in developing countries. This study argues that there is need to examine the slow diffusion and adoption of improved cookstoves from a systemic perspective as well. This study therefore critically examines the systemic factors embedded in the improved bioenergy cookstove development system and how they influence diffusion and adoption of bioenergy improved cookstoves, of which there is limited in-depth study.

There are a number of questions that that formed the basis for this study with regards to the improved bioenergy cookstoves innovation system in Uganda, including: 1) What structural elements support the innovation system? 2) What is the nature of interaction between stove manufacturers, disseminators and end users, nature of markets, institutional settings, knowledge networks, resource envelope to develop and market the innovations, existing human and technical capacity to generate appropriate technologies?

These are pertinent questions as far as successful diffusion and adoption of technologies is concerned, yet are not often asked. This thesis answers these questions not only to illuminate how the improved bioenergy cookstove innovation system works but also to contribute to theories for improving performance thereof and
increasing the likelihood of widespread diffusion and adoption of technologies, especially in Uganda.

Therefore, the purpose of examining the technological innovation system was to analyse the development of the improved bioenergy cookstove sector in terms of the structure, institutions and processes that support or hamper it. This thesis makes an original contribution to the body of literature on the potential for systemic analysis of renewable energy technologies in general and improved bioenergy cookstoves in particular to increase diffusion and adoption of technologies and also inform future policy and practice for successful innovation system building. This thesis also contributes to theory development in the area of technology diffusion by establishing how the innovation system works in Uganda.

1.3 Objectives of the Study

1.3.1 Main objective

The principal aim of this research was to investigate the nature and extent of development of the improved bioenergy cookstove technologies innovation system and the implications for diffusion and adoption of improved bioenergy cookstoves.

1.3.2 Specific objectives

1. To explain how the structure of the improved cookstove innovation system is organised.

2. To examine how knowledge is shared, and how learning takes place within the improved cookstove innovation system.

3. To analyse how the improved cookstove innovation system is functioning and why it is functioning the way it is, and analyse the innovation system problems, their manifestation and causes.

4. To assess the implication of the current state of innovation system for diffusion and adoption of improved bioenergy cookstoves.
1.4 Research Questions

Key Research Question
How is the improved bioenergy cookstove innovation system organised and how does it function, and what does this mean for diffusion and adoption of improved bioenergy cookstoves technologies?

Sub Questions
1. Who is active in the improved bioenergy cookstove innovation system, why and the environment in which they operate?
2. How is knowledge shared, and how does learning take place within the improved bioenergy cookstove innovation system?
3. How does the improved cookstove innovation system function?
4. What implication does the current innovation system set up have for diffusion and adoption of improved cookstoves?

1.5 Rationale for the Study
This multiple case study focuses on the improved cookstove innovation system and how it generates, diffuses and utilises these technologies in Uganda. Specifically, I examine the innovation system for cookstoves in the context of its structure and functions, looking at how the technological innovation system (henceforth TIS) is shaped by the structure and activities, and what this means for generation, diffusion and utilisation of cookstoves. The rationale is that focus needs to go beyond user characteristics and technology attributes that dominate improved cookstove diffusion and adoption studies.

My overarching intention is not to evaluate the performance of the improved cookstove innovation system but rather to describe how the structure is organised (the system environment), explain what the structural elements are doing: key processes, and how they are doing it to fulfil the system functions. I specifically explore how the
activities that the structural elements engage in are carried out and their outcome, and elaborate on the lessons that emerge for policy and practice for renewable energy technologies in general and cookstoves in particular, and for future research. In this thesis, I seek to contribute to the understanding of how the innovation system works in Uganda based on my research on improved cookstoves.

1.6 Organisation of the Thesis

This thesis is organised into eight chapters. Chapter one focuses on the study context, research issues and research design. It sets a stage for the key issues and debates on improved cookstove diffusion and adoption. Chapter Two presents and discusses literature relevant to this study, and Chapter Three deals with the theoretical and conceptual frameworks. The main objectives of Chapter Three are to situate the discussion in theory and to give meaning to the key concepts in the study that are embedded in theory such as structure, interaction and functions as well as mapping their interconnections. Chapter Four covers the methodology. A multiple case study research design is adopted aided by mixed research methods.

This thesis is comprised of four empirical chapters. The first empirical chapter (Chapter five), looks at two structural elements (actors and institutions) of the improved cookstove innovation system in Uganda. Based on the theoretical structural elements of TIS theory (e.g., Edsand, 2019; Hekkert et al., 2011; Bergek et al., 2008a; Hekkert et al., 2007), it describes what each of the theorised structural elements is in Uganda, and what role they play in shaping the cookstove innovation system. The second empirical chapter (Chapter Six) discusses the third structural element: networks. It describes and analyses how information and knowledge is exchanged and how learning takes place in the system. Chapter Seven analyses the different technological frames on improved cookstoves and shows how the divergent perceptions create tension and confusion in the TIS. Chapter Eight derives from the structural and technological frames analysis to examine the functional patterns of the
improved cookstove TIS. Specifically, it answers the question of how the system functions are being fulfilled. As mentioned earlier in section 1.6, my intention is not to judge the innovation system whether it is good or bad, but rather to describe and analyse how the technological innovation system works in a developing country context. Inevitably, while describing and analysing the structure and functions, I identified potential strengths and weaknesses in the innovation system. Chapter Nine discusses and interprets key findings. It also provides the general conclusion of the study by revisiting the main arguments. It also includes the implications for policy, wider improved cookstove diffusion and adoption, and relevance for future research.

### Table 2: Organisation of the Empirical Chapters

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### 1.7 Conclusion

Bioenergy for cooking is expected to remain significant in the foreseeable future in Uganda as it is with most of the developing world. Improved cookstoves, which increase the efficiency with which bioenergy is used, have been promoted for over 30 years now in Uganda, and received a boost in 2007 when they were accepted under
CDM as one of the measures to mitigate climate change. However, despite decades of research and development, coupled with CDM endorsement, the rate of improved cookstove adoption remains slow. This study questions why this is so. It focuses on the institutional framework that generates, diffuses and utilises these technologies to understand this controversy.
CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter is organised into two sections. In the first section I position myself in the literature on diffusion and adoption of improved cookstoves and in the second section I focus on reviewing literature regarding the innovation systems concept, which builds on evolutionary and institutional thinking.

2.1 The Role of Technology in a Wider Context

Technology has always been seen to play a central role in socio-economic development, and change in technology world (Heeks and Stanforth, 2015), playing a fundamental role in wealth creation, improvement of the quality of life and real economic growth and transformation in any society (Anaoto et al., 2016). While technological change can revolutionise individual lives, workplace routines, firms, sectors and even developmental models themselves, drive increases in productivity and create demand for goods and services, it may lead to labour displacement, joblessness and the reshoring of value chains (Salam et al., 2018a).

Technology is achieved through a combination of knowledge, methods, tools and skills. This four-element definition of technology offers the details and clarity required for technology enhancement planning that must necessarily include knowledge and skills upgrade (training) and acquisition of human elements (knowledge and skills) and the tangible elements (methods and tools) of technology form the basis for our thinking and working processes (Anaeto et al., 2016). Therefore, technology raises prospects for entrepreneurism and innovation but, at the same time, requires regulation and the careful nurturing of a favourable investment climate. It offers new ways of solving traditional developmental problems and delivering services while also necessitating new modes of governance (Salam et al., 2018a). This means that a new technology has to adopt the right pathways in order to deliver positive outcomes.
Further, technological progress in one sector can create new economic opportunities in other sectors. The benefits of a new technology can extend well beyond the immediate sector or good in which the technology exists. This is the case if the initial product is an important intermediate good in the production of other good (World Bank, 2008).

2.2 Making a Case for Renewable Energy Technologies

Renewable energy comprises of a heterogeneous set of technologies among which include bioenergy, hydropower, solar, wind and geothermal. The initial interest in renewable energy technologies (RETs) is attributed to the 1970’s oil crisis (Timilsina and Ziberman, 2014; Karekezi et al 2004) where, in an attempt to boost energy security by reducing dependence on fossil fuels, countries looked to RETs as alternatives. Lately, concerns about climate change (Timilsina and Ziberman, 2014; Kaygusuz, 2011), production costs (Smith, 2010) and future energy security (Edsand, 2017) emerged as drivers of demand for alternative energy. Most recently, the Sustainable Development Goals (SDGs), which are currently being pursued globally, recognised energy as a key enabler for development (SDG 7).

Not only that but also almost all other SDGs explicitly or implicitly recognize the contribution and impact of energy on their achievement.

The indispensability of energy in enabling economic growth and sustainable human development is well-documented (Gelvet, 2014; Simonyan and Fisina, 2013; Sovacool, 2012; Cabraal et al., 2005). Energy is needed for many activities - household (e.g., cooking, lighting, heating), agricultural (e.g., tilling, irrigation and post-harvest processing), and industrial use (e.g., milling and mechanical energy and process heat) (Kaygusuz, 2010). Therefore, social and economic development requires reliable and affordable access to the energy resources necessary to provide essential energy.

SDG7: Ensure access to affordable, reliable, sustainable and modern energy for all.
services. And for development to be sustainable, delivery of energy services needs to be secure and have low environmental impacts (Moomaw et al., 2011).

One of the major development challenges facing the world today is the historic increase in the anthropogenic atmospheric Green House Gas (GHG) concentration, which mainly result from the consumption of energy services (IPCC, 2011), and is the major cause of global warming and climatic change in general. Developed countries contribute to GHG emission mainly through fossil fuel combustion (accounting for 56.6% of all anthropogenic GHG emissions (Moomaw et al., 2011), while developing countries contribute mainly through land use change. Land use change (mostly conversion from forests to other land uses) is driven by population pressure, agriculture intensification and increasing demand for fuel wood and charcoal for household, institutional and commercial enterprise use. The resultant effect of land use change is deforestation and forest degradation, which contributes between 15 - 20% of anthropogenic GHG emissions (Bellassen, et al., 2008).

In the different international climate change conferences, calls for developed countries to take responsibility for their historic emissions are getting louder. Demands to contribute funds and transfer of technologies to developing countries for climate change mitigation and adaptation have been placed on developed countries as well. Such calls culminated in financing mechanisms like the Clean Development Mechanism (CDM), which allows a country with an emission-reduction commitment under the Kyoto Protocol to implement an emission-reduction project(s) in one or more developing countries.

Mitigating anthropogenic climate change remains a key development challenge for the world because a changing climate threatens not only current and future development goals but also has potential to ruin the already achieved economic development gains. Indeed, as Smith (2010) opines, the world stands on the verge of
an energy revolution. It will be driven by the realisation that continued reliance on fossil fuels and traditional bioenergy as the major sources of energy for developed and developing countries respectively, will only exacerbate climate change and worsen existing development problems on one hand, and the daunting search for alternative sources of energy, which produce less emissions on the other hand. Therefore, attaining development that is less greenhouse-gas-intensive is a significant sustainable development goal that RETs like improved cookstoves intend to achieve. According to IEA (2014a), bioenergy is energy derived from bioenergy feedstock in the form of solid, liquid and gaseous products. It consists of solid bioenergy (fuelwood, charcoal, agricultural residues, wood waste and other solid waste), biofuels (liquid fuels, including ethanol and biodiesel) and biogas.

Worldwide, roughly 1.3 billion people do not have access to electricity and 2.8 billion rely on traditional bioenergy stoves and open fires for cooking and heating (IEA, 2014b). They rely on traditional bioenergy (wood, animal dung, charcoal, crop waste and coal) to meet their daily energy needs, which is burnt in very inefficient and polluting traditional stoves. More than 99% of people without electricity live in developing regions, and four out of five of them are in rural South Asia and sub-Saharan Africa (REN21, 2013). The majority of people in sub-Saharan African countries lack adequate access to modern energy for the basic needs of cooking, warmth, lighting, and essential energy services for manufacturing, schools, health centres and income generation. Solid bioenergy constitutes 80% of sub-Saharan Africa’s total energy consumption, thus making it the biggest source of energy in the region. It is estimated that 90% of the 280 million tonnes of oil equivalent (Mtoe) of solid bioenergy currently consumed in sub-Saharan Africa, is used by households as cooking fuel (IEA, 2014b).
Existing predictions show that bioenergy for cooking is expected to remain significant for developing countries in the next 30 years (Malla and Timilsina, 2014; Palit and Bhattacharyya, 2014). This is mainly because alternatives to traditional bioenergy are generally expensive and barely available in developing regions (Drensen et al., 2014). Biofuels, biogas and solar energy are better alternatives for clean cooking and for providing electricity, especially in rural areas that are not yet connected to the national grids, but the upfront costs coupled with other factors like quality of solar panels, and issues of food security (in case of energy crops versus food crops) greatly impede their uptake.

Therefore, investments in solutions that allow for significant savings of fuelwood without the need to introduce sophisticated technologies or to change cooking habits are promoted to combat the unsustainable use of fuelwood (Dresen et al., ibid p.1138). Advantageously, bioenergy is a diverse resource and is easy to harness because unlike some other forms of renewable energy like wind, geothermal, it is not site specific. It is available in many forms such as trees, bushes, grasses and forbs, papyrus and reeds and vegetal waste (MFPED, 2015) and can be converted into different energy products like charcoal, briquettes, pellets and high-end fuels like first⁶- and second⁷- generation biofuels. For instance, Karekezi et al. (2004) report that bioenergy-based industries are a significant source of enterprise development, job creation and income generation in rural areas.

The challenge however, is that bioenergy is mainly used in its traditional form in a majority of developing countries. Traditional bioenergy constitutes over a half of total energy demand, mainly for cooking in Sub-Saharan Africa (IEA, 2017). Traditional use of bioenergy is in two forms – resources (e.g., solid bioenergy) and the technologies used to convert resources into energy. The innumerable negative impacts of

⁶ Biofuels generated from food crop feedstock like sugar cane, corn, palm oil, etc.
⁷ Biofuels generated from agricultural and forest residues and from non-food crop feedstock.
traditional bioenergy use are well documented (World Bank, 2020; Lambe and Senyagwa, 2015; Barnes et al., 2015; WHO Report, 2014; Urmee and Gyamfi, 2014; Wisdom et al. 2014; World Bank, 2011). Inefficient traditional methods used to produce charcoal, for example, release significant amounts of methane whose Global Warming Potential (GWP) is 21 times higher than that of carbon dioxide (MEMD, 2013). Inefficient cookstoves contribute to global emissions of greenhouse gases like carbon dioxide and other short lived climate change forcing agents such as black carbon, which are major contributors to the current global warming (GACC, 2012 in MEMD, 2013).

Some earlier studies estimated that solid fuel cookstoves emit roughly 18% of global black carbon emissions (Bond et al., 2013). Black carbon (BC), a component of soot is one of the four short-lived climate pollutants (SLCPs), which have recently emerged as the second main drivers of change, only behind CO₂ (Zaelke and Borgford-Parnell, 2013). Although SLCPs have a much shorter lifetime in the atmosphere than CO₂, recent estimates indicate that they may be responsible for 40–45% of overall present-day global warming (Bond et al., 2013; Zaelke and Borgford-Parnell, ibid p.11). Black carbon, which remains in the atmosphere for a few days to weeks is generated by the incomplete combustion of fossil fuels, biofuels and bioenergy (Zaelke and Borgford-Parnell, ibid p.11). Bond et al., (2013) further estimate that coal and bioenergy burning contribute 60-80% of Asian and African black carbon emissions.

Black carbon is a main component of fine particulate matter air pollution (P.M₂.₅), which is the primary cause of health problems like asthma, respiratory problems, low birth weights, heart attacks, and lung cancer (Zaelke and Borgford-Parnell, 2013). Zaelke and Borgford-Parnell, (ibid, p.12) further argue that BC is harmful to plants by impeding their growth. Therefore, black carbon emission reduction through widespread use of improved cookstoves for example presents not only a potential mitigation strategy that could contribute to reducing and/or slowing down climate
change from anthropogenic activities (Bond et al., 2013; Grieshop et al., 2011), but can also result in benefits to human and plant health.

According to a WHO Report (2014), 4.3 million people died in 2012 due to cardiovascular and respiratory diseases linked to household air pollution – indoor air pollution (IAP), almost all in low- and middle-income countries. The use of solid fuels exposes people to smoke from cooking and this is the fourth most significant risk factor for disease in developing countries, causing four million premature deaths in 2010 (Goodwin et al., 2014). Much of the burden falls on women and children because of gendered roles and responsibilities. Bringing in the COVID-19 dimension, the most recent World Bank Report (2020) further warns that conditions strongly associated with exposure to IAP such as cardiovascular disease, diabetes, chronic respiratory illness, and hypertension are also risk factors for the novel corona virus. That if COVID-19 gains ground in countries with high population exposure to air pollutants linked to the use of traditional cooking fuels and stoves, one could expect an exacerbation of its impact.

Household fuel transition along the hypothetical energy ladder from primitive fuels (fire wood, agricultural waste, animal waste) that rural communities and poor urban dwellers primarily depend on to transition fuels (charcoal, kerosene), which the majority of urban people rely on, and finally to advanced fuels like LPG and biofuels or electricity will take decades in most of Sub-Saharan countries. In addition, at best, many households will not completely abandon the “dirtier” energy carriers and completely switch to clean ones but rather fuel stack\(^8\) (Masera et al., 2000). Considering therefore, that switching to electricity or other clean energy carriers is not an option for many: at least in the short run, wood and charcoal are likely to remain the

\(^8\) Fuel stacking is the practice of using multiple energy options at the same time albeit for different purposes
dominant energy carriers in developing countries in the foreseeable future, and thus investment in research and development on efficient ways of using wood fuel remains not only a crucial but also an urgent goal.

Efficient use of renewable energy offers the opportunity to contribute to social and economic development, climate change mitigation, and the reduction of negative environmental and health impacts (IPCC, 2011). In order to address the negative effects of traditional bioenergy utilisation and improve energy efficiency, security and access and improve livelihoods, while at the same time ensuring that cooking habits are not significantly altered, there has been increasing investment in research, development and promotion of improved bioenergy cookstoves for several decades now. Bioenergy technologies can be grouped into three categories, which include traditional technologies (the inefficient open three-stone stove and metallic charcoal stoves), improved/intermediate/transition technologies and “modern” technologies (Karekezi, 2004). Internationally, efforts such as the Clean Cooking Alliance, as well as national stove programs in India, Peru, Cambodia and Mexico, amongst others, have widely implemented efficient cooking technologies. International carbon markets are also including more cookstove projects (Simon et al. 2014).

The widely documented potential of improved bioenergy cookstoves to achieve win-win benefits of ensuring environmental sustainability and improving livelihoods, has contributed to their popularity both within the international climate change

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9 Improved/intermediate Bioenergy technologies refer to improved and efficient innovations for direct combustion of bioenergy e.g., improved wood and charcoal cookstoves for household, SME and institutional use, improved charcoal kilns, improved tobacco, fish and tea driers.

10 Modern bioenergy technologies refer to the conversion of bioenergy energy to advanced fuels namely liquid fuels, gas and electricity e.g. biofuels for transportation, bagasse-based cogeneration and biogas for the production of heat or electricity.
negotiations on reducing emissions from deforestation and forest degradation (REDD+), and within the Clean Development Mechanism (CDM) and voluntary carbon markets. By May 2013, carbon finance supported approximately 75 cookstove CDM projects and 63 Programme of Activities (PoAs) (Simon et al. ibid, pg 54).

There are many promises attributed to improved bioenergy cookstoves. It is widely documented that efficient use of bioenergy technologies plays a significant role in reducing pressure on forests by reducing demand for wood fuel through providing alternative fuels, such as ethanol or biogas, and by improving the efficiency with which traditional fuels, such as wood and charcoal are produced and used (Parker et al., 2015). It is also prominently argued that improved bioenergy stoves save energy and money, reduce cooking time, and improve the cooking atmosphere/reduce smoke and reduce risk of burns to the user (Barnes et al., 2015; Levine and Cotterman, 2012).

Production of improved cookstove technologies is also an income generating activity, which is capable of growing into a full-blown industry (MFPED, 2015). The key characteristic features of improved bioenergy cookstoves upon which all these promises are premised include: i) they emit less or even no smoke and give more energy than dried wood, maize cobs or cow dung cakes, ii) can reduce wood consumption by up to 50% or more, iii) they are safe to use because they are built unlike the open traditional stoves, iv) they can be fuelled by small pieces of wood or special pellets made from dried and compressed agricultural waste e.g., briquettes, v) they turn waste into energy, and vi) they do not necessitate significant alteration of cooking habits. In the next section, I discuss how these grand promises have paradoxically failed to drive faster adoption of improved cookstove technologies.

2.3 The Paradox of the Improved Cookstove Promise
Paradoxically, despite the well documented promises and benefits of improved bioenergy cookstoves and the well-articulated dangers associated with the traditional
bioenergy devices, the rate of diffusion and adoption of the former is still very slow in many developing countries. According to EIA (2014b), four out of five people in sub-Saharan Africa rely on the traditional use of solid bioenergy, mainly fuelwood and traditional stoves for cooking, and that the change in this trend is very gradual even with increase in income. This literature contradicts the widely held view that uptake and diffusion of clean bioenergy stoves is slowed down mainly by the low incomes of the majority of people in developing countries. I have referred to the contradiction of cookstoves’ grand promises/benefits and dismal uptake as the “paradox of the improved cookstove promise\textsuperscript{11}”. Slow uptake and ineffective use of improved cookstoves persist, despite several decades’ worth of efforts by governments, development agencies, NGOs and the private sector to address this challenge. Even where financial interventions like carbon credit mechanisms have lowered the price of stoves, uptake of cookstoves has still remained low (Barnes et al., 2015; Urmee and Gyamfi, 2014).

Worse still, even when acquisition barriers are overcome and households are able to obtain an improved cooking stove, Barnes et al. continue to argue that the challenge of inconsistent and incorrect use of stoves abounds. Although there are a few success stories of large-scale diffusion and adoption of improved bioenergy cookstoves, for example the New Lao stove in Cambodia, this case is more of an exception than a rule. Many countries especially in Sub-Saharan Africa are still grappling with limited progress (Lambe and Senyagwa, 2015; Rehfuess et al 2014; Simon et al 2012). Amidst multiple players’ efforts and interventions in the development and promotion of improved bioenergy cookstoves, traditional bioenergy use persists with its attendant problems of deforestation and forest degradation, biodiversity loss, pollution (both

\textsuperscript{11} Refers to the irony that despite all the economic, environmental and social benefits attributed to improved bioenergy cookstoves, their diffusion and adoption is slow.
indoor and outdoor) and climate change in most developing countries. I ponder on what these multiple players might not be getting right? In the face of marginal diffusion and adoption therefore, the improved bioenergy cookstove’s grand promises unfortunately stand like an illusion in both the theoretical and practical landscapes.

The paradox of improved cookstoves’ promise in Sub-Saharan Africa becomes even more puzzling, given that even with better technologies that guarantee over 50% efficiency on the market uptake remains slow (Vigolo et al., 2018; Barnes et al., 2015). The pertinent question is why? Research by Lambe and Senyagwa (2015) posits that one key explanation for the lack of progress is that bioenergy cookstove technology developers and promoters often fail to properly take account of key drivers of behaviour related to cookstove and fuel choice, most notably the end-users’ needs and preferences. End-users remain more or less passive participants at the tail of the technology development process. Their involvement is very minimal, yet it is paramount in ensuring acceptability and sustained use of the technology (Juma, 2016; Lambe and Senyagwa, 2015).

Until recently, efforts to promote improved bioenergy cookstoves have concentrated on technological advances to increase efficiency and reduce both emissions and the amount of wood used (Barnes et al., 2015). And tremendous achievements have been registered on this front. For example, there are claims that there are wood stoves on market that reduce fuelwood use by 90% and are smokeless (Vigolo et al., 2018). Although getting efficiency right is a prerequisite for fulfilling improved bioenergy cookstoves’ grand promises, reality clearly shows that this is not enough to trigger diffusion and adoption of these technologies in developing countries.

There is therefore a need to go beyond getting technological attributes right and investigate the other factors which promote or inhibit diffusion and adoption of
improved bioenergy cookstove technologies. Barnes et al. (2015) for example submit that very few stove initiatives have explicitly used behaviour change frameworks to guide their interventions. Recent studies by Memon et al. (2020) and Savacool and Griffiths (2020) underscore the role of behavioural factors, saying that many past bioenergy improved cookstove programmes did not succeed because of the lack of in-depth analysis of the socio-behavioral factors affecting the people. Even where an attempt to use behaviour change approaches was made, Barnes et al. (2015) continue to argue that such behaviour change interventions primarily focused on educating the poor about the negative effects of traditional bioenergy use on their health without paying due attention to other important determinants of adoption and sustained use of improved cookstoves, like inclusion of users in the stove development process.

In this thesis I argue that the widely held view that poor people use traditional bioenergy because they do not understand its dangers needs to be deconstructed. Persistence of traditional bioenergy use needs to be analysed from the systemic processes that produce and promote the improved bioenergy cooking technologies as well. I contemplate on questions such as: (1) To what extent is the controversy of slow diffusion and adoption of improved cookstoves attributable to factors related to the nature of technology development processes, than end-users’ perceived lack of knowledge of the dangers associated with traditional bioenergy use? (2) What is the nature of interaction between the key actors in the improved cookstove institutional setup? (3) How does the existing technology development system include or exclude different key actors like for example end users and marketing/dissemination conduits in the technology development process?

Barnes et al. (ibid, p.4) warns us that decades of research have shown that the modernistic hegemonic appeals of “do it because it is good for you” scarcely succeed. This revelation lends further credence to this thesis’ argument that beyond technology attributes and educating the poor about the dangers of traditional bioenergy use, are
key systemic factors that inhibit successful diffusion and adoption of improved bioenergy cooking technologies. In line with this disclosure, I assert that the contestations around slow diffusion and adoption of bioenergy technologies need to be unpacked and analysed from the systemic point of view. This thesis therefore interrogates the technology innovation system that develops, promotes and disseminates bioenergy improved cookstove technologies and the extent to which it influences their diffusion and adoption in developing country context like Uganda.

There are numerous other studies which attempt to explain the slow rate of adoption and diffusion of bioenergy technologies in Africa (IIED, 2013; Boldt et al., 2012; Sovacool, 2012; Oyedepo, 2012; Kaygusuz, 2012; Kaygusuz, 2011; Haselip et al., 2011; Mondal et al., 2010; Karekezi et al., 2008; Balachandra et al., 2007; Karekezi and Kithyoma, 2003). Empirical review of literature on improved bioenergy cookstove adoption in Africa reveals that the various factors that influence the stoves’ adoption can be grouped into the following three broad categories: (1) factors related to the characteristics of adopters (income, gender, level of education, information and awareness, cultural rigidity); (2) factors related to the characteristics and relative performance of the stove (fitness for purpose, complexity, affordability, availability, perceptions of adopters about the stove) and (3) programme and institutional factors (availability of credit, availability and quality of information on the technology, enabling policies and regulations).

Existing studies mainly focus on factors in category one and two, and this thesis contends that this is only part of the story of dismal diffusion and adoption of improved bioenergy cookstoves in developing countries in general and Uganda in particular. Although institutional factors are scarcely studied, none of those studies explicitly analysed the technology development process and how it influences diffusion and adoption of bioenergy technologies. This is the knowledge gap that this thesis sought to ameliorate by employing the technological innovation systems lenses
to unpack the controversy of slow diffusion and adoption of improved bioenergy
technologies in Uganda. How can the innovation system concept help us to address
this deficiency in the improved cookstoves literature?

2.4 The Innovation System Concept

There is a developing body of literature which argues that the development process
of technologies is a major factor in influencing their diffusion and adoption. This line
of thought argues that technology development takes place within a wider system of
actors, networks and functions, all of which have an intricate relationship with each
other. Technology development takes place in an interconnected system whose
success is a function of quality of interaction between actors and their performance of
system functions (Hekkert and Negro, 2009; Hekkert et al., 2007). Proponents of this
school of thought, recognise that the technology development, diffusion and adoption
process is more of a function of the nature of actors, their activities and interactions,
as well as institutions in which they operate than end-users’ characteristics (Markard
and Truffer, 2008; Hekkert et al., 2007; Jacobsson and Johnson, 2000).

To this school of thought, therefore, the importance of the well-functioning innovation
system to the successful diffusion and adoption of technologies cannot be
overemphasised. To further underscore the state of the innovation system’s
importance, Van De Ven (1993) and Alkemade et al. (2007) warn that weak innovation
systems can delay the progress of an innovation, or decrease the likelihood of its
success. Therefore, analysing and understanding the dynamics of the technology
development process is critical for increasing the likelihood of diffusion and adoption
of technologies. This emerging debate, however, tells us relatively little about systemic
dynamics of innovation development in the developing country context. This thesis
seeks to broaden our understanding of the role of systemic factors in influencing
innovation systems in such a setting.
Still in line with the debates that view technology development as an intricate system of actors and institutions, this thesis sought to go beyond the minimalist end-user blame mantra that has dominated renewable energy technology diffusion and adoption research in Africa and examined other factors within the social system that develops and implements the improved cookstoves technology. This research treats end-users as part of the wider social system that develops and implements the improved cookstoves. The holistic factors that determine improved cookstove development and implementation were therefore analysed from the systemic point of view of processual technology development, an area that is under-researched and under-theorised especially in developing countries.

Technologies can either be incremental improvements to existing ones or disruptive (radically new) that strongly deviate from existing technologies and practices (van De Ven, 1993). Van De Ven argues that for the new technologies that are incremental improvements to existing ones, innovation systems are already in place while for the radically new technologies, innovation systems need to be established, and this takes time and effort. Some cleaner bioenergy cookstoves like the gasifier and high tech stoves like the biolite and eco-stove are disruptive technologies because they are multipurpose, offer novel attributes to users (they are movable, provide phone charging services), are characterised by their novel application of knowledge, while others like the lorena rocket stove can be technically categorised as incremental improvements to the traditional three stone fire place technology. However, the level of development of innovation system of both the disruptive and incremental improved cookstove technologies is not known. This study therefore seeks to contribute to understanding the state of improved cookstoves’ innovation system development and its implication for diffusion and adoption of these stoves.
As was earlier observed by Rogers (2003), Wisdom et al. (2014) argue that most of the technology adoption literature has concentrated heavily on the implementation phase of the process with less emphasis on the exploration (pre-adoption/pre-implementation) phase or sustainability (post-implementation) phase. This information gap affects effective development, promotion and impact assessment of technologies. Wisdom et al. continue that many theoretical frameworks sought to describe the dynamic process of the implementation of technologies but little is known about the institutional context within which technologies are developed and promoted and how the likelihood of diffusion and adoption of technologies can be increased through such contexts. This thesis contributes to filling the knowledge gap specifically on what Rogers and Wisdom et al. refer to as the exploration phase of technology development by examining how systemic factors within the improved bioenergy cookstove technologies’ development process affect diffusion and adoption of these technologies. Figure 3 below describes the technology development process as conceptualised in the literature (e.g., Wisdom et al., 2014; Rogers, 2003), and also shows the focus of this thesis.
Based on the literature reviewed for this study, extensive studies that focus on the characteristics of the users as the factors that largely impede widespread diffusion and adoption of improved cookstoves exist (Namagembe et al., 2015; Mwaura et al., 2014; IIED, 2013; Boldt et al., 2012; Sovacool, 2012; Levine and Cotterman, 2012; Kaygusuz, 2012; Kaygusuz, 2011; Haselip et al., 2011; Mondal et al 2010; Karekezi et al., 2008; Balachandra et al., 2007; Karekezi and Kithyoma, 2003). As presented in Figure 3 above, this study conceptualised that these studies concentrate on the second part of the stove development process, neglecting the role of the first (pre-implementation) stage in influencing the second and subsequent stages of the stove development process. This study focuses on the processes that generate, diffuse and use the improved cookstove technologies and they influence diffusion and adoption of these technologies in Uganda.

2.4 Conclusion

The renewable energy diffusion and adoption research in Africa has mainly focused on identifying technological, economic and social factors, which influence adoption of renewable energy technologies (Tigabu, 2017), and in addition, many studies largely blame end-users for the slow diffusion and adoption of bioenergy technologies. I have discussed these studies and identified gaps within their treatment of the topic. I have also presented the current debates that look at innovation as a collective activity whereby a set of networks of actors and institutions jointly interact to the generate, diffuse and utilise a technology, which has given a peek into the theoretical views upon which this study is anchored. The next chapter discusses how innovation is conceived as a collective activity and the limitations of this conceptualisation.
CHAPTER THREE: THEORETICAL AND CONCEPTUAL FRAMEWORK

3.0 Introduction

The study is situated in innovations theory, specifically the Technological Innovation Systems theory (TIS). This chapter explains the tenets and concepts of the theory and how they are used in this study. I also ponder on the strength and weaknesses of the theory.

3.1 Innovations Theory

Innovation theory is not rooted in a single discipline or school of thought, rather its conceptual strands can be traced from institutional and evolutionary economic theories (Tigabu et al., 2015; Courvisanos and Mackenzie, 2014; Markard and Truffer, 2008; Hekkert et al., 2007). The theory has undergone several conceptual changes from the linear models of 1930s, which viewed the innovation process as a simple, unidirectional undertaking to the current understanding of innovation as a complex and interdependent process that functions within a heterogeneous system of elements to develop, diffuse and use the technology.

There are several approaches of Innovation Systems analysis, which include National Innovation System (NIS), Sectoral Innovation System (SIS), Regional Innovation System (RIS) and Technological Innovation System (TIS) (Lundvall, 1992; Malerba, 2002; Bergek et al., 2008a). The defining characteristic of these approaches is their emphasis and unit of analysis. For example, NIS and RIS are geographical in nature while SIS focuses on industry and TIS on a specific technology. However, all the innovation systems approaches have a similar goal, which is to develop, diffuse and use new technology and technological knowledge (Jacobsson and Johnson, 2000; Markard and Truffer, 2008). Since this study focused on a specific family of technologies – the improved cookstove technologies, the Technological Innovation System (TIS) approach was used to analyse the innovation system. The TIS was preferred for this study because the framework captures not only the structural
characteristics and dynamics of an innovation system, but also the dynamics of a number of key processes, also called the functions, which directly influence the development, diffusion and use of new technology (Bergek et al., 2008a). Innovation processes are often highly complex as technological developments interact with social, economic and political dynamics (Markard et al., 2009), and as such these processes need to be analysed as a whole in order to understand the factors that influence system performance. The framework has also been used frequently in studies of emerging sustainable technologies in the energy and transport sectors (Bergek, 2019).

3.1.1 The Technological Innovations Systems Approach
The foundational contributions to TIS analysis are attributed to Carlsson and Stankiewicz’s 1991 work titled, “On the Nature, Function, and Composition of Technological Systems” (Egbetokun et al., 2017; Bergek, 2011; Lundvall et al., 2009). A technological innovation system is theorised as a heterogeneous set of network of actors and institutions who jointly interact in a specific technological field and contribute to the generation, diffusion and utilization of variants of a technology and/or product (Markard, 2020; Bergek et al., 2015; Carlsson and Stankiewicz, 1991; Markard and Truffer, 2008). The technological innovation systems approach has been developed to explain the emergence and development of new technologies (both radical and incremental technologies (Markard, 2020). The centrality of the Technological Innovation Systems (TIS) approach in studying the dynamics of development, dissemination and adoption of new technologies has increased in the recent past (Jansma et al., 2018). The purpose of analysing the Technological Innovation System of improved bioenergy cookstove technologies is to examine and evaluate the development of this particular technological field in terms of the structures, rules and processes that support or hamper it.
The most important insight that has dominated innovation theory is that innovation is a collective activity, which takes place within the context of a wider system and this wider system is termed as ‘the innovation system’ or ‘the innovation ecosystem’ (Hekkert et al., 2011; Hekkert et al., 2007). The theory suggests that the success of innovations is to a large extent determined by how the innovation system is built up – the structure and how it functions – key processes (functions) (Tigabu et al., 2017; Bergek et al., 2008a; Hekkert et al., 2007) and that the flow of technology and information among people, enterprises and institutions is key to an innovative process and its consequent success - interaction and learning (Hekkert et al., 2007). Flaws in the innovation system, also called system failures can greatly hamper the development and diffusion of innovations (Hekkert, et al., 2011; Hekkert et al., 2007). This study sought to understand how the innovation system for the improved bioenergy cookstoves is organised and how it functions, explore the nature and extent of system failures and explore the implication for diffusion and adoption of improved cooking bioenergy innovations, and elaborate on lessons that emerge for policy and practice.

All innovation systems are characterized by three main components, which include; actors, institutions and networks (Markard, 2020; Hekkert, et al., 2011; Bergek et al., 2008a), which jointly interact to generate, diffuse and utilise a technology. The actors include organizations responsible for education, R&D, industrial activities, developers and adopters or others indirectly involved such as a regulator, financer. Institutions take form of supportive legislation and technology standards and networks are the linkages between organizations in for example research and advocacy, technology developers and dealers. These components form the structure of the innovation system and help to give insight into who is active in the system.
In addition to the structure, innovation systems are characterised by functions. These can be seen as indicators for system health. Measuring how innovation systems are functioning is considered as the big breakthrough in innovation systems research (Hekkert, *et al.*, 2011) because it permits to understand the performance of an innovation system and gives clues on how the system can be improved for successful diffusion and adoption of technologies. Functioning of innovations systems is assessed using an established criteria called functions of innovation systems (Markard, 2020). The structure of the innovation system presents insight into who is active in the system while the system functions present insight into what they are doing and whether this is sufficient to develop successful innovations (Hekkert, *et al.*, 2011).

**i) Technological Innovation System Structure**

There is a general consensus in literature that actors, networks (mechanisms of interaction) and institutions form the structure of an innovation system (Kieft *et al.*, 2017, Hekkert, *et al.*, 2011, Bergek, *et al.*, 2008a). The nature of interaction among these structural elements is a great determinant of feedback loops, which induce or block the system.

**Actors**

The actors include firms within the whole value system including technology developers, service providers, users, universities and research centres various networks and linkages between them (Musiolik *et al.*, 2020; Markard and Hoffmann, 2016; Bergek *et al.*, 2008b). However, Wieczorek *et al.* (2012) added the concept of capabilities of the actors when discussing their role and influence on the innovation system. Capabilities here refer to the technical know-how and other resources to invest in technology development. Through their choices and action, actors generate, diffuse and utilise the technologies (Hekkert *et al.*, 2011).
Networks

Networks are channels of transfer of both tacit and explicit knowledge between actors. Networks play a cardinal role in innovation system building because they not only facilitate interactive learning (Lundvall, 1992) but also drive knowledge and information exchange among actors (Tigabu et al., 2015; Musiolik et al., 2012; Jacobsson and Bergek, 2007; Edquist, 1997; Carlsson and Stankiewicz, 1991), strategically create and shape supportive system resources such as technology specific R&D programmes and support collective action (Musiolik et al., 2012). Jacobsson and Bergek (2007) also view networks as influencers of future expectations, which guides investment decisions at different technological field levels. Networks emerge from the interaction between the different actors and the realisation of the need for collective action to influence institutional elements at system level. Networks develop from links established between different components in the system to perform a particular task such as learning, knowledge creation and diffusion, standardization, market formation (Bento and Fontes, 2015).

Networks can either be formal or informal. Musiolik (2012) defines formal innovation networks as strategically established relationships of firms and other actors with clearly identifiable members and a common aim, and Musiolik and Markard (2011) suggest that such networks may include strategic alliances, working groups of associations, technical committees or project networks. Formal networks can be learning or political networks. Learning networks’ main aim is to link users and suppliers, related firms, competitors or university researchers and industry (Jacobsson and Bergek, 2011; Jacobsson and Bergek, 2006). On the other hand, political networks’ main agenda is to influence institutional set up (Musiolik and Markard, 2011) mainly through collective action.
It is widely acknowledged that there exists a diversity of interactions and feedback loops among structural elements (Bergek et al., 2015; Jacobsson and Jacobsson, 2014; Wieczorek and Hekkert, 2012; Chaminade and Edquist, 2010; Markard and Truffer, 2008) and these multitudes of interactions make the innovation system very complex (Kieft et al., 2017). Interaction between actors takes place mainly through networks (Kieft et al., ibid, pg 34). Indeed, some body of literature perceive technological innovation systems as networks of agents interacting in a technological field under a particular social system, and involved in generation, diffusion and utilisation of a technology (Markard, 2020; Musiolik and Markard, 2011; Carlsson and Stankiewicz, 1991).

**Institutions**

Institutions are the rules of the game and these can be formal or informal. Institutions in the TIS encompass the formal structures such as regulations, technology standards or public policies as well as informal structures such as collective expectations, cognitive frames, user practices, social norms or culture (Markard, 2020; Markard and Hoffmann, 2016; Musiolik and Markard, 2011). Institutions govern and dictate the environment in which actors operate. Indeed, Musiolik and Markard (2011) offer that Institutions influence the activities and decisions of the actors, and they enable, but also constrain action.

**ii) Functions**

A system function is defined as a contribution of a component or a set of components to a system’s performance. System functions influence the build-up of an innovation system (Hekkert et al., 2011; Suurs, 2009; Jacobsson and Johnson 2000). The understanding of what constitutes the vital functioning of innovation system has undergone both conceptual and theoretical changes over time. The conceptualisation
of functions as true system-level variables is attributed to the work of Johnson (2001) in which she carried out a meta-analysis of literature to find out whether or not a shared understanding of which functions ought to be fulfilled in the innovation systems is present (Suurs, 2009; Bergek et al., 2008a; Hekkert et al., 2007). From this literature overview, Johnson identified eight system functions, which include; 1. Supply incentives for companies to engage in innovative work, 2. Supply resources (capital and competence), 3. Guide the direction of search (influence the direction in which actors deploy resources), 4. Recognise the potential for growth (identifying technological possibilities and economic viability), 5. Facilitate the exchange of information and knowledge, 6. Stimulate and/or create markets, 7. Reduce social uncertainty (i.e., uncertainty about how others will act and react), and 8. Counteract the resistance to change that may arise in society when an innovation is introduced (provide legitimacy for the innovation).

Since then, system function lists have been revised and redefined several times. More studies (e.g. Hekkert et al., 2011; Hillman et al., 2008; Bergek et al., 2008a; Negro et al., 2008b; Suurs and Hekkert, 2008; Negro et al., 2007; Hekkert, et al., 2007; Borrás, 2004; Edquist, 2004; Carlsson and Jacobsson 2004; Jacobsson and Bergek 2004) have developed multiple variants of system functions, which presented challenges to identification of which system functions are most relevant to innovation system development and analysis. Lately however, scholars seem to agree on the seven system functions suggested by Hekkert et al., (2007), which are based on Bergek’s initial work, and these include; 1) entrepreneurial activities, 2) knowledge development, 3) knowledge exchange, 4) guidance for search, 5) market formation, 6) resource mobilisation and 7) legitimacy creation. This study used these theorised

\[ \text{Johnson is Bergek’s maiden name.} \]
seven functions to examine the functioning of the improved bioenergy cookstoves innovation system.

One of the principal criticisms of the technological innovation system function analysis is that most of the existing empirical analysis is focused on developed countries (Esmailzadeh et al., 2020; Edsand, 2017; Tigabu, 2017), which suggests a lack of comprehensiveness for application in developing country contexts (Edsand, 2017). Edsand (ibid p.7) suggests that the theorised innovation system functions need to be modified to reflect the context of developing countries if they are to be used. In order to incorporate developing country context, Edsand (2017) made three changes to Hekkert’s list and these include; creating adaptive capacity, and splitting function 6 and 7 into resource mobilisation domestic and international and informal and formal lobbying, respectively. Although the system functions have experienced some modifications, Hekkert’s seven innovation system functions remain the most accepted in the literature on technological innovation system, and continue to be the most widely used albeit with some modifications in some cases like Tigabu (2017), Kebede and Mitsufuji (2017) and Edsand (2017). The second criticism for technological innovation system function analysis is its inward looking nature, it focuses on endogenous factors without considering the influence of exogenous factors on the functional performance of the innovation system (Edsand, ibid pg. 3).

The importance and performance of each innovation function depends on the nature of innovation in question, whether incremental or radical and its phase of development. Some functions become more prominent than others at the different phases of development of the innovation (Tigabu, 2017; Hekkert et al., 2011). In this research, each function as well as the interdependence it has with other functions was analysed separately in order to understand its functional pattern, performance and why it is functioning that way.
As Hekkert *et al.* (2011) suggested, my study analyses the structure of the innovation system first, and this constitutes the actors and rules that make up the system. This is followed by analysing how the system is functioning. The seven system functions that stem from theory and are empirically validated as indicators were used. The major interest of this study was to understand how the technological innovation system for improved cookstoves works in Uganda.

### 3.1.2 The Improved Cookstove Conceptual Framework

Following the assumptions of the TIS model, this study assumes that the improved cookstove TIS is influenced by how the structure is organised and the quality of interaction between the different actors. Organisation and quality of interaction affect the extent and nature of fulfillment of the innovation system functions. Fig 4 below shows the theoretical relationship between the key components and functions of the technological innovations system and the diffusion and adoption of technologies. The connecting factors between the two variables are nature of interaction and functional performance.
Figure 4: Conceptual Framework for Analysing the Improved Cookstove TIS

Figure 4 shows how the improved cookstove TIS is conceptualised. The TIS is shaped by two important components - the structure and function (also called key processes). Structural elements fulfil the functions through interaction. This interaction brings about feedback, which can be an inducement or a blockage in the system depending on how such feedback influences the fulfillment of the system functions. The more robust and effective the interaction is, the better for the system. The extent and quality of fulfillment of the system functions determines the extent of generation, diffusion and utilisation of the technology. Therefore, quality of interaction within the TIS structure and the extent and nature of fulfillment of system functions are the independent variables whereas system performance is the dependent variable.
3.2 Conclusion

Technological Innovation Systems theory explains the emergence and development of new technologies. The frames of this theory were important for data collection and analysis of the findings of this study. The chapter started with the theoretical underpinning of this study and unpacked several concepts, giving the dimensions and also the indicators of the concepts as derived from literature. An illustration of the conceptual framework of the key tenets and assumptions of the theory is given.
CHAPTER FOUR: RESEARCH APPROACH AND METHODOLOGY

4.0 Introduction
This Chapter focuses on the research design methodology of this study. Here I present how I answered the research questions I posed in Chapter one. I describe the research design I adopted and why and explain how I conducted the empirical study and how I analysed my data. I reflectively explain the choices I made throughout the study, giving their strength and limitations.

4.1 Research Strategies
The research question this study sought to answer is; How is the improved cookstove innovation system organised and how does it function, and what does this mean for diffusion and adoption of improved bioenergy cookstoves technologies? As guided by Yin (2009), multiple case study method was selected for this study because it is effective in answering how, what and why questions. The study employed an interpretive qualitative multiple case analysis strategy. Multiple-case studies can be defined as investigations of a particular phenomenon or group of phenomena at a number of different sites (Stewart, 2012; Stake, 2006).

As a qualitative research approach, a case study allows the investigator latitude to explore a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information, and reports a case description and case themes (Creswell, 2013). In this study, I investigated multiple cases of improved cookstove manufacturers and other players using multiple methods such as interviews, observation, FGDs, document and reports reviews to understand the processes that generate, diffuse and utilise these technologies. A case or cases selected to understand a problem is what Stake (1995) refers to as an instrumental case. My unit of analysis
are the multiple cases of stove manufacturers (multisite study) and the focus of analysis is the product – the improved cookstove and its application.

Qualitative research produces holistic understanding of rich, contextual, and generally unstructured, non-numeric data (Mason, 2002). This rich data was obtained by engaging in in-depth conversations with the research participants in a natural setting (Creswell, 2009). Case study strategy was favoured for this study because of its several strengths including the ability to use a variety of research methods, the ability to establish rapport with research subjects, to obtain sufficiently rich description that can be transferred to similar situations and, ultimately in-depth insight (Penolis, 2015).

The case study method supports theory building (Yin, 2009), which is one of the aims of this study. Theory building became an important part of this study’s theoretical framework because existing theoretical knowledge on the study phenomena is limited especially the applicability of the innovation systems analysis in a developing country context. Most of innovation system analysis has been applied in developed countries’ contexts to understand the dynamics of sustainable energy technologies diffusion and adoption, with limited experiences on how the approach works in a developing country setting (Negro and Hekkert, 2008; Negro et al., 2008a). Chetty (1996) suggests that this is one of the circumstances under which theory building becomes necessary. This study therefore did not formulate hypothesis, but rather general ideas, which guided the research.

Benbasat et al. (1987) also explain that case methodology is useful when a natural setting or a focus on contemporary events is needed or when research phenomena is not supported by a strong theoretical base or if it is not necessary to control the subjects of events. Studying the institutions, processes and functions in the improved cookstove innovation system and the implication for diffusion and adoption of
improved bioenergy cookstoves could not be done outside the natural setting and it is also a contemporary event. Finally, the theoretical base of systemic determinants of diffusion and adoption of improved bioenergy cookstoves in the developing country context is limited.

The study was interpretive in nature. The ontological basis for interpretivist paradigm is that all observation is both theory and value-laden and investigation of the social world cannot be the pursuit of a detached objective truth (Leitch et al., 2010). Epistemologically, the viewpoint of the interpretivist paradigm is that our knowledge of reality is a social construction by human actors (Burrell and Morgan, 1979). Therefore, the interpretive research paradigm is hinged on the notion of understanding the world as it is from a subjective point of view and explanations and subsequent interpretations are derived from participants rather than the objective observer of the action (Ponelis, 2015). This study sought to understand the nature and challenges of the improved bioenergy cookstove innovation system through the eyes of the actors.

4.2 Data Sites, Sources, Types and Forms
Primary data was obtained from organisations that develop/promote improved bioenergy cookstoves in natural settings. The data was qualitative at all stages of the research. According to Creswell (2013), the hallmark of a good qualitative case study is its ability to offer an in-depth understanding of the cases. In order to achieve this expectation, I collected data in multiple forms, including interviews, observation, report and documents review.

4.2.1 Selection of Cases and Data Sources
Field research was conducted in Kampala, the capital city of Uganda. Uganda was chosen as a place of study because although TIS studies in the developing world are generally scarce as elaborated in Chapter nine, in Uganda they are even scarcer. The
few studies conducted on improved cookstove development and implementation concentrate on user characteristics and stove attributes (e.g. Stevens *et al.*, 2020; Namagembe *et al.*, 2015; Mwaura *et al.*, 2014; Martin *et al.*, 2013; Clough, 2012; Levine and Cotterman, 2012) as opposed to the entire social system that generates, disseminates and uses the technology. Therefore, studying Uganda contributes to the body of knowledge that seeks to understand how TIS works in a developing country context. Kampala is home to a diversity of organisations working on development and promotion of renewable energy technologies in general and improved cookstoves specifically. More importantly, most of, if not all key improved cookstove developers and promoters of national and international character are headquartered there. Since the study analysed the innovation system of improved bioenergy cookstove technologies, it was crucial that data was collected beginning from the organisations’ headquarters. At the headquarters is where the top managers and other key personnel sit and most of the strategic planning takes place there. Also important documents are normally found at the headquarters.

Some cases were selected using purposive non probability sampling technique while others were selected using snowball sampling. Cases that were purposively selected consisted of improved bioenergy cookstove developers/promoters and these included two international organisations, eight local formal enterprises and one informal entity. Stove users were purposively selected while key informants from organisations that play a central role in the promotion of cookstoves were selected using both purposive and snow ball sampling. One of the criteria for inclusion in the study was that the actor’s main activity was improved bioenergy cookstove generation/diffusion and had been in existence for five years or more.

The list of improved bioenergy cookstove developers/promoters was generated using internet search and available reports like the World Bank Report (2014), then they were subjected to the set criteria, which included how long the enterprise has been in
existence and its core business. In each individual case, key informants were also purposively selected. The key informants from international and local organisations that promote improved cookstoves were selected and an email was sent requesting them to participate in the study and the aims of the study were explained. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Uganda National Alliance for Clean Cooking (UNACC) and Centre for Research in Energy and Energy Conservation (CREEC), Bioenergy Energy Efficiency Technologies Association (BEETA) were initially selected. Through snow ball sampling Uganda National Bureau of Standards (UNBS), Impact Carbon, Private Sector Foundation Uganda (PSFU), Uganda National Renewable Energy and Energy Efficiency Alliance (UNREEEA) were selected as key informants.

Since this study was focused on understanding how the improved cookstove innovation system works in Uganda, informants were selected from a variety of roles including proprietors, managers, artisans, professionals, government officials, donor agencies. Some key informants and cases were contacted beforehand and the managers accepted to participate in the study. Some actors such as GIZ were contacted at the start of fieldwork while others such as Impact Carbon, PSFU, UNBS, CIRCODU were contacted as fieldwork was going on.

The last category of informants included the users. These were selected randomly from the neighbourhood of the factories of stove manufacturers that were part of the multiple cases of this study. The assumption behind this decision was that uptake of stoves in the areas neighbouring the stove factories could be higher than in other places, hence making it economical to find FGD participants. Stove users were subjected to Focus Group Discussions and four were conducted.

A total of 10 cases were included in the study from which 20 in-depth interviews were conducted. Ten organisations that are key to cookstove promotion provided 11 key
informant interviews. In addition, four focus group discussions of improved bioenergy stove users were conducted, as well as observation of some stove production process from four case studies.

I was lucky to be permitted by GIZ to attend the first Clean Cooking Innovation Summit, which took place in October 2018. Here, I got an opportunity to interact and had informal interviews with different actors involved in improved cookstoves and related innovations from all over the country, which enriched my insight into the clean cooking sector in general and improved bioenergy cookstoves in particular.

Table 3 shows what cases were studied and how many key informants were obtained from each case. The sample size of cases included 10 stove manufacturers, 8, were local formal stove manufacturer, 2 were international actors, 3 networks, 3 government agencies, 2 research organisations and 2 financing agencies.

Table 3: Number of Cases and Key Informants

<table>
<thead>
<tr>
<th>Cases (Stove Manufacturers)</th>
<th>Number of Key Informants and Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ugastove</td>
<td>(n=3) Local Enterprise</td>
</tr>
<tr>
<td>2. FOWE</td>
<td>(n=2) Local Enterprise</td>
</tr>
<tr>
<td>3. BM Energy</td>
<td>(n=3) Local Enterprise</td>
</tr>
<tr>
<td>4. MASUPA</td>
<td>(n=2) Local Enterprise</td>
</tr>
<tr>
<td>5. SESSA</td>
<td>(n=1) Local Enterprise</td>
</tr>
<tr>
<td>6. JOSA</td>
<td>(n=2) Local Enterprise</td>
</tr>
<tr>
<td>7. AES</td>
<td>(n=2) Local Enterprise</td>
</tr>
<tr>
<td>8. Humura investments</td>
<td>(n=2) Local Enterprise</td>
</tr>
<tr>
<td>9. Potential Energy</td>
<td>(n=2) International Enterprise</td>
</tr>
<tr>
<td>10. ILF</td>
<td>(n=1) International Enterprise</td>
</tr>
</tbody>
</table>
As noted later in section 4.8, which explains the limitations of this study, this research suffered interruptions from interviewees whenever they had to excuse themselves to go and attend to other impromptu but urgent matters. I used that time of interruption to observe the activities going on in the factories, and to interact with different artisans. This experience enriched my insight about the improved cookstove generation processes, although such unplanned and unstructured discussions were not recorded among the formal study interviews.
Focus Group Discussions

Four Focus Group Discussions of stove users were conducted in Kampala city (Table 4). Users gave insights into what drives adoption, preferred stove attributes, participation in the technology development process, extent of stove usage, impact of stoves, how to improve adoption and diffusion of improved bioenergy cookstoves. The research used an open ended question guide during the discussions.

Table 4: Focus Group Discussions for Stove Users

<table>
<thead>
<tr>
<th>Place of FGD</th>
<th>Number of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wandegeya</td>
<td>(n=5)</td>
</tr>
<tr>
<td>Nalumunye</td>
<td>(n=6)</td>
</tr>
<tr>
<td>Kajjansi</td>
<td>(n=6)</td>
</tr>
<tr>
<td>Makindye</td>
<td>(n=7)</td>
</tr>
</tbody>
</table>

Direct Observation

I observed the different stove making processes to gain deeper first hand understanding of where stoves are generated from, processes stove making go through in the context of Uganda, and what challenges are faced in the different processes. Table 5 shows the different processes I observed and where.

Table 5: Cases and Processes for Direct Observation

<table>
<thead>
<tr>
<th>Cases</th>
<th>Processes Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ugastove</td>
<td>Automated metal cladding, assembling, clay moulding</td>
</tr>
<tr>
<td>BM Energy</td>
<td>Metal cladding, clay moulding, baking of liners, assembling, painting, loading</td>
</tr>
<tr>
<td>FOWE</td>
<td>Metal cladding, assembling</td>
</tr>
<tr>
<td>Potential Energy</td>
<td>Assembling</td>
</tr>
</tbody>
</table>
Document Analysis

I reviewed and analysed key documents relevant to the research question and objectives and Table 6 shows the types of documents I analysed and their sources.

Table 6: Documents Analysed

<table>
<thead>
<tr>
<th>Documents</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reports, policy documents, national plans</td>
<td>Government agencies</td>
</tr>
<tr>
<td>Research reports, programme reports, status reports, stove test reports</td>
<td>Websites for networks (local and international) and stove manufacturers, CREEC website and resource centre</td>
</tr>
</tbody>
</table>

4.2.2 Profile of the Major Interviewees

This sections gives a profile of the main interviewees specifically the stove manufacturing firms since they are one of the major actors on the supply side of improved cookstove technologies. The profiling in Table 7 is based entirely on the information provided by the key informants because there was no available secondary information at firm, network or national level on the profiles of improved cookstove actors to corroborate it with.

Table 7: Profile of Main Interviews

<table>
<thead>
<tr>
<th>Firm</th>
<th>Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>- It is the oldest improved cookstove manufacturing firm in Uganda. It was established in 1980s as a family business, turned into a community based organisation in 2000 called Urban Community Development Association (UCODEA) and later in 2006 into a formal stove making business enterprise. -It was the first firm to qualify for carbon finance PoA under the Gold Standard. Produces charcoal, wood and dual improved cookstoves and institutional stoves. -Suffered a big business setback due to consequences of poor implementation of carbon finance projects in Uganda.</td>
<td></td>
</tr>
<tr>
<td>Company</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Ugastove</strong></td>
<td>Exports stoves to South Africa and some East African countries. Only company moving to fully mechanised stove production, employs 7 people and over 20 casual workers and produces 15,000 stoves a month. Distributions stoves through distributor companies and NGOs in addition the conventional distribution channels.</td>
</tr>
<tr>
<td><strong>Friends of Wealth Environment (FOWE)</strong></td>
<td>FOWE was established in 2008 by former partner of UCODEA. Produces charcoal, wood and dual improved cookstoves both domestic and commercial Saunas and steam baths. Employs 6 people and 20 casual workers and produces 2,500 stoves a month. Distributes stoves through own 5 distribution hubs in Kampala, supermarkets, hardware shops, customers pick up from the factory on Mityana road, exhibitions.</td>
</tr>
<tr>
<td><strong>MASUPA</strong></td>
<td>MASUPA was established in 2012 by 3 friends after they were retrenched from work. Employs 3 people and 30 casual workers. Produces charcoal, and briquettes, and produce 2,000 stoves a month. Distributes stoves through supermarkets, hardware shops, customers pick up from the factory, exhibitions.</td>
</tr>
<tr>
<td>Company Name</td>
<td>Establishment Year</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Save Energy Saving Stove for Africa LTD (SESSA)</td>
<td>2009</td>
</tr>
<tr>
<td>JOSA Green Technologies</td>
<td>2012</td>
</tr>
<tr>
<td>African Energy Environment Saving Stoves &amp; Construction Ltd (AES)</td>
<td>2010</td>
</tr>
<tr>
<td>Potential Energy (PE)</td>
<td></td>
</tr>
</tbody>
</table>
-Employs 5 people and 20 casual workers, and produces 3,500 stoves a month
-Distributes stoves through direct sales, exhibitions, NGOs

-ILF is an international NGO whose operations on improved cookstove manufacturing and distribution started in 2008.
-Production centre based in Lira, northern Uganda and their household stove is known as Okelo Kuc (translated as peace-making stove)
-The Okelo Kuc is registered for carbon finance under the ICSEA PoA.
-Produces household and institutional stoves and produces 3,500 household stoves a month.
-Distributes through direct sales, vendors, distribute in IDP camps

4.3 Data Collection
Data was collected using a multi-method approach. Semi structured interviews, observation, Focus Group Discussions and document analysis were used to collect data. Using multiple sources of data and participants is useful in triangulation of data (Yin, 2009). Semi-structured interviews were preferred because they keep the interviews focused and facilitate cross-case analysis (Carson et al., 2001) and also provide room to explore new and relevant issues that emerge during the interview (Penolis, 2015). Focus Group Discussions illuminated perspectives of the stove users.

Adopting Walsham’s (2006) approach, I wrote down memos of key issues that I picked out every after each interview. After a week’s interviews, I compared the emerging issues from all the cases covered that week, distilling and disaggregating similarities and differences in responses on specific issues, and then I generated sets of themes and issues from the memos. This approach kept me close to, and engaged with my data as I went about with field work, and also helped me to keep reflecting on what I was learning from the field data. This approach also enabled me to identify information gaps and made follow up phone call interviews, and in three cases follow
up physical interviews. I built on these themes when I started main data analysis at the end of the field work.

The field work took place from 4th July to 6th August 2018; I took a break and resumed interviews from 2nd October 2018 - 11th January 2019. All interviews were conducted face to face, at informants’ places of work as preferred by the informants but also advantageous to me because I got to observe various processes and procedures from their real everyday setting. Interviews were pre-arranged on mutually agreed day and time. At the request of interviewees, a total of eight interviews were re-scheduled for more than once because of other commitments, and where necessary telephone follow up interviews were conducted for clarification purposes. Interviews with most of the local stove manufacturers were conducted in both English and Luganda (commonest local language in Kampala) and one in Luganda only. The rest of the interviews with key informants were conducted in English. I translated the Luganda interviews in English and transcribed them.

The interviews were semi structured aided by a question guide (Appendix 2) that helped to explore the topic of interest. Interview sessions lasted between one and half hours and two hours and were audio recorded with the permission of the interviewees. The process of interviewing was continued until it was noticed that nothing new emerged in the last interviews and relative data saturation had been achieved.

4.4 Data Analysis
The fieldwork and analysis was informed by deductive latent thematic analysis, which was guided by the Technological Innovation Systems approach. The interviews were then transcribed, coded, and analysed using a thematic data analysis approach. Building on the themes and issues I had generated from the fieldwork memos, I identified themes that were specific to my study; research questions, research context
and theoretical framework, and these became the categories for my analysis. I then went back and forth in the data to identify texts and images that speak to these themes. This approach allows data to be both described and interpreted for meaning (Roberts et al., 2019).

Observing the guides suggested by several authors such as Braun and Clarke (2006), Ryan & Bernard (2003), and Bazeley (2007), I followed specific steps to perform the thematic analysis in the study: 1) preparation – this was done in two stages. The first stage was writing memos of key issues that emerged out the interviews daily and after a week, memos were compared for all the interviews conducted. These themes that were generated from the memos were used as building blocks for the second stage, which was transcribing the interviews and more familiarisation with the data by listening to the interviews and also by reading the transcripts multiple times; 2) coding - initial open coding, initial organisation of the codes, and reviewing the codes multiple times; 3) themes identification - searching for themes and making decisions on key themes based on content similarities, theoretical link, and also repetition; 4) reporting findings and discussions.

I manually analysed the data thematically because; 1) considering the number of my interviews, I preferred to focus on depth and meaning of data. Coding and theming the data myself helped me to get closer to my data, which made description and interpretation for meaning deep. Trustworthiness of the findings was also obtained by: 2) systematically reviewing the detailed records of the data analysis process including decisions made throughout the study; 3) the appropriateness and the transparency of the data collection and analysis processes were discussed with the supervisory team.

Coding and deductive generation of themes was guided by the Technological Innovation Systems theoretical framework on innovation systems’ structural and
functional analysis. Despite the fact that this approach provides less detailed description of data overall, it gives a richer analysis on a specific aspect of the area of interest (Braun and Clarke, 2006). In this case, the theoretical thematic analysis gives a detailed analysis of the structure and functions of the improved cookstove innovation system, which are the main focus of this study. The deductive thematic analysis gives a detailed account of how the structure of the improved cookstove innovation system is organised, why it is organised the way it is, and what the structural elements are doing to generate, diffuse and utilise improved cookstoves. Thematic analysis was conducted within the constructionist paradigm in order to allow interpretation of contexts and structural conditions from individual accounts of key informants (ibid, pg. 85).

4.5 Ethical Protocol

The study received full ethical approval from the University of Edinburgh Ethics Committee, UK and Makerere University School of Social Sciences Research and Ethics Committee, Uganda. All participants signed an informed consent form after reading out to them and explaining what it is, for those interviewees whose capacity to read was limited. I informed the interviewees that they were free to withdraw at any time, should they wish to do so. Interviewees consented to the recording of interviews, which were subsequently transcribed. When asked whether they should be anonymized, one informant opted for anonymity while the rest did not. Interviews were stored on a password-protected computer, which held all data.

4.6 Reliability and Validity

In considering the multiple case study, I was cognisant of the reservations about qualitative research such as being too subjective (findings are hugely based on the researcher’s value judgment on what is important), difficult to replicate (because the researcher is the key instrument of data collection), lack of transparency (limited clarity on sampling) and problems of generalization of findings (small samples not
being a representative of the entire population) (Bryman, 2016). I was also aware of Creswell (2013)’s reservations about multiple case studies arguing that the more cases a researcher studies, the less the depth in any single case. These reservations were put in consideration when designing my qualitative research study.

My study is deductively anchored on Technological Innovation Systems theory and it guided both data collection and analysis. Therefore, empirical data collection was focused on the information that related to the TIS framework. Data collection and analysis in each individual case was focused only on key issues within the boundaries of TIS. By studying multiple cases to understand the institutional factors that characterise improved cookstove generation, diffusion and utilisation enabled to obtain both deeper and generalizable data about the improved cookstove innovation system. Further, data and methodological triangulations contributed to the rigour as well as validity and reliability. My interpretations and reflections are clearly presented and distinguished from those of the respondents. The selection of cases also followed criteria that minimised researcher bias.

My interpretation and reflection are all based on the data collected and analysed. My standpoint as a researcher is of an outsider (non-stove manufacturer) but also an insider (user of an improved cookstove back home in Uganda). I assumed a critical and reflective stance rather than a stove user one, which allowed me to distance from interviewees personal accounts.

4.7 Reflecting on the Limitations of the Study

I was not prepared for the possibility that my research could raise suspicion from informants. I encountered suspicious insinuations from local manufacturers about my intention for interviewing them. Some suspected I was from Uganda National Bureau of Standards (UNBS) or Uganda Revenue Authority (URA) or run carbon activities, but disguising as a researcher. I needed to prove my neutrality and gain their trust by
presenting my identification cards for both the University of Edinburgh (student) and Makerere University (employment). Some suspected that I wanted to start a stove making business, and was getting knowledge from them without paying for it under the guise of research. This happened whenever I probed on topics like stove making processes and the materials they use for different stove components such as liners, fire box and body and how they are sourced, funding architecture of the stove business and the distribution mechanisms. Whenever this insinuation cropped up, I would again explain my status as a student, intention of the study, and place of work in Uganda. We would then laugh at the insinuation and carry on with the interview. I later understood that the suspicion was mainly because this was the first study that focused on stove manufacturers and the general supply side of the cookstove industry. In the words of Hajji Bulaim Mubiru, one of the local stove manufacturers (Proprietor of BM Stoves), “this is the first time someone who is not a tax collector has visited and sat down with us to understand what we do, how we do it and the challenges we face”.

In six cases, interviews had to posed for between 5 to 15 minutes for more than once as the interviewee attended to other business related matters. This happened with local manufacturers because of thin staffing, which meant that interviewees carried out many responsibilities in the enterprises, and yet interviews were conducted at their work places - factories. This meant that interviews took longer than I had planned. This was mitigated by scheduling only two interviews a day – morning and afternoon to allow flexibility for interruptions. With the permission of the interviewee, I would sometimes use the time of interview interruption to observe the different activities going on in the factories and speak to artisans doing different activities, which added insights into my understanding of the cookstove TIS. Demonstrating goodwill and commitment, in all the cases that experienced such interruptions, the interviewees came back and carried on with the interview to the end.
A key informant from Impact Carbon accepted to be interviewed but only on issues to do with the current projects and partnerships. She declined to answer questions about the previous partnership with Ugastove, yet it is the flagship carbon finance partnership in Uganda. In order to obtain a balanced and deeper perspective on this issue, I conducted specific follow up interviews with UNREEEA, CIRCODU, and stove manufactures including FOWE, AES, BM Energy and JOSA. In my analysis on carbon finance in Uganda in Chapter eight therefore, I mainly use the voices of Ugastove, networks, testing centre, and local manufacturers.

4.8 Conclusion

The chapter is a presentation of the various steps taken in answering the study questions and the justification for decisions made. The finding from the multiple case study can be generalised on the entire population of improved cookstove innovation system. The multi-method approach was instrumental in data triangulation. Without the multiplicity of sources and tools of data collection and analysis, it might have been difficult to arrive at the conclusions in this study.

Table 8: Summary of Research Design

<table>
<thead>
<tr>
<th>Research Question</th>
<th>How is the improved bioenergy cookstove innovation system organised, why is it organised the way it is and how does it function, and what does this mean for diffusion and adoption of improved bioenergy cookstoves technologies?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling</td>
<td>Purposive and Snow ball sampling</td>
</tr>
<tr>
<td>Data Collection</td>
<td>Multi-method approach: semi – structured interviews, observation, focus group discussions and document analysis</td>
</tr>
<tr>
<td>Analysis</td>
<td>Thematic Analysis</td>
</tr>
<tr>
<td>Outcomes</td>
<td>1. Structure of improved cookstove innovation system described and why it is organised the way it is explained.</td>
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<tr>
<td>2.</td>
<td>Knowledge sharing and learning mechanisms in the improved cookstove innovation system understood.</td>
</tr>
<tr>
<td>3.</td>
<td>The improved cookstove innovation system functional pattern examined.</td>
</tr>
<tr>
<td>4.</td>
<td>The implication of existing improved cookstove innovation system on diffusion and adoption of technologies explained and theories on how to improve the acceleration of diffusion and adoption of improved cookstoves generated.</td>
</tr>
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CHAPTER FIVE: A DESCRIPTIVE ANALYSIS OF THE STRUCTURE OF THE IMPROVED COOKSTOVE TIS IN UGANDA: ACTORS AND INSTITUTIONS

The improved cookstove sector is young; it is an easy business to get into because it is unregulated. (Key informant, GIZ)

5.0 Introduction

This chapter describes two structural elements of the improved cookstove innovation system – the actors and institutions. This description is important because it sets the stage for functional pattern analysis in Chapter Eight by highlighting who is active in the innovation system and the environment in which they operate.

In this Chapter, I establish the nature and uniqueness of the environment that shapes the improved cookstove innovation system in Uganda. I show how the improved cookstove innovation system growth has been an externally-induced and phased process with different catalysts at each phase. I reveal how, contrary to existing research, entry of firms in the innovation system does not necessarily indicate system inducement but sometimes a blocking mechanism. My analysis also emphasizes how the existing standards and stove testing protocols are disconnected from local firms’ innovation focus and user habits and preferences, which makes results from stove performance tests misleading and ineffective to address emission reduction expectations and user needs.

Findings in this chapter are a part of the five key themes that were generated from deductive latent thematic analysis of the 31 semi-structured in-depth interviews, observation of different stove production processes from four firms, document analysis, and interpretative work on the question of improved cookstove innovation system structural configuration. These themes include; 1) the history of the improved cookstove technology, 2) supply and demand actors and their roles, and 3) regulations
and standards, 4) the role of networks, and 5) divergent perceptions about innovation and stove quality. This chapter deals with themes 1, 2, and 3, Chapter Six discusses theme 4, and Chapter Seven analyses theme 5.

5.1 Overview of a Technological Innovation System (TIS) Structure

There exists consensus in the literature that a TIS structure is created and shaped by three structural elements: actors, institutions, and networks (Musiolik et al., 2020; Markard, 2020; Tigabu, 2018; Kieft et al., 2017; Bergek et al., 2015; Bergek et al., 2008), which interact to generate, diffuse and use a technology. Some authors, such as Jacobsson and Jacobsson (2014), Hekkert et al. (2011), Jacobsson and Bergek (2011), and Chaminade and Edquist (2010), suggest technology (artefacts and technological infrastructure) as a fourth element of the TIS structure. Since there cannot be a TIS without a focal technology, and structural elements exist to intentionally or unintentionally generate, diffuse and use a technology, I considered the three structural elements and analysed how they work in the case of improved cookstoves.

Each of these elements (illustrated in Figure 5) performs different systemic roles individually or collectively to generate, diffuse and utilise the technology. It is generally agreed that there are numerous interactions and feedback loops that take place between these structural elements (Markard, 2020; Kieft, et al., 2017; Bergek et al., 2008a; Bergek et al., 2008b). Some of this feedback can be positive hence bringing about synergy or inducement mechanisms or negative leading to lock-in/group-think effect (blocking mechanism) (Bergek et al., 2008a).
The TIS theory considers the three structural elements in Figure 5 as the bedrock of innovation system building. The ensuing discussion on the structural configuration of the improved cookstove innovation system in Uganda follows these same principles. Although each of the different components performs distinct roles to support and shape the innovation system, components reinforce each other and sometimes play roles outside their perceived functional spaces (Bergek et al., 2015).

5.2 The Development of the Improved Cookstove TIS in Uganda

Uganda’s improved bioenergy cookstove innovation system is young and largely informal, with a large number of artisanal producers. This study, like previous research (Stevens et al., 2020; Clough, 2012) locates the emergence of improved bioenergy cookstove technologies in Uganda in the 1980’s and generated the interest of actors like the government and GIZ in the early 2000s. GIZ is among the first external promoters of the improved cookstove in Uganda and remains a principal actor to date.

Box 1 briefly shows how the journey of improved cookstoves started in Uganda. Although classified as incremental (section 2.4), improved cookstove innovation started with barely any organised structural elements in place. The sector was started by artisans in the informal sector. Existing literature however tends to suggest that
incremental innovations always have some form of structure in place (Hekkert et al., 2011), unlike radical innovations whose structural build-up mostly starts from scratch (Begerk et al., 2008b). These two observations do not seem to accurately depict the creation of the improved cookstoves innovation system in Uganda. Results of this research reveal that the improved cookstove innovation system in Uganda co-develops with the technology, although it is not a radical innovation. This is because there was no structure in place to build upon when cookstove generation started.

**Box 1: Beginning the Improved Cookstove Journey in Uganda**

Ugastove is the oldest stove manufacturing enterprise in Uganda, which evolved from a ceramic and blacksmith family business that started in the late 1970s, and later became a community-based organisation. The founder of Ugastove, Kawere obtained the stove making knowledge from his father Mugwanya who was a ceramicist as well as a blacksmith (making metallic stoves). When Mugwanya died, Kawere took over the family business. In the 1980s, Kawere started making clay stoves using ceramics and blacksmith knowledge. To make the stove last longer, he baked them the same way he used to bake pots. In 2000, Kawere teamed up with friends and they started a community organisation called Urban Community Development Association (UCODEA), which engaged in clay stove making and waste collection at a bigger scale.

In 2001, GTZ (now GIZ) trained UCODEA in improved cookstove and briquette making. GTZ also provided technical capacity-building on stove manufacture, basic tooling, and marketing. The association upgraded from clay stoves to making improved cookstoves and briquettes. It was however dissolved in 2006 and Kawere established Ugastove and registered it as a formal enterprise in 2007 and his business partner Kasirye registered FOWE in 2008 as a formal stove making enterprise.

**Source:** Narrations by Nakyazze (Ugastove) and Kasirye (FOWE)
Markard (2020) argues that the innovation system co-develops with the focal technology and this co-development happens in two main phases – the formative phase and growth phase. The formative phase is characterised by experimentation with competing technological variants, low market volumes, frequent entries and exits and a high degree of uncertainty (Markard, ibid, pg 3), with external factors playing a significant role in influencing the system (Edsand, 2019). Depending on the technology in question, the formative stage is long, lasting on average over 20 years (Bento and Wilson 2016). Bento and Wilson however were not clear about the categories of technologies that take a shorter period to develop an effective system and those that take longer, and why. Factors that determine the faster progression of the formative stage and those that impede it are not articulated, and Bento and Wilson (ibid, p.98) acknowledge this knowledge gap. The absence of knowledge on such key determinants presents a theoretical gap in understanding how to propel an innovation system from the formative to the growth stage of system development. What stimuli can push an innovation system to take off from the formative to the growth stage?

In explaining the institutional difficulties facing the industry, 25 out of the 31 key informants (constituting 80.6%) gave “industry being young” as one of the underlying reasons responsible for the many challenges the industry faces. The argument is that there is a lot of learning, organisation, mobilisation, and coordination that needs to be done in the improved cookstove sector. The Ugandan improved cookstove sector is about 35 years old, having started in the 1980s. The cookstove innovation system presents some of the characteristics of the formative stage as presented by Markard (2020), Edsand (2019), and Bergek et al., (2008a), which include low market volumes, formation of networks, frequent firm entries and exits, high degree of uncertainty, and demand not being well articulated. As predicted by Edsand (2019), I found that the system experiences strong exogenous influence, especially from donors and other development partners, hence constricting room for independent decision making by
key actors on priority activities at firm, network and system levels. The characteristics above represent a nascent system in formative stage. However, the improved cookstove TIS has been growing for about 35 years now, which points to the system being more stunted than young. Based on my interviews, the formative phase for improved cookstoves innovation system has been an incremental process as well, with different catalysts at each phase.

**Phase I 1980s – 1990s: Stove Development as Artisan-Led Undertaking**

The first phase started in the 1980s as a family business, and it was characterised by stoves made entirely of clay without metal cladding. The objective at the time according to Nakyazze (Ugastove) and Akumu (Ministry of Energy and Mineral Development) was largely fuel saving. The fire charcoal chamber was smaller compared to the metallic stove and took less charcoal per loading in addition to being made of clay, which retains heat longer than the metallic stove. These clay stoves were however susceptible to damage because as explained by Nakyazze, baked clay is naturally brittle especially depending on the clay quality and the temperature at which it is baked. These kinds of stoves could serve a user for about three months or less. The improvement came when a wire mesh was wrapped around the entire stove body to give it a layer of protection. At this stage, stove making was an entirely informal business.

In Uganda, improved cookstove research and development started in the early 2000s. Interest in research and development for these technologies was triggered by international debates and concerns on fuel crisis and increasing biodiversity loss. Industry formalisation began in the 1990s, as a result of the entry of GTZ as a key structural element. In India on the other hand, improved cookstove use started way much earlier in than Uganda. The driver of the initial improved cookstove drive in India was mainly the reduction of smoke exposure in the kitchen, which culminated with the introduction of chimney stoves in the 1950s (Kshirsagar and Kalamkar 2014).
However, Kshirsagar and Kalamkar say that no scientific research and development of the improved cookstoves took place until the late 1970s or early 1980s. The entry of GTZ into the system was the hallmark of the second phase, which led to formalisation of the stove making business.

**Phase II 1990s – Mid 2000s: Stove Development as a Formal Business and Expert Induced Intervention**

The second phase of improved cookstove development started in the 1990s. At this stage, the innovation system attracted entry of a key structural element (GTZ), which changed the dynamics of not only the structure of the innovation system but also its functions. GTZ offered training initially to the partners of UCODEA in improved stove and briquette making in addition to basic tooling and marketing. GTZ’s involvement brought about technical changes in the system in terms of knowledge impartation on generation of higher quality stoves as well as introducing a complementary product - briquettes. As a result of this change in the structure and activities of the innovation system, stove manufacturing started becoming an organised business.

According to Kasirye and Nakyazze from FOWE and Ugastove respectively, the main objective at the time was still to reduce fuel use, one of the key drivers of deforestation in the country at the time. Kasirye (FOWE) and Noah (UNREEEA) observed that the 1990s saw tremendous work by NGOs to curb deforestation, and improved cookstoves received attention as viable means to this end by reducing fuel and charcoal use. This information corroborates with the responses on motivation to start an improved cookstove making enterprise in Section 7.1, and what Stevens et al. (2020) found out about the drivers of the emergence of improved cookstoves in Uganda and Kenya in the 1980s and 1990s.
On the other hand, Kshirsagar and Kalamkar (2014) argue that the 1970s’ oil crisis made the world pay attention to energy issues and as result, improved cookstoves received attention as an answer to the fuelwood crisis and consequent deforestation. My findings and similar observations in literature (e.g., Simon et al., 2014; Kshirsagar and Kalamkar, 2014) place the need to combat deforestation in Uganda and other developing countries behind the emergence of improved cookstoves. It was also at this phase that aspects of quality and durability became part of the improved cookstove development focus. In this phase, improved cookstoves were made with metal cladding and more minerals added into the clay to make a more durable insulation liner. These stoves were more durable than the clay ones, but the artisans were mainly operating at a small scale and the sector was entirely unregulated. Emerging environmental issues, as we shall see, drove the entrance into the third phase.

**Phase III Mid 2000s – to date: Stove Development as a Climate Change Driven Intervention**

The third and current phase of stove development started around the mid-2000s, and seeks to standardise performance, and streamline stove making activity in Uganda. This phase was triggered by the international climate change negotiations that culminated into setting up the Clean Development Mechanism (CDM) as a way to mitigate climate change in developing countries. This is one of the major external developments (*push factors*) that caused tremendous changes in the internal dynamics of the cookstove innovation system. The role of improved cookstoves in reducing deforestation, indoor and outdoor emissions, and improving human health became prominent during the climate change negotiations (Simon *et al*., 2014), and this resulted in improved cookstove projects becoming part of the global carbon fund markets under CDM in 2007.
Once exogenous factors come into play, state Bergek et al. (2008a), they influence the innovation system’s internal dynamics. In Uganda’s case, when improved cookstoves became part of CDM, it brought changes in the structural elements especially actors and institutions, and increased interaction in the system through the formation of formal networks. These changes included the entry of new actors, and the establishment of both formal networks and regulatory mechanisms to standardise the stove manufacturing activity. To standardise the stove making processes, UNBS developed the first voluntary standard for cookstoves in 2007. The first national standard (US 761/2007) for household improved cookstoves was hardly used because it was more like a manual on how to make a stove rather than a standard guideline. It did not give any key performance indicators like thermal efficiency, emission, safety, or durability requirements. The only specifications outlined in the standard was the $<45^\circ$C as minimum temperature for stove surface. An informant from UNBS affirmed that;

(1) The first voluntary improved cookstove standard was difficult to implement because it was mostly descriptive. It described how to make an improved cookstove - like which materials to use. At the time it was developed, there was limited knowledge about these technologies. (Julius Mugabi, Manager Standards, UNBS)

Extract 1 above confirms that the standard remained more on paper than a practical guide to achieve improved stove quality, and this had a direct negative effect on system functions such as entrepreneurial activities, knowledge development and diffusion, guidance of the search, and creation of legitimacy. The extract also reveals that the spaces of interaction (networks) as well as system function on knowledge creation were weak in the innovation system that they could not support generation of an appropriate standard. UNBS published the second standard in 2018 that includes performance parameters but remains voluntary and viewed by local manufacturers as largely disconnected from the local needs. Voluntary standard presents difficulties
in compliance and enforcement. Although the objective of the new voluntary standard is, according to UNBS, to allow cookstove actors to build capacity to comply, all 10 cookstove enterprises involved in this study did not find the need to comply with the standards set by UNBS a priority, because to them, the standard is out of touch with reality (cf. section 5.4).

In line with the CDM objectives, cookstoves had to meet specific international performance standards to qualify for enrolment onto carbon finance schemes. As predicted by Edsand (2017) that exogenous factors may have greater influence in developing country context because of low levels of development of the various innovation system functions, endorsement of improved cookstoves at the CDM had a greater influence on cookstove innovation system in Uganda. It aimed not only at shifting the focus of innovation from fuel saving to more technical parameters but also necessitated putting in place performance testing mechanisms. At the time of research, carbon finance was still the biggest influence on the innovation system, even though PoAs had reduced due to the changes in the international voluntary carbon market.

Although the climate change factor shifted the focus from fuel saving to other international parameters such as thermal efficiency, emission reductions, safety, there was no significant change in stove design and engineering geometry to correspond with the new performance standards. Eilenberg et al. (2018) confirm for example that emission reduction depends on stove design, fuel type and cooking practices. This, therefore, means that stoves need to have the required designs to achieve the set performance indicators. In response to carbon financing opportunities, new stove enterprises sprung up to participate in the distribution of stoves to PoAs for carbon schemes without the requisite technical knowledge. Comments from stove testers and

\[\text{such as thermal efficiency, indoor and outdoor emission reduction, safety and durability.}\]
network leaders confirmed the existence of a dichotomy between stove designs and engineering geometry on one hand, and carbon financiers’ performance expectations.

(2) There was no change in stove designs as a result of carbon financing. Manufacturers only add efficiency and emission reduction as benefits of the stoves to attract financing. (Asinga, UNREEA)

(3) The only main change in local stoves is colour but the design is the original rocket stove from Ugastove. (Joseph, CIRCODU)

The main issue in the quotations above is that practically stove designing mainly targets fuel saving and not emission reduction or other carbon finance performance parameters. Even when networks offer training in stove making, no significant change is realised. Noah attributes the reluctance to the need to prioritise affordability and other user needs, which compels manufacturers to favour cheap materials over improving stove designs.

According to experts from CREEC, stove performance is determined by the quality of the design and engineering geometry. This is confirmed by Memon et al. (2020) who stated that to develop an efficient cookstove, technical considerations such as materials and geometric variables must be determined based on heat transfer and combustion parameters. Stove makers, however, continued to imitate the Ugastove body shape with little attention to the details of inner design, which are crucial to achieving thermal efficiency and emission reduction. This explains why to date the majority of locally manufactured stoves perform poorly on those parameters but perform better on fuel saving. I therefore, conclude that local stove manufacturers stressed user needs over carbon financiers’ desires, favouring fuel saving over technical performance.
Conclusion

This section has described how the cookstove innovation system structure was formed and how it is developing. In *The Life Cycle of Technological Innovation Systems*, Markard (2020) suggests that a TIS needs to be conceptualized as a system whose structures and processes change as the underlying focal technology changes. With this life cycle perspective, Markard assumes that structures and key processes are primarily influenced by changes in the focal technology. While it is true that the structure and key processes (also known as functions) change with time as the as the focal technology changes, my findings show that the changes in the improved cookstove TIS are driven more by exogenous factors (what I have referred to as *catalysts*) than the focal technology. In Uganda, the entry of GTZ/GIZ brought in substantial changes not only in the system structure but also key processes. GTZ’s intervention as a structural element brought about changes in the focal technology through technical training of artisans in improved cookstove making and the introduction of a complementary product – the briquettes.

In the late 2000s, we see significant changes in the entire structure, including institutional changes and entry of firms, and in functions of the TIS because of carbon finance. Carbon finance is the catalyst that led to an increase in stove production and dissemination, attracted new firm entrants and influenced standardisation of the stove making business. Network creation and their project and programme portfolios were key network-level processes impacted by this exogenous shift. My findings, therefore, demonstrate that changes in the structure and key processes of the TIS can greatly be driven by exogenous factors, sometimes with varying consequences. We now turn to the actors in the improved cookstove TIS.

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14 Entry of long term R&D funder in the TIS
15 Training local artisans in improved cookstove construction and briquette making
5.3 Improved Cookstove Actors in Uganda

This section maps the different actors in the improved cookstove TIS and what they do. I reveal how the entry of firms in the innovation system does not predict system inducement, contrary to existing research. Hekkert et al. (2011) advance the notion that actors in a TIS are elements who through choice and actions produce, disseminate and utilise the technology. Actors can include technology manufacturers, suppliers, vendors, research institutes, associations, public authorities, NGOs, and others (Markard, 2020; Bento and Wilson 2016). The improved bioenergy cookstove landscape in Uganda is characterised by various players who fall into five broad categories, including: suppliers and distributors, financiers, regulators, researchers and stove testers, and users on the demand side. This research examined the supply side of the innovation system and its characteristics. The successive paragraphs describe the key actors in each of the five categories and what their role is in the TIS and what drives them. Figure 6 illustrates how the improved cookstove structure is organised.

At the top of the structure in Figure 6 are the different actors, including stove users (households, institutions, and commercial enterprises), stove suppliers (manufacturers, importers, assemblers, and distributors), research and testing centres and a host of financiers who directly support the development and diffusion of cookstove technologies. At the bottom is the supporting infrastructure, which includes institutions and networks, whose role is to organise, guide, mobilise and coordinate the activities of stove suppliers and to protect the interests of stove users.
Figure 6: Structure of the Improved Cookstove TIS in Uganda

5.3.1 Stove Entrepreneurs

The supply side, which produces and distributes the technologies is characterised by a diversity of players that include artisanal producers, semi-industrial producers, and industrial producers as illustrated in Figure 7, as well as a host of distribution channels.
Each production system in Figure 7 produces stoves of different quality and functionality as explained below.

a) Artisanal producers rely solely on manual processes. All activities are manual, from clay collection and mixing to stove moulding and baking. The producers are mainly self-trained or possess minimal informal training from fellow artisans. Artisanal producers make clay stoves, light metal-cladded ones and sometimes use wire mesh as a protective barrier. Production sites are open spaces in a swampy area where individual producers erect makeshift factories and communally use kilns in turns. A typical example of such sites is the Kajjansi stove making association that was part of this study. There, seven out of the 18 makeshift factories belonged to women. Women’s high participation in this business was attributed to low cost of business start-up and faster sales because the production process is short. As one respondent said, “the most important resource for this business is one’s physical strength”. The production process is shorter than that of the more durable improved cookstoves because processes like liner making, drying and baking are not done. The stoves also
have no metal cladding. The main processes in this production system are clay collection, mixing, stove moulding, drying and baking. Quality control is based on the individual stove maker’s judgement.

b) Semi-industrial producers employ both artisanal and industrial means of production and they are wide ranging. A World Bank report (2014) says that this is the most difficult mode of production to define because it ranges from relatively low-skilled assembly of prefabricated components to domestic manufacturing with moderate levels of automation. My findings confirm this observation because some players like MASUPA and Humura Investments use minimal automation while others like BM, SESSA, FOWE, JOSA and AES use moderate levels of automation and incorporate some quality control. Specific activities are mechanized, like clay mixing and metal bending, while others such as liner moulding, metal cutting and assembling are still manual. Among local stove producers, Ugastove operates at the highest level of automation with only liner moulding remaining manual and has quality control procedures in place for every stove model and key stove components. Stove assemblers like Potential Energy and international players such as International Lifeline Fund are also in this category.

My analysis further established that semi-industrial producers can further be sub-categorised into imitative producers/entrepreneurs and copycats. The difference between imitative entrepreneurs and copycats is the degree and nature of novelty they bring to the sector. Imitative entrepreneurs mimic stove designs originally from Ugastove and replicate them to meet the users’ needs. FOWE, SESSA, BM, MASUPA, ILF, JOSA, Humura Investments and AES can be categorised as imitative entrepreneurs. The target market for these producers is the low-income population.
According to BM Stoves, this population segment does not need a sophisticated stove but rather a device that is more efficient and affordable, compared to the traditional metallic charcoal stove (Picture 2), which in Luganda language is nicknamed “lumala manda” (excessive charcoal consumer). Therefore, care is taken to ensure that the materials used are not very expensive to make the unit cost of the stove within reach of the target population. The objective is to make an improved household stove that costs between UGX 15,000 – UGX 50,000 (£3 - £10) that can last two years. A respondent from BM Energy had this to say;

(4) You see…… our aim is to achieve wide spread access and adoption of improved stoves to the people that need them most. Our current and targeted market is not the upscale population but rather ordinary Ugandans whose daily struggle is to reduce charcoal expenses and attain an improved cooking atmosphere. Making a classy household stove that for example costs up to UGX 100,000 (~£20) or more is to alienate them from the innovation. (Hajji Bulaimu Mubiru, Proprietor BM Stoves)

The opinion in extract 4 above, which was echoed by Kasirye (FOWE), Lugwana (AES), Samuel (JOSA) and Margaret (Masupa), demonstrates that local manufacturers have a specific niche of stove users that they are targeting. It also means that the target
is to make a stove that saves more fuel than the baseline traditional stove (Picture 2), yet remains affordable. Although Stevens et al. (2020) suggest that local stove producers are forced to sell their products at lower prices because users lack the means to pay, hence creating an affordability gap, my findings suggest otherwise. Nine out of the ten formal stove producers interviewed expressed knowledge about the price ranges that their targeted users can afford, and like Hajji Bulaimu in the quotation above stated, manufacturers produce and price their products with user needs and affordability in mind. Therefore, affordability was not raised as one of the big challenges facing stove sales in Uganda, but other factors like counterfeit poor quality stoves, transportation and distribution, and the low priority of stoves in a household hierarchy of needs. Concerns about affordability were raised by Potential Energy, the assembler and distributor of the Berkeley Darfur Stove (BDS) (Picture 3). The BDS is a dual stove (uses both wood and charcoal), and a unit costs about £16.

On the other hand, copycats, who are predominant in the sector, do not put much initiative in stove design and development. Their major aim is to mimic the shape and colour of the good stove brands using scrap and other waste materials to confuse buyers, and as a result benefit from the market. The price of counterfeited stoves is
the same or less than that of the genuine brands. Copycats are blamed for the proliferation of poor-quality stoves and for distorting the market through unscrupulous pricing systems. Key informants emphasized the challenge of counterfeit stoves and its impact on pricing systems and meeting user needs as follows:

(5) It is frustrating to put in efforts to produce a good quality stove, only to find the market flooded with low quality stoves that look exactly like yours. I have had to adjust prices of my stoves in order to survive in the market …… of course, with a negative effect on my business overall. (Ssesanga, SSESSA).

(6) Pricing becomes a problem because poor quality and low-priced stoves are many on the market. We are forced to reduce the actual prices of our good quality stoves. We get low profit margins per unit stove…. sometimes as low as only 500/= (~£10p). (Jessica, Potential Energy).

(7) I know what I need to do to improve the quality of my stoves but what difference will it make if fake stoves still dominate the market unhindered? (Margret, MASUPA).

(8) Cookstove business is difficult…… no matter the effort I put in to improve quality, I still receive reports from users accusing my brand of being poor quality simply because counterfeit stoves with the same design and colour as my brand are distributed alongside mine. (Samuel, JOSA).

These voices were reiterated by a Network leader saying,

(9) Copycats are destroying this industry. They lack both the knowledge and motivation to produce quality stoves. For them it is about short-term gains (daily bread). (Asinga, UNREEA).
The central issue in the quotations above is that copycats retard innovation, distort prices and derail market expansion. These narrations also show that copycats drive the pricing systems in the improved cookstove industry, which is paradoxical because genuine brands are compelled to reduce prices of their stoves to remain competitive with counterfeits. Although this benefits users, it affects growth and expansion of these enterprises as well as knowledge development in the system. Such abnormalities in pricing structures retard innovation because it erodes the incentive to innovate. From the comment of the network leader above (quotation 9), objectives of copycats are largely opportunistic and short term in nature, hence derailing innovation.

The proliferation of copycats was mainly attributed to production underperformance that characterises the key stove suppliers in the sector. Underperformance was exacerbated by carbon finance, which pushed for massive distribution of stoves to earn carbon credits. Due to structural problems, genuine brands cannot produce enough stoves to meet the household, institutions and SMEs demand. In addition, copycats are informal manufacturers who neither pay taxes nor go through stove testing processes, in addition to using cheap/waste material, hence making it easy for them to sell their poor-quality stoves at low prices and still profit.

The industrial producers are majorly foreign companies that import stoves such as AVISI, Environfit, Solar Now, Bright Life, UpEnergy, Biolite, and EcoZoom. Stoves are imported from different countries, including India, China, Kenya and the USA. Some imported stoves, like the biolite, are sophisticated and multipurpose. According to responses from FGDs, they can for example be used to cook, charge mobile phones and for light. Table 9 below shows the characteristics of the different improved cookstove production systems.
Table 9: Production System Characteristics

<table>
<thead>
<tr>
<th>Production System</th>
<th>Key Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artisanal</td>
<td>Very limited or no automation, largely informal, cottage industries or groups of artisans work from a common place e.g., swampy area where clay is mined, mainly use scrap materials</td>
</tr>
<tr>
<td>Semi-Industrial</td>
<td>Very basic to high automation, e.g., use of extruder machines, welding, drilling, painting, bending, use mixture of scrap and superior materials, mainly family businesses, imported quality components, basic to moderate quality control, some possess designated manufacturing places away from homes while others run as cottage industries</td>
</tr>
<tr>
<td>Industrial</td>
<td>Imported high quality stoves, high to full automation, high quality material, high quality control</td>
</tr>
</tbody>
</table>

Source: Interviews and observation of production processes of four enterprises

From the characteristics listed in Table 9, local stoves are produced through artisanal and semi-industrial systems. No local manufacturer had full automation. There are more informal stove producers than formal ones in Uganda because the sector is largely unregulated and therefore easy to enter. The sector is comprised of small and medium enterprises, with formal enterprises generally producing similar stove designs of more or less the same quality. Locally made stoves are mainly differentiated by the colour of the paint on the outer cladding. While no database for cookstove producers exists, apart from membership registers held by BEETA and UNACC, various respondents suggested that the industry is characterised by a high rate of informal firm entry. Many small enterprises (cottage industries) exist and participate in the stove market but are not known officially. Such limited knowledge about actors in stove production, even within the formal networks, partly explains why dealing with counterfeits and substandard stoves remains a huge challenge in Uganda.

Research (e.g., Bergek et al., 2008a; Bergek et al., 2008b) indicates that having entrants in the industry is good for a TIS because they can experiment with new combinations, fill “gaps” by becoming specialist suppliers or meet novel demands such as
developing new applications and boosting knowledge formation. Therefore, from Bergek and her colleagues’ point of view, new entrants are an *inducement mechanism* in the innovation system. However, for Ugandan improved cookstove technologies, firm entry does not seem to bring those predicted, positive changes in the system. Instead, firm entry is largely associated with compromising stove quality, thereby frustrating innovativeness, ruining higher quality brands’ reputation, reducing sales due to user dissatisfaction and consequently retarding market expansion. These negative feedbacks in the system directly affect the legitimacy of firms and their brands, which as Rogers (2016) warns is inconstant and can be lost if consumer concerns are not addressed. Markard *et al.* (2016) further emphasize the role of legitimacy for both new and established technologies, saying it is key for mobilising resources necessary for growth and survival. Issues that compromise legitimacy directly affect technology growth and survival. In other words, they are systemic threats. As conceptualised in the conceptual framework in section 3.1.2, the quality of interaction of the entrants in the improved cookstove TIS brings about blockage rather than an inducing mechanism.

Crucially, Bergek and her colleagues only mention entry of firms as an important inducement without qualifying the nature of entrants that have the qualitative power to act as inducing mechanisms in the system. This presents a theoretical gap in terms of understanding the key features of the different structural elements that are necessary for the growth of the innovation system. Many entrants in the improved cookstove innovation system in Uganda largely do not add value to the system, they are a *blocking mechanism* instead. The context in which new entrants in the improved cookstove TIS are referred to as a blocking mechanism is based on Bergek *et al.*’s (2008a) assertion that mechanisms that work to hinder development towards the desirable functional pattern are blocking mechanisms. This finding brings in the issue of quality and intentions of entrants when discussing their role in the TIS building in
a developing country. From Uganda, we can learn that opportunistic and ill-equipped entrants are counterproductive (blocking mechanism) to the growth of the innovation system. This finding and conclusion is confirmed in Wieczorek and Hekkert’s (2012) view that proper functioning of a TIS is not simply a function of the presence of structural elements but their capabilities as well. This therefore suggests that in order to fully understand the qualitative features of structural elements that are necessary to shape a successful innovation system, it is necessary to move beyond just mapping the presence or entry of actors in the system, and analyse their features and capabilities as well.

5.3.2 Improved Cookstove Marketing and Distribution Networks

The stove distribution system influences the key process (function) of legitimacy creation. A technology’s legitimacy is made apparent by increasing the rate of diffusion (Bergek et al., 2008a). Improved cookstove manufacturers engage in a variety of distribution models. Importers distribute stoves through their own outlets, supermarkets, distribution companies like Simoshi, NGOs and other renewable energy dealers like solar appliances dealers. On the other hand, local manufacturers distribute through direct sales to users, their own distribution hubs, supermarkets, petrol stations, local markets, charcoal vendors, hardware shops and exhibitions like the annual energy week, cookstove demonstration shows and camps. Among the eight local formal stove firms that were part of this research, only Ugastove operated distribution partnerships with a distribution company - Simoshi. Figure 8 shows the main improved cookstove distribution channels in Uganda.
Figure 8: Main Channels of Improved Stove Distribution in Uganda

Figure 8 shows that stove manufacturers use a variety of distribution channels to disseminate stoves, although at a small scale and concentrated mainly in Kampala city and suburbs. All ten formal cases and the one informal case studied here distributed stoves through direct sales as one of the main ways of stove diffusion. They reported that although it is an effective way of diffusion, it is very costly in terms of the logistics required to market the stoves to end users. The direct sales marketing model not only increases transaction costs but also suffocates growth along the cookstove value chain. That is why other channels of diffusion, that shift some of the marketing and distribution logistical burden, are applied alongside direct sales. Only two out of ten formal cases had distribution points in the different suburbs of Kampala and Wakiso districts.
FOWE had three distribution hubs in Kampala district, SESSA had three distribution points, two in Kampala and one in Wakiso district. According to Kasirye (FOWE) whose response was corroborated by other local manufacturers including SESSA, JOSA, Humura Investments, MASUPA and Ugastove, stove storage and transportation are big problems because improved stoves are both bulky and fragile. One needs to rent bigger spaces to stock stoves, which is expensive. This is one of the reasons why some manufacturers produce stoves mainly on order instead of stocking up. This finding concurs with Stevens et al.’s (2020) findings on the challenge of efficient stove distribution in Uganda.

Third party private distributors such as hardware shops, supermarkets, petrol stations and solar equipment distributors are channels of improved cookstove distribution as well. The challenge that manufacturers reported with this channel is that distribution is limited by the third party’s reach and most of them are urban based. This challenge was noted in the World Bank Report on clean and improved cooking in Sub-Saharan Africa (2014) saying that using third party dealers for stove distributions means that stove suppliers are limited by partners’ reach, which may not include remote or rural areas. Competition also exists between the manufacturers for the few existing third parties and their chain of outlets. With this distribution channel, stove dissemination remains concentrated in urban areas where private, third party distributors reach.

Other channels of bulk improved cookstove distribution are carbon finance projects, institutional distributors such as bulk purchase and distribution by government programmes in both rural and urban government aided schools, relief agencies which distribute stoves in refugee camps, social sector such as NGO networks buying and distributing to communities such as refugee camps, targeted market activation events where financing agencies provide logistical support to manufacturers to penetrate new markets in upcountry areas and through annual events like the energy week. The challenge that was associated with the latter channel is that manufacturers in most
cases do not go back to the open markets because of high costs of transportation and marketing of stoves upcountry. Therefore, market activation remains more like a one-off event.

Traditional stove producers distribute mainly through open markets, and fresh food and charcoal stalls. Imitative entrepreneurs and copycats take the biggest improved stove market share because their stoves are reasonably priced (between £3 - £11 for household stoves) compared to imported ones whose prices start from £16.

Ugastove is the only local stove making company that has a partnership with a distributor company to disseminate both household and institutional stoves. Ugastove partners with Simoshi, a company that distributes both household and portable institutional stoves. Ugastove offers basic training in proper stove use and maintenance to Simoshi to ensure quality and customer satisfaction. This partnership increased stove circulation as Simoshi employs its own unique networks. Simoshi distributed 150 Ugastove institutional stoves to Kampala City Council Authority schools through the KCCA Go Green Campaign between 2013 and 2017.

One of the biggest challenges facing dissemination of institutional stoves is their high upfront cost. In order to increase uptake of institutional stoves, companies that construct institutional stoves and sell fuels like briquettes are encouraged to incubate a business model where institutions, especially schools that are in need of institutional stoves but lack the initial financial investment are supported by the companies to purchase stoves on credit. Under this arrangement, the stove company enters into a contract with a school and agree to construct the stove without the school having to pay the £800-1,500 cost upfront. The company recovers the money by supplying briquettes to the school. This arrangement was first incubated by Josa Green Technologies, an improved cookstove and briquette making company and a member
of BEETA. As a result, 11 schools in and around Kampala city have switched from traditional inefficient fire places to the more efficient institutional stoves.

A stove making company however needs external financing to meet the initial investment of stove construction for interested institutions, which the majority of stove producers cannot attract. It can take between one and three years to recoup the initial investment before the stove company starts to make profits on the briquettes. Without external financing, local stove producers cannot afford to implement this business model. Such business models remain unsustainable if no external financing exists. We now move to another category of actors: researchers and stove testers.

5.3.3 Research and Stove Testing

Research activities are mainly carried out by networks, specifically UNACC and UNREEEA. Development agencies such as SNV, WWF conducted research market, and surveyed behavioral change and stove adoption. Research activities are funded by GIZ, SNV, and the Clean Cooking Alliance (CCA). Details of the nature and extent of research in the system is discussed in Chapter Eight. Research activities are generally limited because of funding.

Stove testing is key for quality assurance. Stoves are tested to ensure that the new design provides a significant improvement, considering the prevailing cooking practices (Adkins et al., 2010). The baseline for stove testing in Uganda is the metallic charcoal stove (Picture 2) or the traditional three stone fire place (Picture 1). There are five testing centres in Uganda: UNBS, CREEC, CIRCODU, Chemipher, Nyabyeya. Among them, only UNBS laboratories and CREEC are certified to carry out stove testing. Testing centres have to go through a laboratory recognition scheme by UNBS and ISO in order to be certified.
UNBS tests all stove performance parameters except emissions because they do not have the equipment to do so. This then leaves CREEC as the only certified testing centre that tests all parameters. One of the key financing requirements for cookstoves is a performance testing report. This means that most stove testing jobs are done by CREEC. Because of the near monopoly that CREEC enjoys in stove testing, the exercise is expensive. UNBS charges UGX 300,000 (~£64) to test a single stove model for all parameters except emissions while CREEC charges UGX 4,000,000 (~£853) for all parameters. What a manufacturer receives after testing is a testing report only, which 8 out 10 manufacturers studied could not interpret beyond the stove’s fuel savings. A sample stove performance testing report can be found in Appendix 8.

Some local entrepreneurs interviewed like Margaret (Masupa), Lugwana (AES), Hajji Bulaim (BM Stoves) and Kasirye (FOWE) reported that they do not see the value in paying for testing because the huge investment in testing does not bring economic returns. Tested stoves are not given any quality certificate that outlines their performance. Stoves that are tested and those that are not are the same in the market. The consumer cannot tell them apart because there is no mark that declares the tested stove’s quality. After incurring the cost of testing, the manufacturer is left without any protection from counterfeit stoves and so is the consumer. Entrepreneurs suggested a need for an energy certificate that declares the quality of the stoves- the Q-mark. One of the local manufacturers had this to say;

(10) Stove testing does not benefit companies as much. I cannot use it to increase the price of the stove because there is nothing to show to the consumer that it is a tested and superior stove, yet it a very expensive exercise. There is no testing evidence that is given to us apart from a report. Whether you have tested your stove or not, the consumer can’t tell. We still struggle with counterfeits on the market.

(Margaret, Managing Director, MASUPA)
The frustration expressed in the extract above casts doubt on the usefulness of stove testing to manufacturers. There is no tangible incentive for stove testing because tested stoves are not given any unique identifiers to distinguish them from counterfeits. This means neither the genuine stove brands nor users are protected from counterfeit stoves even when some stove manufacturers subject their stoves to quality control tests.

Another issue with stove testing was that it lumps different parameters into a single tier. The tier system classifies stove performance in tiers, from 0 - 4. Mainly four stove parameters (thermal efficiency, durability, indoor and outdoor emission, and safety) are tested to assess stove performance. Due to the fact that stove performance varies on the different parameters, lumping all the different performance levels into a single tier is unrealistic. For example, a stove can perform well on thermal efficiency and durability but poorly on emissions and safety. Such a stove might be classified as tier two instead of each parameter being classified in its individual capacity.

Stephan (ILF) and Kasirye (FOWE) explained that this is a disservice to users, who are not interested in the complete set of parameters but rather a few that meet their needs, namely: fuel saving, durability, fitness for purpose, and price. Therefore, classifying a stove as poor because its engineering geometry and design does not meet the emission reduction requirement, while its performance on fuel saving and other parameters like durability are high, is unfair. Each performance parameter needs to be classified separately, so that the user can make an informed choice depending on their interest.

The next set of actors to discuss are financiers.

**5.3.4 Financiers**

The improved cookstove financing landscape is comprised mainly of development partners. Table 10 displays the financing actors that have been involved in the improved cooking sector for the last 19 years, and the funding models employed.
<table>
<thead>
<tr>
<th>Organisation</th>
<th>Key Area of financing</th>
<th>Nature of financing</th>
<th>Financing Period</th>
</tr>
</thead>
</table>
| GTZ/GIZ                 | a) Technical – stove and briquette making capacity building  
a) Technical – Upscaling production  
c) Demand generation/Distribution  
d) Skilling  
e) Behavioural change  
f) Stove testing  
g) Research                 | Grants  
Co-financing  
Performance based financing | 2001 to date                        |
| EEP Africa              | Technical – designing and automated production                                           | Grants                                       | 2015 - 2018                |
| SNV                     | Behavioural change  
Research  
Skilling                           | Grants                                       | 2012 - 2017                |
| WWF                     | Behavioural change  
Skilling                           | Grants                                       | 2015 – to present          |
| World Bank              | Demand generation and stove distribution                                                 | Result based financing/indirect subsidy     | 2016-2020                  |
| UNCDF                   | Entrepreneurial growth                                                                  | Performance based financing/indirect subsidy | 2012-2016                  |
| Renewable Energy Challenge Fun | Demand generation and distribution                                     | Grant                                         | 2017                      |
| Catalytic Small Grants East Africa | Demand generation and distribution                                         | Grant                                         | 2015                      |
| Spark Fund              | Marketing and distribution                                                               | Grant                                         | 2012                      |
| Switch Africa Green     | Capacity Building                                                                       | SEED Award                                   | 2015- to present          |
| Impact Carbon*          | Distribution, demand generation                                                         | Direct stove price subsidies  
Indirect subsidies                                                   | 2007 – 2012  
2013 - date
<table>
<thead>
<tr>
<th></th>
<th>Distribution</th>
<th>Direct stove price subsidies</th>
<th>2010 – to date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Up Energy</strong>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em><em>Uganda Carbon</em> Bureau</em>*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Interviews and documents review *Carbon financiers (Carbon project developers)

Table 10 shows that GIZ has invested in improved cookstoves for 19 years now, thus making it the principal funding agency of the sector. It also shows that the R&D funding focus in the improved cookstove sector has been mainly about marketing, demand generation, stove distribution and capacity building. Demand is a key factor in the selection and success of a technology (Mugwagwa and Wamae, 2016). This explains why most of the big funding targeted demand stimulation. Although the existing literature generally alleges that adoption of improved cookstoves in Uganda is slow (MECS, 2020; Tebugulwa, 2015; Levine, 2012), there is no concrete data to show adoption trends over the years. The rate of adoption of improved cookstoves in urban areas stands at 15% (MECS, 2020), while Price (2017) puts it at 13% and it is much lower in rural areas. Very limited data exists on the trend of stove adoption in Uganda. No studies exist to explain the baseline rate of stove adoption before external financing including carbon finance for example, which could help to examine the rate of adoption following the different promotional interventions. The only available literature on the rate of adoption is by Levine *et al* (2012) where they indicated that at the time, adoption was at 4% in Kampala city. Based on this sketchy information coupled with the fact that improved cookstoves received targeted investment and promotion from early 2000s, it can be concluded that the rate of adoption is somewhat slow. This somewhat slow rate of diffusion and adoption can be explained by the underdeveloped distribution networks, the nature of grants (activity specific and time bound), and stoves’ unreliable performance. Funding mainly caters for demand generation and distribution, leaving production largely peripheral to the funding architecture, yet it is one of the main challenges that firms face.
Carbon project developers develop improved cookstove projects under the Clean Development Mechanism to implement projects under the voluntary carbon market to distribute emission reducing stoves. These project developers are mainly international organisations that possess the expertise to bid for and implement complicated international financing schemes of this nature. They partner with firms in the global south to generate and distribute stoves to meet the emission targets, under agreed terms and conditions.

The government of Uganda does not directly fund R&D activities in the improved cookstove sector. Through partnerships with development agencies such as GIZ and World Bank, the government implements projects on awareness and sensitization, demand generation and stove dissemination. Key R&D funding schemes for improved cookstoves are discussed in details in Chapter Eight. The succeeding discussion is about the second structural element: institutions.

5.4 Improved Cookstove Institutions
This section specifically focuses on standards and regulations, which are part of the institutional structures at the core of the TIS (Hekkert et al., 2011). My analysis emphasizes how existing standards and stove testing protocols are disconnected from local firms’ innovation focus and user habits and preferences, making stove performance test results misleading and ineffective in addressing emission reduction expectations and user needs. Institutions consist of formal structures such laws, policies, standards, property rights, and informal structures such as collective expectations, cognitive frames, user practices, social norms or culture that govern political, economic and social interactions (Markard, 2020; Bento and Wilson 2016). This section shows how the standards in place, including stove testing protocols are detached from local firms’ innovation focus and user habits and preferences, which raises questions on the usefulness of stove testing processes.
5.4.1 Improved Cookstove Policy and Regulation in Uganda

The relevant policy for improved bioenergy cookstoves is the renewable energy policy of 2007, which was under review at the time of research. The policy acknowledges that renewable energy technologies in general face the challenge of inadequate standards and quality assurance, but it does not explicitly outline the necessary strategies to overcome this challenge. The policy for example does not talk about issues of financing, awareness raising for both consumers and suppliers, or capacity building to improve standards for improved bioenergy cookstoves. I learnt from UNREEA that the proposals in the policy under review are to prioritise awareness, end user financing and capacity building. It is proposed that the government should capitalise the Uganda Energy Credit Capitalization Company to design funding schemes for improved bioenergy stoves. The current schemes are mainly for solar. It is also proposed that the Directorate of Industrial Training will design certified apprenticeship training for cookstove artisans.

The sector does not have a clean cooking policy in place. The improved bioenergy cookstove is regulated by the Ministry of Energy and Mineral Development (MEMD). Cookstoves are part of improved cooking and fall under the Directorate of Energy Resources Development, Department of Energy Efficiency and Conservation. We turn now to the paradoxical standard, yet the principal institution of the improved cookstove TIS.

5.4.2 Whose Standard and for What Purpose? The Exclusion of Users’ and Local Manufacturers’ Needs from Improved Cookstove Standardisation in Uganda

Standards are important in technology development, they are required to ensure performance, conformity, and safety of new products and processes (Allen and Sriram, 2000). Allen and Sriram (ibid, pg. 172) define standards as technical guidelines that are aimed at ensuring that materials, products, processes, representations, and
services are fit for their purpose. The main of use of standards is to systematise certain product and trade processes, and this means that all relevant actors adhere to the same procedures or product specifications to facilitate trade, ease logistical procedures, prevent consumer fraud or improve quality (Meybeck and Redfern, 2014). Improved cookstove performance is standardised at both international and national levels. Internationally, improved cookstoves performance is rated using a tier system, where the lowest is rated as tier 0 and the highest performance as tier 4. The ISO tier system categorises improved stoves into the following tiers as shown in Table 11.

Table 11: ISO Improved Cookstove Standards

<table>
<thead>
<tr>
<th>ISO Tier</th>
<th>Stove Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Traditional stoves (baseline)</td>
</tr>
<tr>
<td>0-1</td>
<td>Simple improved cookstoves (usually enclosed and with some improvement to combustion (e.g., basic bioenergy portable stoves)</td>
</tr>
<tr>
<td>1-2</td>
<td>Intermediate improved cookstoves (use improved combustion chambers e.g., rocket stoves, highly improved charcoal stoves, natural draft gasifier)</td>
</tr>
<tr>
<td>2-4</td>
<td>Advanced Improved cookstoves (use forced ventilation with or without secondary combustion (gasification), e.g., fan-assisted bioenergy stoves, forced draft gasifiers).</td>
</tr>
<tr>
<td>4</td>
<td>Clean Stoves (these are non-bioenergy stoves relying on different forms of gas or liquid fuels, i.e., LPG, biogas, ethanol or electricity)</td>
</tr>
</tbody>
</table>

Source: Puzzolo et al., 2013

The baseline for improved cookstoves is the traditional three-stone open fire (picture 1) or the metallic charcoal cookstove (Picture 2). All performance parameters tested for improved stoves are compared to the baseline. Based on ISO classification, Uganda’s locally produced stoves largely fall in tier 0-1 (simple improved cookstoves). Puzzolo et al., (ibid p.47) indicate that stoves in this category have varying performance levels depending on design and conditions of use, with some causing little or no reduction in emissions and exposure. Nationally, improved cookstoves are standardised by the National Bureau of Standards (UNBS), a government parastatal that is responsible for coordinating the elaboration of standards in the country, and it
is a member of ISO. On the standard of locally manufactured stoves, CREEC reported that with the exception of a few stove models from a few local enterprises such as Ugastove, the majority of locally manufactured stoves range between tier 0-2. We turn now to the problematic testing protocols themselves.

5.4.2.1 Stove Testing Protocols

Improved cookstove performance tests, which include the Water Boiling Test (WBT), Controlled Cooking Test (CCT) and Kitchen Performance Test (KPT), were developed in the 1980s (Johnson et al., 2010). WBT and CCT are laboratory-based tests while KPT is a field test. CREEC, the main stove testing centre not only in Uganda but also in most of the East African region uses the WBT to test stoves. WBT is a laboratory based testing where following a defined protocol; stove performance is evaluated by heating a standard quantity of water across a specified range of temperatures (CREEC, 2018). Susan Abbo (MD, CREEC) explained that the parameters this test measures include; thermal efficiency, specific fuel consumption, time to boil, burning rate, turn-down ratio, and firepower. Performance on these parameters is assessed while completing a standard task of boiling water in the laboratory.

I however understood that this test method only reveals the technical performance of the stove, and not necessarily what it can achieve in practice in households. This is because measuring time to boil is only a part of the cooking process in a typical Ugandan household. As explained in Chapter 7, cooking practices involve a process of simmering, sometimes for hours on low power. The testing duration is one hour is below the average cooking time in a Ugandan household, which is on average about 2 1/5 hours (CREEC, 2018), and therefore may underestimate cooking time. Nsamba et al. (2021) in their paper on the evaluation of cooking cultures and practices in rural Uganda established that time spent cooking a day ranged between 2-4 hours. Although the findings of this paper speak specifically about rural Uganda, data from FGDs (cf. Chapter 7, section 7.1) show that cooking time remains long even in urban areas.
Therefore, the capability of the WBT to accurately test parameters such as fuel consumption and cooking time is very limited in Uganda.

Research shows that laboratory tests like the WBT use highly prescribed testing protocols (Eilenberg et al., 2018), and earlier works by Johnson et al. (2009), Berrueta et al. (2008), and Bailis et al. (2007) had established that these tests do not reflect real-world stove performance in households. A more recent report by Gold Standard Foundation (2016) further warns that although WBT is the most basic method because it is cheaper and easier to implement, it does not always accurately represent household cooking conditions. My findings, therefore, serve to further confirm that laboratory tests like the WBT cannot reveal the actual performance of stoves in households in Uganda, and as such results from such test methods can be misleading for policy interventions.

The Uganda household bioenergy stove standard (US 761: 2019) tests five major stove performance parameters: 1. Thermal efficiency, 2. Outdoor emissions (particulate and gaseous air pollutant emissions – PM$_{2.5}$), 3. Indoor emissions (Carbon Monoxide and gaseous air pollutant emissions), 4. Safety (stability, heat transmission to the surrounding, fire chamber design, finishing-no sharp edges, handle temperature), and 5. durability. Although it remains voluntary, this newly published stove standard sets performance criteria for both carbonised and uncarbonised stoves, which is an improvement from the previous standard. Table 12 shows the standard performance for both carbonised and uncarbonised stoves in Uganda.

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16 Thermal efficiency is the ratio of useful energy expended by the fuel to the pot. Expended energy per unit time defines fire power which influences boiling time (CREEC, 2018)
Table 12: National Performance Criteria for Carbonised and Uncarbonised Stoves

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Stove Type</th>
<th>Carbonised¹⁷</th>
<th>Uncarbonised¹⁸</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency(^a), (\eta_c), % (min)</td>
<td>30</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Emission factor (max)</td>
<td>PM(_{2.5}), mg/MJ</td>
<td>250</td>
<td>386</td>
</tr>
<tr>
<td></td>
<td>CO, g/MJ</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>Safety, % (min)</td>
<td>72</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Durability, % (min)</td>
<td>70</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)High power thermal efficiency

Source: UNBS, 2019

Table 12 shows the minimum performance expected of both the carbonised and uncarbonised improved cookstoves. The standard stipulates the maximum emission of particulate matter and carbon monoxide an improved stove should emit. From Table 12 still, it is evident that stove thermal performance is conducted only at high power, which is limiting given Ugandan cooking habits. The standard does not capture the entire cooking spectrum according to cooking habits in Uganda because cooking does not take place only at high power but also at medium and low power. Results from FGDs also corroborated the CREEC stove testing expert, confirming that sometimes cooking takes longer at low power than at high power. From FGDs, it was established that food (especially banana meals) is cooked in phases – first at high power until when it is ready to be processed into the final desired form that is then cooked at low power for some hours until when it arrives at what FGD participants termed “being cooked properly”. Section 7.1 details the different food preparation and serving systems practiced in Uganda. This means that results from such a testing

¹⁷ Carbonised stoves use fuel that has undergone chemical reaction for example charcoal or briquettes from charcoal dust.

¹⁸ Uncarbonised stoves use fuel from raw bioenergy for example firewood, briquettes from sawdust, ground nuts husks and maize cobs.
protocol are far from what happens in real situations and as such, misinforms about stove performance in Uganda.

The national standard further classifies stoves according to their performance. Ugandan performance criteria follow the international stove testing standard - the ISO tier system. Uganda classifies stoves into 3 classes; 1 - 3, and classifies in reverse order of the tier system. The national standard classifies class 1 as the highest performance achievable for improved cookstoves and this same tier is tier 3 for ISO. The reason behind the change of classification could probably be explained that 1-3 in ascending order resonates well with the general classification system in Uganda and as such easier for especially local actors to associate with and understand. Table 13 shows the classification criteria for carbonised stoves.

Table 13: Classification Criteria for Carbonised Stoves

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Efficiency, $\eta_c$, %</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Emission factor</td>
<td></td>
</tr>
<tr>
<td>PM$_{2.5}$, mg/MJ</td>
<td>&lt;60</td>
</tr>
<tr>
<td>CO, g/MJ</td>
<td>&lt;9</td>
</tr>
<tr>
<td>Safety, %</td>
<td>≥95</td>
</tr>
<tr>
<td>Durability, %</td>
<td>≥94</td>
</tr>
</tbody>
</table>

Source: UNBS, 2019

Table 13 shows that class one is the highest achievable performance in biomass cookstoves, and stoves in this category are expected to be more than 50% thermal efficient, emit less than 60mg/MJ of P.M$_{2.5}$, emit less than 9g/MJ of carbon monoxide, achieve a score of greater than or equal to 95 for safety and finally achieve a score of greater than or equal to 94 for durability. There is currently no locally made stove in class one, and the majority are class three stoves. Save for Ugastove products, class one and two stoves on the market are imported. In order to support operationalisation of the standard, the national standard guidelines also include testing protocols for
each of the performance parameters, although some protocols are not aligned with actual performance determining factors such as cooking habits. As explained above, for example the thermal efficiency test operates only at high power, yet in reality, cooking behaviour is different.

Noteworthy though, fuel saving is not among the performance parameters in the national standard, yet it is an important attribute users look for in an improved stove. As discussed in Chapter Seven, fuel saving is one of the priority stove performance needs for end users, and a main driver of local manufacturers’ innovation. Although fuel saving is not part of the performance parameters, CREEC estimates that on average locally manufactured carbonised stoves save about 40% of the fuel while uncarbonised ones save about 50%. At the request of manufacturers, CREEC run fuel savings tests for locally made stoves and some imported stoves.

Test results were not available from CREEC due to disclosure restrictions, but some had been published on the website, which this study used as an example to analyse and understand stove testing and performance in Uganda. Among the cases studied, only Ugastove and BM shared their test results with the researcher (Appendix 8). Table 14 shows the example of test results for carbonised stoves. Since this is data obtained from the website, some firms whose data is used for this analysis are not part of this study’s core sample. The example includes only carbonised stoves because they are the most diffused and used in urban areas.
Table 14: Example of Performance Test Results for Carbonised Stoves

<table>
<thead>
<tr>
<th>Firm/Stove Name</th>
<th>Test Method</th>
<th>Year</th>
<th>Description</th>
<th>Thermal Efficiency High power (%)</th>
<th>Emission Factor P.M 2.5 (Mg/MJ)</th>
<th>Emission Factor CO (g/MJ)</th>
<th>Safety</th>
<th>Durability</th>
<th>Fuel Savings (%)</th>
<th>Time Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AES</td>
<td>FDUS 761:2018</td>
<td>2018</td>
<td>Size II Charcoal stove</td>
<td>30</td>
<td>6</td>
<td>15</td>
<td>88</td>
<td>86</td>
<td>44</td>
<td>-5</td>
</tr>
<tr>
<td>BM</td>
<td>FDUS 761:2018</td>
<td>2018</td>
<td>Size II Charcoal stove</td>
<td>31</td>
<td>8</td>
<td>26</td>
<td>88</td>
<td>86</td>
<td>52</td>
<td>-1</td>
</tr>
<tr>
<td>MASUPA</td>
<td>FDUS 761:2018</td>
<td>2018</td>
<td>Size II Charcoal stove</td>
<td>34</td>
<td>7</td>
<td>9</td>
<td>88</td>
<td>86</td>
<td>44</td>
<td>-3</td>
</tr>
<tr>
<td>PECO</td>
<td>FDUS 761:2018</td>
<td>2018</td>
<td>Size II Charcoal stove</td>
<td>33</td>
<td>6</td>
<td>13</td>
<td>88</td>
<td>86</td>
<td>41</td>
<td>2</td>
</tr>
<tr>
<td>PETSD</td>
<td>FDUS 761:2018</td>
<td>2018</td>
<td>Size II Charcoal stove</td>
<td>32</td>
<td>7</td>
<td>14</td>
<td>88</td>
<td>80</td>
<td>48</td>
<td>-8</td>
</tr>
<tr>
<td>Smart Cook</td>
<td>FDUS 761:2018</td>
<td>2018</td>
<td>Size II Charcoal stove</td>
<td>33</td>
<td>10</td>
<td>22</td>
<td>88</td>
<td>86</td>
<td>51</td>
<td>0</td>
</tr>
</tbody>
</table>

Source of data: CREEC Website - [https://www.creec.or.ug/stove-tests/](https://www.creec.or.ug/stove-tests/), accessed on 5th October 2020 (data tabulated and analysed by author)
Data in Table 14 reveals that locally manufactured carbonised stoves perform better on fuel savings than thermal efficiency. On average the stoves are 32% efficient and save 48% of fuel relative to baseline. However, the stoves do not generally save time, they take longer to cook. This time lag can be attributed to the sluggish start, which is associated with improved cookstoves, especially those whose insulation is heavily ceramic.

To further explain performance and classification of stoves in Uganda, Table 15 was generated to compare performance and class of carbonised stoves based on Uganda’s national standard.

Table 15: Performance and Class of Carbonised Stoves

<table>
<thead>
<tr>
<th>Performance Parameter</th>
<th>AES</th>
<th>BM</th>
<th>MASUPA</th>
<th>PECO</th>
<th>PETSD</th>
<th>Smart Cook</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal Efficiency</td>
<td>30</td>
<td>31</td>
<td>34</td>
<td>33</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>Class</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Emission Factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM$_{2.5}$, mg/MJ</td>
<td>6</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Class</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CO, g/MJ</td>
<td>15</td>
<td>26</td>
<td>9</td>
<td>13</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>Class</td>
<td>3</td>
<td>Out of range</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>Out of range</td>
</tr>
<tr>
<td>Safety (Points from 10 weighed safety parameters)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety Rating</td>
<td>88</td>
<td>88</td>
<td>88</td>
<td>88</td>
<td>88</td>
<td>88</td>
</tr>
<tr>
<td>Class</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Durability (Cookstove scoring system)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durability Rating</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td>86</td>
<td>80</td>
<td>86</td>
</tr>
<tr>
<td>Class</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>


Table 15 shows that the stove models in Table 14 generally fall in category 3 of the classification criteria for carbonised stoves but are class three on emission reduction.
Poor performance of local stoves on CO emission reduction is attributed to poor stove design and engineering geometry. Superficially, it can be concluded based on stove classification criteria in Table 13 and stove performance in Table 14 and 15 that locally manufactured improved cookstoves have good capacity to contribute to reduction of emission of particulate matter (P.M\textsubscript{2.5}). However, this is far from the truth because particulate matter emissions are under-reported. The stove testing protocol in the national standard starts to measure particulate matter after the ignition stage - when the pot is ready to be mounted on the stove, yet particulate matter emission mainly happens when lighting the stove. Different materials are used for lighting stoves, and from the four FGDs the following starter materials were listed: kerosene, polythene bags, tiny pieces of pine tree, paper, dry grass and embers/hot coal. The standard considers cooking time as starting when the stove is lighted and the cooking pot is mounted on it, yet emission starts at ignition. This anomaly was confirmed by the expert stove tester at CREEC who reported that:

(11) Particulate matter in charcoal stoves is mostly at the lighting phase before the pot is placed onto the stove, yet unfortunately the standard does not consider that time (lighting time). (Derrick Kiwana, CREEC)

This means that by design, the stove testing protocol does not capture particulate matter, which results in misinformation about the capability of improved cookstoves to reduce indoor and outdoor emissions. Additionally, the stove test’s aim to help to determine if the implementation of a specific type of improved stove might reduce indoor air pollution and the impacts of the stove on users’ health (CREEC, 2018) cannot be realised. The resultant effect of this inappropriate testing is that human health benefits expected to be delivered by the improved cookstove remain unattainable. P.M\textsubscript{2.5} is associated with asthma and other respiratory problems, low birth weights, heart attacks, and lung cancer (World Bank, 2020; Zaelke and Borgford-Parnell, 2013). These findings, therefore, challenge the received wisdom that ensuring
widespread use of improved cookstoves will result in health benefits (Mitchell et al., 2020), and present a daunting challenge: to use appropriate testing protocols that reveal stoves’ real performance on emissions and efficiency.

The other critical issue is that these false positive results on emission reduction cannot motivate manufacturers to improve stove designs that are required to achieve higher emission and efficiency performance. After all, local manufacturers can qualify to participate in carbon finance projects and other related funding schemes with the superficial “good test results”. From the findings of this study, I am therefore persuaded to conclude that with the current testing protocols and their attendant misinformation on stove performance in Uganda, widespread diffusion, adoption and use of improved cookstoves will lead to neither reduced emissions nor the development of better quality stoves. This also means that system functions such as knowledge development, knowledge diffusion and guidance of the search remain derailed by this anomaly.

Secondly, locally manufactured stoves have a lower thermal efficiency, on average about 32% as analysed from Table 14, and confirmed by CREEC report, which puts it at 30-33% (CREEC, 2018). According to CREEC, this modest performance is a result of poor stove design because thermal efficiency is greatly affected by fire power which is dependent on stove design and engineering geometry that facilitate combustion efficiency. The combustion chamber of locally manufactured stoves is insulated with a high thick conductive thermal mass that lags heat transfer to the pot. The thicker the insulation layer, the less the amount of conduction heat transfer through the insulation to the pot (CREEC, ibid, pg 27).

However, data in Table 15 shows that locally manufactured stoves perform better on fuel saving. Although not part of the national standard stove performance indicators, fuel savings is of great interest to local users. Locally manufactured stoves are made
of cheaper insulation materials, which affects the stove’s fire power. However, because clay is one of the main insulation materials used in local stoves coupled with the cooking habits of Ugandan households, they save more fuel than imported stoves because clay performs better at heat retention. Since fuel saving is one of the key attributes users look for in stoves, failure to include it as a test parameter suggests that the national standard failed to domesticate the international improved cookstove standard to Uganda’s context.

Crucially, being a voluntary standard means that the government doesn’t enforce it and there are no ramifications for non-compliance. Unlike mandatory governmental regulations, actors are free to choose whether they comply with the voluntary standards or not (Meybeck and Redfern, 2014). This means therefore that compliance is left at the discretion and goodwill of entrepreneurs. This model of standardisation can be effective if consumers are aware about standards and demand for them, which is not the case in Uganda. Asked if they were aware of the existence of the improved cookstove standard and its importance, all the participant in the four FGDs that were conducted in this research responded that they were not aware. This therefore means that Ugandan consumers’ capability to demand for standardised stoves is almost non-existent.

Furthermore, the existing voluntary standard only covers household stoves, institutional stoves and other related technologies such as ovens, grills and briquettes, remain unstandardised. The justification for a voluntary cookstove standard according to the Uganda National Bureau of Standards (UNBS), is to allow local manufacturers time to build capacity to comply with the standard. Although this is a policy incentive to aid the sector’s growth, the cookstove sector has a unique challenge of proliferation of low-quality counterfeits, which affects not only the market but also the realisation of the stoves’ intended socio-economic, environmental and human
health benefits. Compounded by limited consumer awareness, a voluntary standard cannot remedy the problem of poor quality stoves.

Although the UNBS reported that one has been requested, no standard for institutional stoves exists yet. Standards are demand driven – UNBS develops product standards that are asked for, and demand for a standard can come from a variety of sources such as artisans, consumers, regulators, research, presidential directives, or a complaint about the product. The standard for cookstoves was requested for by the regulator – the Ministry of Energy and Mineral Development. Having a voluntary standard for household stoves and no standard at all for institutional stoves has meant that poor quality stoves have continued to be churned out, which has negatively affected the reputation of locally manufactured stoves, and distorted the pricing system and the market in general. This in the end does not only affect user attitude towards these technologies but also limits market expansion. Research by Bergek et al. (2008a) warns against absence of standards in the TIS because it leads to a fragmented market, hence blocking the system function of market formation, in addition to reflecting poor awareness and capabilities. My findings however demonstrate that having an inappropriate standard is equally problematic for the TIS because it discourages compliance, and consequently affects key processes such as market formation and legitimacy creation.

5.5 Conclusion

The improved cookstove innovation system growth has been an externally induced as well as a phased process with different catalysts at each phase. Contrary to existing research (e.g., Bergek et al., 2008a), entry of firms in the innovation system does not generate system inducement. This is mainly because of the capability challenges as well as rather dubious and opportunistic intentions of the entrants. The existing standard is disconnected from local firms’ innovation focus and user habits and preferences, which makes results from stove performance tests misleading and
ineffective in addressing emission reduction expectations and user needs. The challenges of firms’ capabilities, opportunistic intentions and the inappropriate standard are compounded by the consumers’ very limited capability, if any, to demand for quality stoves. These challenges point to poor interaction in the system and relate to the conceptual framework of this study (section 3.1.2), which theorises that the quality of interaction between actors influences not only fulfillment of system function but also system performance in general. The lack of a suitable regulation on clean cooking in addition to having an inappropriate standard jeopardises efforts to improve stove quality. The resultant effect is that the human health, environmental and economic promises, which are the main drivers of international and national drive for cookstove promotion, remain largely unfulfilled.

This chapter has discussed two structural elements: actors and institutions. The chapter has revealed who is active in these structural elements and the environment in which they work. The next Chapter discusses the third structural element: networks. Chapter Six shows how interaction, learning and information sharing takes place within the formal structures of the improved cookstove innovation system.
CHAPTER SIX: THE ROLE OF NETWORKS IN SHAPING THE IMPROVED COOKSTOVE INNOVATION SYSTEM IN UGANDA

More often than not, financial dependence does not allow us freedom to decide and implement activities that we identify as priority for our members. (Network Respondent)

6.0 Introduction

The previous chapter described and analysed two structural elements - actors and institutions) of the improved cookstove TIS. This chapter looks at the third structural element of the innovation system: networks. My analysis here highlights how formal networks’ autonomy and efficacy is limited by dependence on donors for survival and low legitimacy among local manufacturers, which inhibits interaction. I also reflect on the long absence of formal networks as vehicles of interaction and learning, and how this could have contributed to slowing down the rate of development, application and diffusion of improved cookstove technologies. I also show how social media supports more technical and professional interaction and networking among the different structural elements in the improved cookstove innovation system, and the challenges associated with this new role.

6.1 The Role of Networks in Technological Innovation System Building

The TIS theory places networks at the centre of innovation system building as conduits of knowledge and information exchange, learning and research. Actors cannot work independently to influence system-level elements, so they join forces in networks (Musiolik, 2012). Therefore, networks work as conduits through which strategic changes at system level can be influenced through collective action.

This chapter analyses how knowledge is generated and shared, and the way interaction and learning take place within the improved bioenergy cookstove innovation system. The role of knowledge sharing to the successful development of
innovations is well documented. Kremer et al. (2019) argue that it is unlikely that innovation can occur in the absence of knowledge and information sharing. This view is supported by Castaneda and Cuellar (2020) and Plessis (2007), who they claim that innovation is highly dependent on knowledge exchange among actors, and that such sharing is critical to both creation and utilisation of knowledge.

Knowledge sharing is the interaction between human actors by exchanging experience, skills, insights and tacit and explicit knowledge (Castaneda and Cuellar, 2020; Wiewiora et al., 2013; Hogel et al., 2003). Plessis (2007) further argues that knowledge management facilitates collaboration, knowledge sharing, continual learning and improvement. Although Plessis (ibid. p.22) is of the opinion that knowledge management is a planned and structured approach to create, store, share and utilise knowledge, this study established that some aspects of knowledge management like knowledge storage, sharing and utilisation can, in some cases, be unstructured. My results show that knowledge and information storage and sharing increasingly employs unconventional, mainly unstructured mechanisms like social media, giving knowledge receivers and users freedom to choose which knowledge to store, use and share with others. Individual actors are becoming repositories of knowledge as opposed to conventional knowledge management systems where institutions played the biggest role.

Uganda’s cookstove innovation networks cannot be distinctively categorised as learning or political networks because they largely perform activities across this divide, although the original aim at establishment places each in a distinct category. For example, UNREEEA is an alliance whose major aim is to influence institutional setup in the TIS through advocacy, lobbying and research but this study established that like the other networks, UNREEEA’s core work is related to education and capacity building. One reason for the blurry character of cookstove innovation networks is that they pursue donor priorities as opposed to their strategic goals.
Donor interests directly influence the networks’ activity portfolios and plans, and most times donor interests differ from the networks’ own. Another reason is that some networks like UNACC have limited autonomy to pursue its membership generated strategic agenda. Through the Ministry of Energy, the government chairs the Executive Committee of UNACC and donors like GIZ, SNV, WWF form part of it. Therefore, only those activities that are sanctioned by the government and donor representatives are implemented. Indeed, at the time of research, the UNACC office was located in the Ministry of Energy. Therefore, UNACC’s loyalty and accountability is to the government and donors, not its members.

While formal networks are purposefully established to fulfil a strategic agenda, informal networks emerge with less planning. Musiolik and Markard (2011) view informal networks’ role as mainly linking actors and facilitating the exchange of knowledge and information rather than the execution of specific tasks at the system level. Musiolik and Markard further offer that actors often deliberately join forces in formal innovation networks to strategically create and shape the elements and structures of the TIS they operate in. This view assumes that firms are always active participants in the creation and shaping of the networks, which is not the case in Uganda.

Although the entrepreneurs are supposedly key members of the networks, none of the networks was established by cookstove entrepreneurs. The need for establishment of formal networks was identified and spearheaded by different actors. This is how UNACC, BEETA and UNREEEA came into existence. Entrepreneurs were brought on board later, after the networks have been established “for them”. Therefore, cookstove networks were largely externally stimulated and shaped, which partly explains the low loyalty of members, especially firms, to these networks. Noah Asinge from UNREEEA confirmed this view that networks are externally driven:
All the networks are initiatives of donors who identified the gap in clean cooking development and promotion and suggested why networks are important purpose vehicles for clean cooking promotion. This is how UNACC, UNREEEA and BEETA came into being. Recruitment of firms and other members in the network was part of the project that established the networks. (Noah Asinga, UNREEEA)

Musiolik (2012) argues that firms join formal networks mainly for two reasons: 1) to gain access to the immediate services a network provides (e.g. information exchange), and 2) to establish or change institutional structures at the level of the innovation system. Although Musiolik does not talk about the relative importance of these motivations, firms in Uganda join formal networks primarily to access the immediate services like training, funding, information and opportunities related to market activation. Firms’ subscription or renewal to UNACC or BEETA is therefore determined by the availability of immediate services they provide at the given time. Firms opportunistically switch subscriptions between networks in search of immediate services. Others pay subscription to both networks in order to tap both for benefits. Long term services like pursuing institutional change were less appealing to firms compared to immediate services.

6.2 Nature and Role of Industrial Networks in the Improved Cookstove TIS

This section analyses the dynamics of interaction as part of the process for exchanging information among networks of actors. The explanation in this section is premised on two arguments: 1) the innovation systems framework postulates that actors function in networks of different sizes and influence, and 2) the quality and breadth of knowledge and availability of robust avenues for its sharing, are a recipe for successful innovation development and dissemination. The technological innovation models stresses that the interaction between the different actors who generate, diffuse and utilise the technology is of paramount importance to successful development of a TIS (Hekkert et al., 2011).
UNCTAD (2018) views the role of networks in a developing country context as wide ranging, from linking technology developers and societal needs, to testing, promoting and diffusing innovations. Actors in the improved bioenergy cookstoves TIS formally interact in three industrial networks. However, as discussed in the preceding paragraphs, some of these industrial networks’ characters are ambiguous from governance to activity portfolio.

Improved stove manufacturers are organised by different players with varied interests. This means that more often than not, stove producers remain passive participants in the very organisations that are meant to advance their interests. The activity portfolio in these associations is determined by donor priorities as opposed to the manufacturers’ interests and priorities. This passive participation manifests in their lack of interest and involvement in network activities and suspicion regarding the motives of the networks’ managers. A total of six out of the ten formal manufacturers that were part of this study expressed doubts about the networks’ ability to advocate and lobby for necessary policy reforms in the sector. One manufacturer underscored the dilemma of networks and conflict of interest thusly:

(13) These associations are their avenues for fundraising and as such have minimal impact on our work as manufacturers. In some cases, association leaders learn from us and start to compete with us by vying for jobs that we members would be doing, for example, distributing stoves to benefit from carbon finance. (Kawere, FOWE)
Table 16: Formal Networks in the Improved Cookstove Innovation System in Uganda

<table>
<thead>
<tr>
<th>11</th>
<th>UNREEEA</th>
<th>UNACC</th>
<th>BEETA</th>
<th>CCA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Founder/year of foundation</strong></td>
<td>Industrial networks 2015</td>
<td>Public authorities and donors 2013</td>
<td>Researchers 2011</td>
<td>International networks 2010</td>
</tr>
<tr>
<td><strong>Member organisations</strong></td>
<td>6</td>
<td>Around 50</td>
<td>Around 200</td>
<td>More than 400</td>
</tr>
<tr>
<td><strong>Technical Focus</strong></td>
<td>Rallying and supporting private sector actors to advocate for better business environment</td>
<td>Advocacy, awareness raising and capacity building</td>
<td>Advocacy, awareness raising and capacity building</td>
<td>Driving consumer demand, mobilizing investment, and supporting clean cooking sector in general</td>
</tr>
<tr>
<td><strong>Main actors</strong></td>
<td>Private sector</td>
<td>Public, private and NGO in cleaning cooking</td>
<td>Individuals, public, private and NGO in bioenergy energy sector</td>
<td>Public, private and NGOs</td>
</tr>
<tr>
<td><strong>Network Mission</strong></td>
<td>Coordinates, supports and represents members to foster growth in the energy sector</td>
<td>Enhance Coordination and Synergy among stakeholders for universal access to clean cooking Solutions</td>
<td>Promote bioenergy energy efficient technologies and conserve the environment</td>
<td>Achieving universal access to clean cooking solutions</td>
</tr>
<tr>
<td><strong>Network Characterisation</strong></td>
<td>Strategic national alliance</td>
<td>Strategic national alliance</td>
<td>National industrial network</td>
<td>Global alliance</td>
</tr>
</tbody>
</table>

**Source:** Interviews and Networks Homepages [www.unreeea.org](http://www.unreeea.org); [www.unacc.org](http://www.unacc.org); [www.cleancookingalliance.org](http://www.cleancookingalliance.org). Last accessed on 18th November 2019
Although improved cookstoves have been a topic of research and development for more than 40 years (Kshirsagar and Kalamkar, 2014), interaction spaces for this technological field through networks building were not created until about a decade ago (see Table 16 above). Globally, the first and main network for improved cookstove technologies is the Clean Cooking Alliance (CCA), formerly the Global Clean Cooking Alliance (GCCA), which was established in 2010. This global alliance directly supported or influenced establishment of similar alliances at national level in some African countries including among others Uganda, Kenya, Nigeria, Ghana, Malawi, and DR Congo, and at the regional level such as the West African Clean Cooking Alliance for West African countries and an alliance for Latin America. In Uganda, the first network was founded in 2011 by researchers on bioenergy, yet as expounded in section 5.3, the creation of the improved cookstove TIS in Uganda started in the 1980s.

Networks, especially formal ones, play a significant role in building up a TIS. Research (e.g., Tigabu et al., 2015; Musiolik et al., 2012; Jacobsson and Bergek, 2006; Edquist, 1997; Lundvall, 1992; Carlsson and Stankiewicz, 1991) describes networks as vehicles for knowledge and information exchange, learning, research and supporting collective action. Based on these cardinal roles that networks have in technological innovation system building, I reflect on the long absence of networks in the improved cookstove TIS creation and shaping. I argue that having research and development going on in the cookstove technological field for three decades without organised formal networks inhibited learning and collective action, which consequently may have contributed to the slow rate of generation, dissemination and utilisation of improved cookstove technologies. The succeeding paragraphs profile the networks,
drawing upon interviews and network homepages. The discussion does not follow any specific order.

1) Uganda National Renewable Energy and Energy Efficiency Alliance (UNREEEA)

UNREEEA is an umbrella organisation for associations whose membership focuses on renewable energy and energy efficiency. Its operations started in 2015 with the aim of bringing together organisations working on developing and promoting renewable energy and energy efficiency, provide a platform for enhanced interaction, create more business linkages and advocate for favourable sectoral policies. One of UNREEEA’s major roles is to build the capacity of its network members. For BEETA, this has been done through implementation of training activities related to improved cookstove construction, basic business management and participation in policy and cookstove standards review. It also offered training to the BEETA leadership through sponsorship of executive board members to attend a one-month leadership training at the Uganda Management Institute. This one-off, academic (as described by one of the beneficiaries) training is not sufficient to improve decision making abilities at association board level.

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2) Uganda National Association for Clean Cooking (UNACC)

UNACC’s role in the clean cooking sector, character and origin is as ambiguous as it is confusing. Framed as a policy advocacy and capacity building outfit, this umbrella association for clean cooking was started in 2013 by the Ministry of Energy and Mineral Development and a host of development partners including GIZ, SNV and WWF. Although UNACC operates as a loose network that rallies all players in the clean cooking sector to influence clean cooking policies, its founders still hold strong influence over the activities and strategic direction of this network up today because they form part of the governing board. The purported members and owners of the network, who comprise of local stove producers among others, have very limited influence, if any, on its operations. The biggest influencers are the Ministry of Energy and Mineral Development, which chairs the Executive Committee and GIZ a member of the Executive Committee. Therefore, UNACC favours GIZ and other partners’ agenda over the local innovators. This was confirmed by a former worker at UNACC who reported:

(14) Having government, GIZ and other development partners on the Executive committee narrows the possibility of independence to implement the members’ cause. Sometimes partners’ priorities conflicted with members’ needs and we had to act in the interest of the partners. On several occasions we were forced to abandon the core objectives agreed on by the membership to do what the development partners wanted. The partners in most cases determine the programme and activity portfolio of the network. Respondent anonymised at their request.
The interview extract above is a vivid example of the dominant influence of external structural elements in influencing the growth trajectory of the cookstove innovation system in Uganda. Indeed, I learnt that local firms wanted UNACC to advocate for a higher import duty on imported stoves and removal of tax on stove making materials for local producers. However, funders were against this cause and instead advocated for removal of all import duty so that foreign manufacturers could import stoves unhindered. Therefore, UNACC and other networks could not continue to lobby and advocate for the cause its subscribing members had interest in because the funders were against it. Pitting against funders endangered their survival as donor dependent networks. In the end, a higher import duty on imported stoves was never achieved, resulting in an increase in stove imports and consequently increasing competition for struggling local manufacturers. The fundamental question remains: whose agenda does UNACC pursue and serve?

There is also the issue of conflicting roles with BEETA. UNACC and BEETA target the same membership – stove producers and innovators and offer similar benefits to members – information, capacity building, and awareness raising. This duplication leads not only to conflicts over members, fomenting confusion within the membership, but also leads to resource wastage through duplication of effort. It also leads to unhealthy competition for representation on relevant government technical bodies. Some government agencies like the National Bureau of Standards expressed disappointment about not knowing who to work with as far as improved cookstoves are concerned. This duplication consequently affects the legitimacy of these networks before their members, government agencies and other partners. As a result, many
firms do not subscribe to any network, some subscribed to both associations and others to one.

3) Bioenergy Energy Efficiency Technologies Association (BEETA)

This is an industrial association, which brings together private sector players including individuals, companies, academic/research institutions and civil society organizations with an interest in bioenergy in Uganda. BEETA was established in 2011, making it the oldest association for improved cookstoves in Uganda. Like its rivals, BEETA’s main focus is information exchange, awareness raising, advocacy, pointing members to financial and market opportunities, and capacity building for members. However, the efficiency and effectiveness of this association is affected by conflict of interest. The Executive Committee of BEETA is comprised of stove manufacturers who are supposed to guide the organisation’s strategic and policy direction. However, it was reported that when funding or new market opportunities come up, the information is not disseminated to the membership. Instead, members of the Executive Committee take advantage of such opportunities for their own benefit. As a result, the membership loses trust in the association, which affects its legitimacy.

The commonest challenge that all the local networks faced was dependence on external funding. Funding challenges push the networks into survival mode, with constrained capacity to maintain an independent voice. Domestic corporate philanthropy and public funding in Uganda is limited and as such civil society, which industrial networks are a part of, rely on grants from international donors to function (Uganda NGO Forum, 2014). Although industrial networks are membership based and as such collect fees from firms and other members, the sporadic subscriptions
cannot support even 5% of the network budget. It is well documented that overdependence on external funding to implement programmes and projects undermines CSOs’ independence, distracts them from their missions and affects the sustainability of their interventions and accountability to the communities they claim to serve (Akindele et al., 2017; Uganda NGO Forum, 2014).

4) Clean Cooking Alliance (CCA)

A global alliance focusing on clean cooking especially through advancement of clean cookstove technologies, CCA supports the improved cookstove innovation system in Uganda through information sharing and research and funding of activities. This alliance works closely with UNACC. Testing standards and parameters are benchmarked on CCA research outputs. The succeeding discussion goes into the specific detail of the activities the networks engage in.

6.3 Activities of Networks that Build the Cookstove Innovation System

The main purpose for creating networks is to build assets at the system level, which individual enterprises would not build if they operate individually (Musiliok, 2012). Such system level assets include: 1. Standards, 2. Regulation, 3. Political will, 4. Financing, 5. Knowledge and information, and 6. Skills development. According to UNREEEA, rallying the different associations for clean cooking has enabled participation of networks into the ongoing review of improved cookstove standards and the renewable energy policy.

The activities which networks undertake contribute to building the firms, networks and the system. System level assets are collective assets generated by actors and networks whose excludability is unlimited (Musiliok, 2012, pg. 47). They are accessed
and used by all stove producers and other actors in the improved bioenergy cookstove sector. Networks in the improved cookstove sector implement diverse activities, some of which directly benefit members while others create externalities that benefit the entire TIS. The formal networks implement activities in the following broad areas: 1. Knowledge creation and exchange, 2. Capacity building, 3. Lobbying and advocacy, 4. Standards and regulation, and 5. Marketing and awareness creation. Table 17 (below) shows the different specific activities implemented by the networks.
Table 17: Networks Activities in the Improved Cookstove TIS Building in Uganda

<table>
<thead>
<tr>
<th>Main Activities</th>
<th>UNREEEA</th>
<th>UNAAC</th>
<th>BEETA</th>
<th>CCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge creation and exchange</td>
<td>✓ Joint Profiling of clean cooking firms</td>
<td>✓ Market intelligence</td>
<td>Information exchange through WhatsApp</td>
<td>Standards and testing protocols, research</td>
</tr>
<tr>
<td></td>
<td>✓ Joint study on standard gaps in the cleaning cooking sector</td>
<td>✓ Repository for research products on cleaning cooking in Uganda</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Disseminate knowledge products from CCA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity Building</td>
<td>✓ Training on stove making</td>
<td>✓ Training on stove making</td>
<td>✓ Training on stove making</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Business development</td>
<td>✓ Business development</td>
<td>✓ Business development</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Training on governance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lobbying and Advocacy</td>
<td></td>
<td>✓ Vat waiver, import duty on imported stoves</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Coordinating the Inter-Ministerial Committee on clean cooking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standards and Regulation</td>
<td>✓ Sensitizing manufacturers on standards and compliance</td>
<td>✓ Sensitizing manufacturers on standards and compliance</td>
<td>✓ Sensitizing manufacturers on standards and compliance</td>
<td></td>
</tr>
<tr>
<td>Joint committee to review the Renewable Energy Policy</td>
<td>Popularising the standard</td>
<td>Popularising the standard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joint committees to participate in standards development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Marketing and Awareness creation | Joint exhibition stall during the energy week | Fumba Live campaign | Radio talk shows |
| | Market activation | Radio talk shows and adverts | Exhibition stall during the energy week |
| | Branding and product finishing | Tv shows | Cooking demonstration |
| | | Exhibition stall during the energy week | Baraza |

Source: Interviews
Table 17 shows that the networks engage in activities that contribute to building both network and system-level assets, for example training on governance issues at network level and participation in the review of policy and standards, knowledge creation and exchange, marketing and awareness creation at system level. Capacity building, marketing and awareness creation are however at the core of all the national networks. These finding differ from existing research. For example, Musiolik and Markard (2011) established that information exchange and knowledge creation were at the centre of stationary fuel cell networks’ activities in Germany. In Portugal, Bento and Fontes, (2015) found that networks’ major work is in political activities like advocacy and lobbying government to establish incentive schemes in wind energy. While in India and South Africa Papaioannou et al., (2014) established that the industrial associations were formed as public actors, which provide their members with what they call industry-specific public goods (ISPGs) (i.e. resources that are public and industry specific such as particular set of skills, capital good equipment, technical services) as well as influence innovation policy and politics of development. These findings suggest a rather interesting pattern that is worth exploring in more detail. For example, is there a correlation between the stage of TIS and networks’ core work? Or is it an issue of contextual differences in levels of development of the different countries?

The tabulation of the activities of the networks in the cookstove TIS in Table 16 further shows that the national networks all engage more in technical roles such as training, sensitization and awareness creation than in political activities such as lobbying and advocacy. This means that the political arm of the networks is weak, limiting attempts at institutional, system-level change. For example, key political issues like government financing for the clean cooking sector, policy on clean cooking, and regulation of imported stoves, remain largely neglected. Yet, Papaioannou et al., (ibid., pg 2) view industry associations as key policy making actors whose main focus is less to do with
operations and more with negotiating and affecting the institutional and governance arrangements of the line industry. Earlier research by Doner and Sheneider (2000) suggests that in developing countries the creation of successful institutions of innovation happens only under significant pressure from actors such as industry associations. Studies elsewhere, like in Germany, show that networks put much focus on influencing strategic system-level elements such as technological standards, lobbying for public support programmes, setting up training modules, creating value chains and increasing public awareness of fuel cells (Musiolik, 2012) than other areas like technical capacity building. This therefore means that networks concentrating more on technical activities than political ones will inevitably delay the achievement of the necessary policy and institutional changes in the improved cookstove TIS. The succeeding paragraphs explain the specific activities implemented by the networks in Uganda.

6.4 Knowledge and Information Creation and Exchange

Apart from government agencies, research institutes and development agencies, networks are the main producers of information in the clean cooking sector. Among the three associations, UNACC is the main producer of knowledge on clean cooking while UNREEEA focuses more on the power sector – off grid and biogas. The Networks have produced knowledge on issues like market intelligence for improved cookstoves, health risks associated with traditional bioenergy use, challenges of implementation and compliance to standards and policy briefs. They also work as repositories for relevant online and print knowledge products produced by other actors including international actors such as CCA. Research and other knowledge products are disseminated through workshops, conferences and exhibitions.

Another important actor for knowledge management on clean cooking is the Centre for Research in Energy and Energy Conservation (CREEC). Being a regionally recognised testing and knowledge management centre certified under ISO 17025,
CREEC operates a knowledge hub on mainly stove testing, baseline and feasibility studies, and funding opportunities. CREEC undertakes knowledge transfers by incorporating students in various projects like cookstove testing and clean cooking demonstration campaigns. CREEC also generates stove prototypes for example the micro-gasifier stoves and trains the private sector in construction of these stoves.

It was evident however that, although knowledge and information creation and exchange is one of the key activities that makes up the different actors’ activity portfolios, information deficiency exists in the sector. There are some studies on effects of traditional bioenergy use, barriers to uptake of improved cookstoves, market intelligence for improved cookstoves, cookstove financing, and charcoal production and consumption in Uganda. However, studies on user preferences and inclusion in the stove development process, impact studies on stove performance, consumer awareness studies on various aspects such as standards were lacking. Online materials can be hardly found on their websites, thus limiting access to information. Although still at a small scale, knowledge products in form of improved cookstove prototypes, which are spearheaded and incubated by CREEC do exist at the centres stove library.

We turn now to the networks’ second core activity.

**Capacity Building**

Capacity building by networks and other actors in the improved cookstoves sector is aimed at boosting capacity of firms and networks and concentrates on three major areas – technical, business and leadership training.

**a) Technical Training**

Technical capacity building focuses on training stove producers in improved cookstove construction. Through membership associations like BEETA and UNACC, residential workshops are organised to train stove producers on the science of improved cookstove making, focusing on the main performance parameters. CREEC
participates in some training activities. However, due to limited coordination between the different actors, it emerged that the same training activities are offered most of the time, regardless of the organisers. This has led to loss of interest by stove producers. Established stove producers feel that they have enough knowledge to make a modern stove, they only lack the requisite machinery and related logistics. Some questioned the trainers’ competence:

(15) I no longer go for training activities whether organised by BEETA, UNACC or UNREEEA. I used to go every time I was invited but later realised that the content is always the same – how to make an improved stove, marketing, book-keeping. There were cases where I felt I was fit to be the trainer and the trainers fit to be the trainees because I am more competent than them on these issues. The knowledge we need is about networking, how to pursue collective action, getting better machinery for production (Kasirye, FOWE)

Quote 15 above expresses a sentiment shared by four other local manufacturers and illustrates that local stove firms perceive their production challenges more as an issue of inadequate physical capital and distribution problems than lack of technical capacity. It also emerged that distribution was a bigger challenge than marketing. This is because improved stoves are both fragile and bulky, which makes their transportation challenging. Fewer distributor companies are involved in the stove business. This means that most manufacturers both produce and distribute their own stoves (cf. section 5.3.2).

Local stove producers claim that they lack the proper equipment and material to produce high standard stoves, good partnerships and distribution systems and not knowledge of making a stove. Since the majority of new entrants in the industry are not members of the industrial associations, through which trainings are channeled, they are left out of the skilling activities. The challenge remains that networks need to
profile and mobilise new entrants so that training is given to the right people. Some stove producers were not keen to subscribe to the existing industrial associations arguing that such subscription only helps to legitimise the networks before their donors with minimum benefit to manufacturers. After all, the business remains profitable even in absence of any association with formal networks. This means that industrial networks must build creditable network assets to attract subscriptions and generate interest from the targeted enterprises. In an effort to strengthen networks and streamline stove making, some funding agencies like GIZ have started to make affiliation to UNACC or BEETA a requirement for funding.

Network assets take form of shared goals that are well articulated and understood by the membership, trust among network members, reputation and influence of the network and network culture: mode of operation (Musiolik, 2012). Industrial associations and networks still need to put in place these assets in order to attract cooperation from members and gain power to influence decision-making at different scales. Currently, networks have to deal with some liabilities like a disinterested membership, which affects their legitimacy. On the legitimacy of the networks, one stove manufacturer commented:

(16) Whose interest do these industrial associations serve? In most cases they work to please donors and may be government. I do not know what the mission of BEETA is yet I pay annual subscription. When we try to ask for programmes like how to link up with regional and international partners to support growth and expansion of our business, they will be quick to remind us how GIZ or another funding agency will not accept such proposals. So, whose associations are these? (Amir Lugwana, AES)

The frustration expressed in the quotation above questioning the loyalty of the networks was recorded in five more cases. This signifies that the legitimacy of the
networks is questionable in the eyes of the manufacturers, and this can only work to
derail mobilisation for collective action at the system level.

d) Lobbying and advocacy
Lobbying and advocacy has mainly centred on VAT and import duty. Through their
networks, stove producers launched campaigns to compel the government to remove
VAT from all stove manufacturing materials. They also advocated for an increase of
import duty on foreign-made cookstoves. They argued that the latter is in line with
the government policy of Buy Uganda, Build Uganda (BUBU). Imported stoves, which
are normally of better quality than those manufactured locally, present unfair
competition, including for carbon finance. As already established, locally made stoves
grapple with quality challenges among other structural rigidities. In order circumvent
this challenges, it was reported that the key financiers of the improved cookstoves
sector instead advocated for tax exemption on imported high quality stoves. Networks
and their financiers pursuing conflicting goals was a recipe for tension in the sector
and ultimately the agenda stalled.

Regarding VAT, it emerged that some of the stove making materials like steel metals
and paint, are not unique to the sector. They are used in other sectors like construction
and VAT is incorporated at manufacturer’s level. The government could therefore not
lift tax on them. Other stove making equipment that are imported are however tax
free.

An effort to lobby for clean cooking in government agencies that heavily rely on
traditional bioenergy energy was started in 2016 through the establishment of an
Inter-Ministerial Committee on Clean Cooking. This is a loose network at policy level
that was supposed to create a link between policy makers and the clean cooking sub-
sector players in Uganda. This effort was spearheaded by UNACC. It was believed
that encouraging government agencies that rely heavily on bioenergy would be more
effective if their line ministries were included. Therefore, ministries that are directly responsible for agencies like police, prisons, army barracks, government schools and other institutions of learning form part of the committee.

Relevant government agencies, development partners, industrial associations and research institutes are also members of this committee. Some goals the committee held at the time of its formation were: 1) a clean cooking status report which will lead to the formation of a cabinet memo, 2) influence policy formulation within different ministries and agencies to influence the demand and supply of clean cooking solutions country wide, 3) engage line ministries to achieve streamlining and prioritization of clean cooking issues in both national and district budgets beginning with the 2017/2018 budgets, 4) address issues of tax waivers for clean cooking material and equipment, and 5) increase access to finance and credit for both fuel and stove manufactures.

It however turned out that the Committee was active for a short time and later became dormant. Apart from facilitating interaction between government agencies and other improved bioenergy cookstove actors, which could have had indirect benefits for especially awareness raising about clean cooking, there were no concrete achievements that were registered by this Committee in relation to the goals they set at its inception. Its inactivity and low influence are mainly attributed to conflicts of interest. Although a brainchild of UNACC, this committee was chaired by the Ministry of Energy and Mineral Development. As a decision- and policy-maker, the Ministry’s leadership of a loose network that is supposed to influence policy making and institutional change at system level presents issues of conflict of interest.

e) Standards and quality assurance
Activities in this area are usually implemented jointly by collaboration and participation of all networks. Key among the issues addressed here is the review of
the improved cookstove standard and the renewable energy policy. Networks organised joint review meetings to solicit views from their members. These views formed the basis for the networks’ input at government organised review meetings. Networks earned themselves a seat at the improved cookstove standards and Renewable Energy Policy technical committees. Research (Scott, 1992, in Papaioannou et al 2014) suggests that the state collaborates with networks and industrial associations to tap their expertise in developing new governance frameworks. This is what happened with the stove standard. UNBS tapped into the expertise of the networks to come up with a biomass stove standard. Networks’ input in the renewable energy policy included the need to prioritise awareness raising for clean cooking, end user financing, and capacity building through establishing certified programmes for cookstove producers by the Directorate of Industrial Training.

f) Awareness Creation
Awareness campaigns are used as behavioural change techniques for clean cooking. Industrial associations and networks run individual and joint campaigns to address the issue of uptake of improved cookstoves. Initially awareness messages were crafted emphasising the dangers of traditional bioenergy use. However according to Noah Asinga (UNREEEA), this strategy didn’t elicit the expected response of driving adoption because people found no urgency in such threats. Noah explained that such unconcerned attitudes towards indoor air emission are rooted in the traditional manner of food preparation. Users reasoned that food preparation has been done that way since time immemorial and it never presented “any serious health challenges”. This information corroborates with findings from FGDs in Chapter 7. In order to overcome this negative outcome, awareness campaign messages changed and focused on the benefits of using an improved cookstove. The following techniques are used to raise awareness about the benefits of improved cookstove use: 1. Radio talk shows, 2. Road shows, and 3. Exhibitions (more on this in chapter 8).
Research results also show that networks do not always work independently. Some activities were coordinated between networks. These joint activities mainly related to market activation in upcountry areas. UNREEEA coordinated network’s participation in standard and renewable energy policy review. This finding is in line with what Musiolik (2012) established in stationery fuel cell innovation system building in Germany. Networks in some cases join forces to achieve a strong collective voice to influence decisions at political level. For example, the advocacy agenda related to VAT waiver.

Examining the role of formal networks in the improved cookstove TIS has shown that networks’ establishment and their activity portfolio are externally engineered. We also learn that national networks all engage more in technical roles such as training, sensitization and awareness creation than in political activities, which limits attempts at institutional, system-level change.

**Conclusion**

The above analysis of the formal networks and nature of interaction in the improved cookstove innovation system has demonstrated that the existing formal networks have to overcome technical and governance issues in order to become effective avenues for interaction and learning for system actors. Under the current arrangement, these networks cannot build assets like shared goals, building trust and legitimacy among network members, which are necessary to strengthen the networks’ supporting role in the system. In an effort to circumvent the interaction challenges within the formal mechanisms, some actors like networks themselves and firms employ informal systems to support their learning and information sharing role. This mainly takes the form of use of social media and other informal mechanisms as discussed in the next section.
6.5 Overcoming Interaction Failure through the Use of Informal Networks: Social Media and the Improved Cookstove TIS Building in Uganda

In a bid to address the interaction gaps, some actors like networks use social media, specifically WhatsApp for research and information dissemination, albeit with challenges. WhatsApp is increasingly becoming a major tool for interaction and information sharing within the improved cookstove sector. This finding concurs with Yunis et al. (2018) and Filo et al.’s (2015) assertion that social media is becoming a valuable platform for facilitating knowledge sharing, communication and learning. It has revolutionised the way people share information, communicate, interact and collaborate with each other. However, although some scholars (e.g., Yunis et al., 2018; Bilgihan et al., 2016) argue that the most prominent social media platforms for knowledge sharing and interaction include Social Networking Sites (SNS) (like Myspace and Facebook), microblogs (like personal blogs or Twitter), pictures or video-sharing applications (like Flickr or YouTube), and do not mention WhatsApp among these, I established that in the improved cookstove sector, the single most prominent social media platform used is WhatsApp. This variation in findings can be attributed to the differences in geographical contexts in relation to availability and sophistication, affordability and awareness of technological tools for social networking.

Associations like BEETA run a WhatsApp forum as a main platform for sharing knowledge and information about government laws and policies, and new developments in the sector generally, and what actions members need to take. It is also used to share information about upcoming national and international events, including conferences, workshops and exhibitions. Manufacturers use these events in a number of ways including: 1. Learning about new stove designs and equipment, 2. developing networks with different players including those outside Uganda, 3.
opening up new market opportunities, 4. learning about the latest research products on improved cookstoves and clean cooking in general, and 5. Fundraising.

Important as WhatsApp platform may be to stove manufacturers, it is constrained by limited control on what information is shared. Although the aim of forming the WhatsApp group was to ensure timely information sharing in the improved cookstove sector and qualitative interaction between members on matters related to improved cookstoves, more often than not these groups are littered with jokes, memes and other irrelevant information to the disappointment of some group members. One respondent who is a member of the BEETA WhatsApp group had this to say;

(17) Our WhatsApp group is my main source of information for all the developments in the improved cookstove sector. But sometimes I get disappointed when I miss an important piece information because it was buried down the myriad of jokes, memes and other irrelevant information, sometimes including altercations between some group members. It is time consuming to sieve through 100s of messages to pick out the important ones. Sometimes my data gets used up before I complete reading all the messages and downloading the videos. (Margaret, CEO Masupa).

The interview extract above reveals the complexities and challenges of transforming a social media platform into a controlled space for business or professional engagement. Entrepreneurs like Masupa, Josa, FOWE, and AES reported that they have budget lines for internet access including specifically WhatsApp access for business development. These entrepreneurs invest in internet data in addition to paying the Over the Top Tax (OTT), which the Uganda government imposed on social media access, to specifically learn about the market landscape, get updates on different policy agendas they are advocating for like VAT waivers for cookstove manufacturing materials, to share or access information about new products/stove designs on the market, funding and networking opportunities among others. Actors
invest in data bundles and pay OTT tax of £1.30 monthly with an expectation that they will gain information they need through the WhatsApp platform to build their businesses. This means that local manufacturers perceive the WhatsApp platform as a one-stop information hub for them, and as a mechanism that should facilitate interactive learning among group members. The extent to which WhatsApp can meet this expectation is, however, a function of availability of up-to-date and relevant information, diligence of group administrators to post the information and generate discussion on the platform, responsiveness of the members on the platform, willingness of individual members to share information in their possession and to participate in discussions that ensue on the platform.

As confirmed by Virginia, one of the BEETA WhatsApp group administrators and a leader of the association, the WhatsApp space is useful for promoting interaction and educating members on issues pertaining to clean cooking in general. BEETA also uses this platform to obtain ideas about members’ needs and expectations. Indeed, some of the activities especially on sensitization that BEETA implemented were generated from WhatsApp discussions. It is the most cost-effective way of reaching all members who are subscribed to the WhatsApp group and to get any required feedback from them in time. According to Virginia, information dissemination in a timely manner to members and between members is much easier and cheaper with WhatsApp than with other means like convening meetings, emails and phone calls. This finding is in agreement with Panahi et al. (2016) where they stated that the use of social media platforms is associated with greater opportunities for rapid knowledge transfer and information flow between people working across different geographical areas, than could be provided through conventional tools. Virginia however admitted that the challenge of restricting the information that is posted and nature of discussions that ensue on the platform to the main issues remains daunting.
6.5.1 Other forms of informal Interaction

Besides these network WhatsApp groups, firms interacted informally among each other and with different actors. Cases were reported where actors developed linkages from conferences or workshops, which culminated into free exchange of knowledge and information. Some entrepreneurs kept in touch with each other through WhatsApp and phone calls and shared information on the issues or opportunities that come up in the sector. Indeed, Egbetokun et al. (2017) suggests that such informal linkages are important in developing countries where formal interactions face challenges like weak legal infrastructure and resource constraints. They further argue that the interaction in innovation systems in developing countries is actually not holistically weak as suggested by research (e.g., Bernardes, 2003; Intarakumnerd, et al., 2002) because a lot of informal interaction takes place ‘off the record’, and that sometimes this kind of interaction is enough to implement an innovation. Earlier on, Carlsson and Stankiewicz (1991) had also observed that networks are often informal more than formal, which makes it difficult to delineate their boundaries. In Uganda, informal interactions seemed to be based on mutual understanding and interest.

6.6 Conclusion

Due to the limited autonomy caused by donor dependence, the voice of formal networks is weakened, and the dominant structural elements influence the agenda of both actors and networks. Networks enjoy very limited autonomy to implement activities in line with their members’ priorities and interests. This therefore means that, as Bergek et al. (2008a) suggested, networks may fail to aid a new technology because of poor connectivity between actors. This means that as suggested in the conceptual framework (section 3.1.2), the quality of interaction between the actors in the system affects system performance. In this case, a weak network voice inhibits learning and research. Civil society’s role is key in advocacy and lobbying for policy change, especially in developing countries where the state may be thin on ground.
Having weak networks, especially in terms of autonomy, is a big challenge for the sector’s advocacy work. The legitimacy of the networks among manufacturers is affected, which hinders not only effective knowledge sharing and learning but also collective action. These challenges coupled with duplication of activities and unhealthy competition for members and other resources leads to what Jacobsson and Bergek (2011) refer to as interaction failure. This ultimately leads to network voices being weak and fragmented, which affects overall influence especially at the system level.

Largely perceived as a platform for social interaction, WhatsApp is assuming more formal roles like interactive learning and knowledge and information exchange on technical issues among different groups of people. It is deemed cost effective, convenient and fast compared to other means of communication like physical meetings, emails, mails and phone calls. WhatsApp is indeed becoming an essential means of communication among improved cookstove actors and networks. Although WhatsApp is a promising platform that can transform information sharing, learning and interaction among small and medium entrepreneurs in the improved cookstove sector, it has to overcome conceptual and perceptual hurdles in order to become an effective communication tool. How possible is it to restrict WhatsApp group discussions to the information that strictly serves the purpose for which it was formed? Can WhatsApp be a controlled space in terms of nature of information shared and discussions permitted, without stifling group interaction?

In a nutshell, structural elements in the improved innovation system have to overcome scores of structural, technical, and coordinational challenges in order to shape a more efficient innovation system that can facilitate wider diffusion and adoption of technologies. Having discussed the structural configuration of the improved cookstove TIS in chapters five and six, we now turn to analysing how the actors frame innovativeness in the focal technology. In the next chapter (7), I examine
the different technological frames espoused by the different actors and show what these divergent perceptions mean for generation, adoption and use of improved cookstoves in Uganda.
CHAPTER SEVEN: TECHNOLOGICAL FRAMES AS SOCIO-TECHNICAL CONSTRAINTS: IMPROVED COOKSTOVE FRAMING INUGANDA

An improved stove should help me to save fuel and time but also allow me to prepare my dishes the way I enjoy them. (FGD Participant)

7.0 Introduction

Chapters five and six analysed the structural elements of the improved cookstove innovation system. In these chapters I showed who is active in the innovation system, why, how they operate and the environment in which they work. This Chapter expounds on the environment in which actors operate and analyses the divergent perceptions about the cookstove innovation. It shows how the different actors perceive the cookstove technology and how these divergent perceptions create tension in the system, and derail fulfillment of key processes such as entrepreneurial activities, knowledge development, resource mobilisation and legitimacy creation.

Innovation is widely known to be subjective (Everleens, 2010; Koellinger 2008; Jacobs and Snijder, 2008), and it is not only an idea but also its implementation. Research (e.g., Borras and Edquist, 2013; Everleens, 2010) suggest that innovations take different forms, which are determined by type of innovation (whether product, process or service), degree of novelty (whether radical or incremental), type of innovating organisation (whether private firm or private organisation), and size (whether done on a small or large scale). The innovation system build-up may vary for each form of innovation, because each form may be working under different drivers and systemic catalysts. On the other hand, Koellinger (2008) argues that it is the observer who qualifies what is innovation and what is not.

In Uganda’s case, manufacturers perceive their products as innovations because of their effect on fuel use and the cooking environment, compared to the baseline
traditional metallic stove or open fire place. Therefore, in this case, judgement about innovation is not a privilege of the observer or user only but also the innovator, especially where the innovator is deliberate about the problem they are solving. My analysis in this chapter shows how different actors perceive innovation and stove quality, and how the divergent perceptions (technological frames) work to slow the generation, diffusion and adoption of improved cookstoves. I reflect on how indigenous knowledge (informal structures) is applied in some stove making and use processes (at firm and user levels respectively); yet it is excluded from knowledge generation and exchange mechanisms at the network and system levels, and how this exclusion impedes the generation of appropriate technologies.

7.1 Local Innovators Frames on Stove Innovation

Local firms view innovation in cookstoves in five main forms – fuel saving, a clean cooking environment, compatibility, safety, cost, and durability. The focus is on direct emission reductions that is; lessening wood and charcoal use, thereby reducing smoke and other by-products of burning these fuels like ash, and finally giving users a product that can last between two-five years without altering people’s cooking habits. Carbon emission reduction (indirect emissions) was not initially part of local firms’ innovation targets; it became an issue later with carbon financing in late 2000s. Local firms view carbon emission reduction as funders’ need as opposed to local stove users’ need, although reducing fuel wood and charcoal use contribute to this target.

An emphasis on deforestation and fuel saving as the drivers of improved cookstove enterprises can be attributed to the work of environmental NGOs in Uganda whose main focus in the late 1990s and 2000s was advocacy and awareness raising about the challenges of environmental degradation and deforestation. Excessive consumption of charcoal and wood was singled out as one of the main drivers of deforestation and biodiversity loss in the country. The 2000s saw vigorous debates about the need for sustainable environmental management. During this same time, the majority of local
cookstove firms were founded. Therefore, it is not surprising that local manufacturers claim deforestation and the need to reduce fuel wood and charcoal use as a key motivation for their enterprises. Table 18 displays the responses with regards to motivation to start a cookstove enterprise.

Table 18: Motivation to Start and Improved Cookstove Enterprise

<table>
<thead>
<tr>
<th>Enterprise</th>
<th>Year of establishment</th>
<th>Extra-financial Motivations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ugastove</td>
<td>1980s</td>
<td>Family business and later in 2000 motivated by the need to reduce charcoal use to protect forests</td>
</tr>
<tr>
<td>WE</td>
<td>2008</td>
<td>Reduce deforestation, funding opportunity</td>
</tr>
<tr>
<td>SESSA</td>
<td>2009</td>
<td>Reduce deforestation, funding opportunity</td>
</tr>
<tr>
<td>AES</td>
<td>2010</td>
<td>Putting skills from my Germany training into practice, funding opportunities</td>
</tr>
<tr>
<td>Humura Investments</td>
<td>2010</td>
<td>Concern about deforestation and carbon finance</td>
</tr>
<tr>
<td>MASUPA</td>
<td>2012</td>
<td>Loss of formal employment and rising charcoal prices</td>
</tr>
<tr>
<td>JOSA</td>
<td>2012</td>
<td>Rising fuel prices and carbon finance</td>
</tr>
<tr>
<td>BM Energy</td>
<td>2013</td>
<td>Rising fuel prices and carbon finance</td>
</tr>
<tr>
<td>ILF</td>
<td>2013</td>
<td>Deforestation and Carbon Finance</td>
</tr>
<tr>
<td>Potential Energy</td>
<td>2015</td>
<td>Health and environment concerns</td>
</tr>
</tbody>
</table>

*Source: Interviews*

Although some literature situates the drivers of small firm entrepreneurship in developing countries more to necessity than opportunity (Krause *et al.* 2010) and poverty and a lack of accessible formal employment (World Bank, 2017), my findings show the importance of other drivers. According to Table 18, the improved bioenergy cookstove enterprises in Uganda are largely driven by both the need to address the problem of deforestation and the need to reduce fuel wood/charcoal use, and opportunity (financing, e.g. climate change financing, market availability). There could be informal firms whose motivation might be as stipulated by Krause *et al.* and the World Bank, but many incumbent, formal improved cookstove enterprises (six out
of ten in Table 18) were attracted by the opportunity of carbon finance that opened new funding opportunities in the sector.

The perceptions of stove manufacturers seemed to be driven by the socio-cultural realities of food preparation expressed by stove users’ needs and expectations.

7.2 End-user’ Frames on Stove Innovation

In terms of innovation, local stove manufacturers focus more on how to reduce fuel use, increase safety and durability of the stoves: any benefits on emission reduction are accidental rather than intentional. In the same vein, according to focus group discussions, users are driven more by how much fuel the stove saves, its durability and sturdiness, and price. Although carbon finance is mainly about emission reduction, local stove manufacturers are focused more on user needs such as fuel saving, durability (a stove should last for at least 2 years), safety, cost, creating a better cooking environment (reducing or eliminating ash and smoke), and the ability of the stove not only to cook the food but also to keep it hot for some time (fitness for purpose). According to the local cooking behaviour, an improved stove has to function as both a stove and food warmer. The need for a cookstove to function as a food warmer is situated in the cultural food preparation systems in most parts of Uganda. The cooking behaviour for traditional local dishes such as those made from green banana (matooke), perceives that the longer the food stays on the stove simmering on a low fire, the better the taste and aroma. The same perception applies to different sauce recipes.

Responses affirm that local manufacturers prioritise user needs over emission reduction:

(18) Stove users determine our innovation focus not government or the unsustainable funding schemes (Ssesanga, SESSA),
(19) Our product prices are deliberately kept affordable to many users because we use cheaper materials and focus more on making good insulation liners (Hajji Mubiru, BM Energy),

(20) the priority is really on saving fuel because our cultural cooking habits are very fuel consuming …. cooking for almost a whole day! (Kasirye, FOWE)

The central issue in the quotes above is that local manufacturers’ innovation focus is rooted in the users’ cooking behaviours. The quotes also allude to the fact that local manufacturers are looking at sustainable ways of building their businesses, rather than depending on external funding.

Findings from the local manufacturers’ perceptions corroborate the findings from the Nalumunye, Wandegeya, Makindye and Kajjansi Focus Group Discussions (FGD). Stove users in FGDs made remarks about food preparation as below:

(21) I enjoy my steamed matooke dish and ground nuts sauce mixed with fish when after cooking it, it is mashed and put back on low fire well covered with banana leaves for at least an hour (FGD Participant, Makindye).

(22) My dinner meal has to be given time to cook properly because my husband loves coming back to a dish well prepared after a long day. I leave it to cook on low fire for at least three hours (FGD, Kajjansi).

(23) Even if it is posho, I enjoy it more if it is wrapped in banana leaves and put back on the fire to cook for some time after mingling it (FGD Participant, Nalumunye).

(24) I prepare lunch and supper at once to save time. We serve lunch and leave the supper portion on the stove until dinner time (FGD Participant, Nalumunye)
(25) Most of us here in Wandegeya food market cook lunch and dinner at once. After our customers have had lunch, we leave the food we serve in the evening on the stoves simmering on low fire. This does not only save time and fuel but also wages because some workers’ shifts end at lunch time and we remain with just a few that serve customers in the evening (FGD Participant, Wandegeya Food Vendors).

Extracts from stove users above confirm what the local manufacturers emphasised the importance of fuel saving given local cooking behaviour. These extracts further reveal that much as stove users want to save fuel and time; they were not willing to alter their cooking habits. They still preferred to prepare their dishes the traditional way. Preparation of staple foods in Uganda is culturally given ample time. Serving food immediately after it gets ready is perceived as “rushing”, and therefore not giving it time to “cook properly”, and such food cannot have the “desired taste”. Responses from the FGDs reveal perceptions that the flavour of dishes that are given ample time to “cook properly” (taking a little more time, a minimum of 30 minutes from the time it gets ready before it is served) is different from that of “rushed dishes”. The issue of cooking behaviour was re-echoed in FGDs and interviews with stove manufacturers. A participant in the FGD had this to say;

(26) Preparing a decent matooke dish cannot be rushed. Rushed dishes can easily be distinguished from properly prepared ones by their taste and aroma (FGD Participant, Nalumunye).

Quotation 26 above expresses the widely held perception that longer cooking time is associated with good taste and aroma. It is also a practice to simmer food on stoves with low fire for hours, and this practice applies not only to household dishes but also in food markets and food prepared for social functions like weddings and other ceremonies. This means that a locally acceptable stove must be both thermally efficient as well as good at heat retention, if the user is to save fuel.
Cooking time differs by region depending on the staple foods of different ethnic groups. This research took place in Kampala city, the capital of Uganda, which is a multiethnic urban area with higher income levels and as such, it offers a diversity of dishes but *matooke* is central to the city’s diet (MECS, 2020). *Matooke* is a staple food in central, western and southern parts of Uganda and its cooking time depends on the dish recipe prepared. Box 2 explains the cooking behaviour for different *matooke* dishes.
Box 2. The Process of Preparing Steamed Green Banana (Matooke) in Uganda

No meal particularly in central, western and southern Uganda would be complete without matooke (banana, plantain). To be hosted in home in central Uganda including Kampala city and be served food without matooke as part of the menu is unorthodox and can be construed as a lack of hospitality on the host’s part. The majority of restaurants and food markets in and around Kampala have matooke as part of their daily menu too. Matooke can be steamed, boiled or braised but the most preferred way of preparing it is by steaming. To prepare steamed matooke, one has to have banana leaves which are sold at road side markets. Matooke is peeled with a kitchen knife and it is neatly wrapped with the banana leaves and secured with banana fibres. Then a small amount of water put into the saucepan, but without submerging the matooke. The wrapped matooke is wedged in the saucepan by pieces of banana stalks to reduce on the amount of water entering the wrapped matooke and then after placing it in the saucepan, it is again wrapped in banana leaves to trap as much heat as possible to steam the banana.

Then the saucepan is placed on the stove and set on high heat, allowing the water to boil for an hour or more. Then simmering takes place on medium heat, which can take about two hours or more. The banana leaves turning brown is an indication that the matooke is ready to be mashed. Mashing takes place when the saucepan is removed from the stove and is done by hand, using banana leaves that have cooled down. Matooke is mashed to the consistency of mashed potatoes. The mashed matooke is then wrapped in banana leaves and returned to the saucepan adding more water and ensuring that the water does not touch the matooke, again covering it with banana leaves. The saucepan is mounted back on to the stove and brought to boil before reducing the heat and allowing it to gently simmer. The simmering duration can vary from minutes to several hours depending on user preference, but the unwritten principle is that the longer the food is allowed to simmer, the better.

Source: Narrations from FGDs with additional explanation from MECS, 2020

The elaboration of the main dish (matooke) preparing process in Box 2 confirms the voices of FGD participants (quotes 21, 22, 23, 26), stove manufacturers (quote 20) and expert opinion (quote 27) that food preparation takes many hours in Uganda. Furthermore, in most cases stew is prepared separately and necessitates different
procedures depending on the type of dish. This is why it is common to find households with two or more stoves to cater for staple dish and stew dish preparations or adopting double chamber stoves that enable the simultaneous cooking of two dishes. This elaboration serves to confirm that cooking behaviour has a strong influence on both efficiency and acceptance of stove innovation.

FGD participants identified five major drivers for acquiring an improved cooked stove, and these include; fuel saving, fitness for purpose, safety, price, durability and creating a better cooking environment. According to a FGD among Wandegeya market food vendors, the ability of the stove to keep food warm for hours with little fuel use is what works for them. Other participants talked of saving time by preparing both lunch and dinner at once around late-morning/early afternoon, having lunch and leaving the dinner portion on the stove until evening, with the food expected to still be hot when served.

Serving cold food is perceived as unacceptable in most of Uganda’s food preparation cultural systems. Responses from FGDs revealed that eating cold food is associated with causing sickness in children especially, and the gendered cultural expectations do not permit women to serve cold food to their husbands. Stove users in FGDs further reported that the other reason for preferring hot food is because of the limited availability of proper food storage, warming and preservation mechanisms. Stove users apply indigenous knowledge to adjust the stove fire from high to medium and low heat in order to maintain the right food temperature. This technique involves using ash (the by-product of charcoal combustion) to cover the charcoal that still has live fire to regulate the amount of heat transferred to the cooking vessel, while keeping the vessel simmering to maintain the right food temperature. Therefore, a stove that offers services that meet the specific needs of users can be referred to as an innovation that is fit for purpose in Uganda.
As already seen in section 5.4, locally manufactured stoves perform better on fuel saving than imported stoves because of the nature of insulation materials used. Local manufacturers use ceramic liners for insulation, which are made from cheap materials, mainly clay mixed with minerals like vermiculite, sand, mica, or saw dust, among others. These materials make locally manufactured stoves bulky but with improved heat retention. On the other hand, imported stoves use more modern insulators (fiber glass, for example), and are more thermally efficient than locally manufactured stoves, but they do not retain heat for long when the fire dies out. This means that these kinds of stoves are not fit for purpose for local needs to “properly cook” food (having to leave food on the stove for extra time on low power after it finishes cooking) and saving time by preparing both lunch and dinner dishes at once.

Saving time in this context is two-pronged: i) the well documented time saving by cooking faster (efficiency) (Vigolo et al., 2018; Loo et al., 2016; Barnes et al., 2015; Levine and Cotterman, 2012; Jeuland and Pattanayak, 2012), and ii) the Uganda specific one that I established in this study, which is time saving in relation to enabling users to prepare two meals at once, serve lunch and leave the dinner portion on the stove and keep it hot until dinner time (expressed in quotes 24 and 25 above). This therefore means that an improved cookstove saves a user’s time by cooking faster and by cooking the day’s main meals at once and keeping the cooked food hot for hours. The importance of fuel saving and cooking behaviour was expressed by an expert from CREEC who said that;

(27) Imported stoves are better when it comes to thermal efficiency and emission reduction because they use better designs, materials and proper engineering geometry, which remains a big challenge for local manufacturers. The only advantage locally made stoves have over imported ones is fuel saving….. local stoves have greater capacity to retain heat longer, which is a big advantage for our cooking behaviour. (Derrick Kiwana, Bioenergy Technician and Stove Tester)
The expert opinion in quote 27 above expresses that thermal efficiency is not sufficient to reduce fuel use in Uganda’s context. Thermal efficiency is the ratio of useful energy expended by the fuel to the cooking vessel, and the expended energy per unit time defines fire power which influences cooking time (CREEC, 2018). Therefore, the higher the fire power the shorter the cooking time. Although increasing thermal efficiency generally reduces fuel requirement for a given activity (Grieshop et al., 2011), the cooking behaviour in most parts of Uganda takes long time, which affects fuel use. A cooking activity in Uganda can last for as long as six hours, which necessitates having a stove that is both efficient and with capable of retaining heat longer in order to save fuel. Quote 26 therefore underscores the importance of matching stove attributes with cooking behaviour to influence stove adoption and use.

Through FGDs, it emerged that some users were able to acquire very efficient stoves such as biolite but were “disappointed” with their performance on meal preparation. One participant reported that a user upgrades to a superior stove to overcome all the challenges the inferior one presents, and therefore does not expect to deal with the similar or new challenges after acquiring a ‘superior’ stove. One FGD participant in Nalumunye reported that her daughter bought a biolite stove for her as a gift but she was not impressed with the fact that it uses wood and she also had to chop the wood into small pieces. She said she needs to walk a fairly long distance (2 1/5 km) to find a stall that sells wood (in towns wood markets are not as accessible as charcoal ones) and then has the extra task of chopping it. She further reported that she had to continue feeding the wood chamber with wood to keep her food hot until she served it, which meant that she used a lot of wood in a day. She gave this reason for purchasing an improved cookstove, which she uses regularly to meet her cooking needs. She only uses the biolite stove (Picture 4) for preparing breakfast and snacks, and then only when she gets someone to buy wood and chop it for her.
Another participant reported that the size of the biolite stove did not impress her because she kept worrying about the possibility of a big pot tipping off the stove. That she finds a local improved cookstove sturdier. One of the challenges that the improved cookstoves seek to address is the risk of fire burns associated with the baseline metallic stove and open fire place (Barnes et al., 2015), and learning that users feel the same threat with efficient stoves such as biolite alludes to innovation asymmetric to user needs.

According to Derrick Kiwana, a stove tester at CREEC, stoves like the biolite (Picture 4) are more thermally efficient and multipurpose (cooking, phone battery charging, lantern for lighting) hence providing more advantages to the user compared to locally manufactured stoves. The biolite stove’s multi-functionality was confirmed by users in the FGDs, however, their voices focused more on cooking experience than other benefits. This is possibly because the other benefits that a biolite stove provides such as phone charging and lighting at night are not a big challenge in urban areas because of the regular availability of electricity. There are imported household stoves that meet the specific needs of users such as the Jikokoa stove from Burn manufacturing.
company in Kenya but the cost is prohibitive to the majority of local users. The unit cost of a Jikokoa charcoal household stove is £31 while locally manufactured stoves for the same purpose range between £3 - £10 (picture 5).

The preceding narrations illuminate the importance of fitness for purpose as a driver of stove adoption and use. As explained in the FGDs, context matters: for example, urbanites have different stove needs to those in rural areas, because of the different sources of fuel users can easily access as well as availability of alternative sources of energy. Charcoal and briquette stoves are preferred in towns, especially for household use, because charcoal and more recently briquettes are the main sources of fuel in urban areas. This means that improved cookstove innovation need to contextually match the users’ needs and predominant fuel type to achieve wider acceptance. In order to realise the human health and environmental benefits associated with improved cookstoves, there has to be both extensive adoption of these technologies (Mitchell et al., 2020) and their intense and sustained use (Ruiz-Mercado et al., 2011). Although this study did not go into the details of interrogating the patterns and intensity of use of the different stove types on the market, findings from the FGDs allude to the possibility that there is a strong correlation between fitness for purpose and intensity and sustained use of the stove.
A systematic literature review by Vigolo et al. (2018) on the drivers and barriers to clean cooking tends to suggest that the reasons for not switching to improved cookstoves relate to reluctance or fear to try new technologies. However, evidence from users of the biolite stove in Uganda in the preceding paragraphs shows that actually users are willing to try new technologies but only abandon them when they do not meet the users’ needs and expectations. Based on the findings of this research therefore, I argue that bias against new technologies does not necessarily only happen before adoption (what I have termed pre-adoption bias) as Vigolo and his colleagues suggest but rather can develop post-adoption (what I have termed post-adoption bias), and the latter is what leads to a technology having limited use or being abandoned altogether as it happened with some biolite stove users in Uganda. We turn now to the technological frames of another group of stakeholders - the government and external actors.

7.3 Government Perception of Stove Innovation

Government agencies look at innovation in improved cook stoves differently from local manufacturers and users. To this category of actors, an improved cookstove innovation needs to meet specific, standardised, performance parameters, notably: thermal efficiency, emission reduction (particulate matter and carbon monoxide), safety and durability, and this follow from international cookstove standards. Stoves are graded according to their performances on these parameters. Uganda has a national standard that is largely in line with the international stove performance standard. Based on these performance criteria, locally manufactured stoves are categorised as low quality (largely falling between tier 0-2) compared to imported brands, the majority of which are tier 3 and 4. Local manufacturers argued that this is inappropriate criteria for their innovation because the locally manufactured stove aims to solve specific end users’ needs, notably: fuel saving, fitness for purpose and
cost. Yet, fuel saving and fitness for purpose are not even among the national standard performance indicators.

Eight out of the ten entrepreneurs interviewed complained about the unfairness of the testing parameters to their innovation focus and user preferences. Respondents expressed that having government and other actors judge their stove performance based on elements like emission reduction, which are only a component of the innovation, as unfair. Indeed, as one of the local manufacturers contested, local stove producers view this criterion as unfair to them and out of touch with the reality of stove users. A local stove manufacturer commented that;

\[(28) \text{I don’t understand these performance standards they set for us. What is important for users is to be able to save as much fuel as possible without having to change their cooking habits. Stove users never ask us for stoves that reduce emissions, yet government and GIZ base on this criterion to criticise our products. Our products meet the needs of the users. I would rather they set for us standards that are synchronised with user needs not their \{government and funders\’\} needs. (Kasirye, Proprietor, FOWE)}\]

Comment (28) above demonstrates that there is a mismatch between what government and development partners perceive as improved cookstove innovation on one hand and what local manufacturers’ understand. The technological frames constructed by both local manufacturers and users view improved cookstove innovation mainly in terms of fuel saving while other actors especially the dominant financiers view it in terms of emission reduction. These divergent perceptions present a conflict over what innovation means for improved cookstoves in Uganda.

Secondly, the end user is interested in different performance parameters, fuel saving being a priority. So, who will pay extra for emission reduction when stove
affordability also remains key to stove acquisition? The better the performance and the more performance parameters there are to fulfil, the higher the stove’s cost. Local manufactures are therefore caught up in a complex situation where they are expected to meet the divergent needs of different actors: those of stove users, which they understand from their applied research, and the overlapping governmental and funders’ standards, and yet they have to keep the stoves reasonably priced to remain competitive in the market.

Interestingly, when the question of emissions was brought up during FGDs for stove users, participants perceived emissions as of little priority to them compared to pressing needs like fuel and time saving, safety and fitness for purpose. One participant in Nalumunye posed a question in reference to emissions from cooking:

(29) But where are all these bad gases that people keep talking about? I hear they are dangerous, they kill people………if this were true, majority of the people in Uganda would be dead by now. I hate smoke though because it irritates my eyes and causes runny nose. (FGD participant, Nalumunye)

Perceptions like that one in quote 29 were recorded in all the four FGDs. Perceiving emissions as normal signifies that the impact of emissions on human health (direct emissions) is not well appreciated among stove users. This revelation validates Barnes et al.’s (2015) warning that the hegemonic appeals of ‘do it because it is good for you’ rarely work. These results show that users are only able to prioritise the attributes they have framed as important to solve their constructed problem within their specific context. Secondly, such views can suggest that acceleration of adoption of improved cookstoves cannot be driven by emission reduction campaigns primarily, but largely by fuel- and time-saving campaigns because it is the end users’ overriding need. Earlier studies by Thurber et al. (2014) in India, Martin et al. (2013) in Uganda and Hanna et al. (2016) in India established that behavioural campaigns that emphasised
smoke reduction and health-related benefits did not significantly influence willingness and decisions to adopt stoves.

7.4 External Actors’ Perception of Stove Innovation

External actors that include improved cookstove financiers and promoters perceive improved cookstoves innovations in terms of national and international standardised parameters. Through carbon finance, stove standardisation to meet the international and national expected standards for carbon credits was enforced, albeit with minimal success because implementation challenges as explained in section 5.2.

7.5 Conclusion

From these findings, I am convinced that emission considerations and persuasions alone as prioritised by the government and external dominant actors are not sufficient motivation for users to adopt the improved cookstove technologies. Therefore, marketing campaigns largely focused on emission reduction capabilities of the stoves are unlikely to be sufficient. In Uganda, stove users value fuel and time savings, fitness for purpose, safety, durability and cost beyond thermal efficiency and emission reduction. These divergent technological frames are a recipe for tension and confusion in the system, which derails growth of the TIS. Informal institutions such as user needs and expectations as well as local manufacturers’ understanding of innovation are strong. The question of how informal structures such as for example adjusting fire power can be blended with scientific knowledge to generate more appropriate stoves that fit the cooking behaviour of Ugandan users remains a pertinent one. These results further suggest that networks have a big role to play in ensuring that there is effective blending of informal structures with formal ones in system functions such as knowledge development and diffusion, guidance of the search, legitimacy creation to generate appropriate technologies.
The preceding chapters on structuration and technological frames usher us into chapter eight, which examines how the different structural elements are fulfilling the innovation system functions - the improved cookstove functional pattern.
CHAPTER EIGHT: THE FUNCTIONAL PATTERN OF THE IMPROVED COOKSTOVE INNOVATION SYSTEM IN UGANDA

Improved cookstove making is not just a random assemblage of different materials, it is a science. (Key Informant, ILF)

8.0 Introduction

After describing the structural composition and characteristics of the improved cookstoves innovation system in chapters five and six, and the different technological frames that dominate the technological field in chapter seven, this chapter goes into the specifics of analysing what the structural elements are doing to develop, diffuse and adopt the technology. This chapter is not normative in nature; therefore, I am not assessing how well the functions are fulfilled but rather analysing the functional pattern, how each function is being fulfilled in the system.

The analysis in this chapter brings out how the largely labour-intensive, unsystematic production processes compromise critical issues of quality control, optimum production, and safety of artisans. Expanding on the results in chapter five, I demonstrate how external catalysts strongly sway and drive key system processes, and the consequences this external influence has had on the system’s growth. I also reveal how the R&D financing schemes are largely not adapted to the needs of the system and how this creates negative feedback. As mentioned in section 1.7, as I explored the functional pattern, I also identified some potential strengths and weaknesses in the improved cookstove TIS, which are discussed in section 8.2.

8.1 Functional Pattern of the Improved Cookstove TIS

By examining TIS functions as indicators of system performance, this section analyses the activities implemented to fulfil the seven key system processes.
8.1.1 F1: Entrepreneurial Activities

This function was analysed by mapping entrepreneurs and what they do, and at what scale. The aim is to understand the nature of industrial actors in the system, their level of production and the number of experiments with cookstove innovations. Building on the discussion of actors in Chapter Five, the analysis of this key process gives insight into the vitality of innovativeness in the improved cookstove system.

Stove Typology and Quality

This section discusses the typology of stoves produced and their quality. A diversity of carbonised and uncarbonised improved stoves covering different users’ needs are produced in Uganda. Carbonised stoves use fuel that has undergone a chemical reaction, for example charcoal or briquettes from charcoal dust, whereas uncarbonised stoves use fuel from raw bioenergy for example firewood, briquettes from sawdust, ground nut husks and maize cobs.

Although standardisation of stove size was not uniform across all the cases, from studying and observing Ugastove’s systematic production process as well as interviewing and observing other manufacturers such as BM, FOWE, and Masupa, I learned that stoves are produced in different sizes, and shapes for different purposes. For household use, charcoal, wood fuelled and dual stoves are produced and these are made in three sizes (1-3), size being determined by the dimensions of the pot it can hold and number of people it can cook for (i.e., family size). Size 4-8 are big stoves that are used by small businesses like kindergartens and restaurants. It was observed and confirmed in interviews that household stoves are portable whether they are single fuel or dual. This is because there are many families in both urban and rural areas that have no kitchens, and as a result they only improvise and cook on verandas or in similar spaces in the home. A portable household stove is therefore convenient, and increases mobility and functionality for users.
Another category of stoves produced in Uganda is institutional stoves. These are mainly wood-fuelled and are mostly fixed, although some portable ones are produced. Institutional stoves are used in organisations that cook large amounts of food at one time, for example prisons, hospitals, schools, food businesses and refugee camps. Other innovations like ovens, barbeque stoves, grills, and incinerators are constructed. Table 19 shows the categorisation of improved stove technologies in Uganda.

**Table 19: Improved Cookstove Categorisation**

<table>
<thead>
<tr>
<th>Stove size</th>
<th>Capacity</th>
<th>Users</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size 1 (small)</td>
<td>Cooks for a family of up to 5 people</td>
<td>Household</td>
<td>Portable</td>
</tr>
<tr>
<td>Size 2 (medium)</td>
<td>Cooks for a family of 11 people</td>
<td>Household</td>
<td>Portable and dual</td>
</tr>
<tr>
<td>Size 3 (large)</td>
<td>Cooks for a family of up to 16 people</td>
<td>Household</td>
<td>Portable and dual</td>
</tr>
<tr>
<td>Sizes 4 - 8</td>
<td>Commercial use</td>
<td>Kindergartens, Restaurants</td>
<td>Portable</td>
</tr>
<tr>
<td>Institutional stoves (wood)</td>
<td>Boils between 30 - 500 litres</td>
<td>Schools, police and army barracks</td>
<td>Portable and fixed</td>
</tr>
<tr>
<td>Gasifier stoves using wood, maize cobs, saw dust, rice husks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other related technologies</td>
<td>Ovens, Grills, Barbeque stoves</td>
<td>Small scale enterprises</td>
<td>Portable and fixed</td>
</tr>
</tbody>
</table>

**Source: Interviews and observation**

Table 19 shows the typology of stoves produced in Uganda. Stove use ranges from households, to institutions and small businesses. However as discussed in the previous chapter, locally made stoves grapple with quality challenges especially on emission reduction.
Stoves are produced for both household and institutional use and consume different types of fuel including wood, charcoal and briquettes. Other related innovations produced include grills, ovens and fuels (briquettes and gas). Both household and institutional stoves are made in a variety of sizes to cater for the differing user needs. All the firm cases studied categorised stoves according to size and fuel type used. The dimensions of household stoves are standardised by family size, and each size has a corresponding liner mould. Institutional stoves on the other hand are customised according to institutional needs. The size is standardised by height and diameter of the saucepans used.

There were, however, observable differences in the actual dimensions of what different firms categorise as size two or three. For example, a size two from Ugastove was the same as size twos from BM, SESSA and FOWE, but slightly bigger than the same size stove made by Masupa. AES’ size two was also bigger and heavier (15kgs) than Ugastove (12kgs). This discrepancy stems from the lack of industry-wide standards for different sizes of liner moulds. This means that consumers can be misled by size categorisation as a basis for determining which stove to buy to meet their household needs.

Stove size two is the most popular on the market because it caters to the cooking needs of an average household in the city and towns. Stoves are made portable or fixed, some use only charcoal or wood and some are dual (both charcoal and wood or briquettes). Portability is contested though, because one misgiving about these stoves is that they are heavy. On average, a size two stove weighs 13kgs, which makes moving it a challenge.

An innovation system cannot exist without entrepreneurs because they play a central role of turning the potential of new knowledge, networks, and markets into concrete actions to generate business opportunities and meet societal needs (UNCTAD 2018;
The majority of improved cookstove entrepreneurs in Uganda are new entrants who took advantage of the business opportunity in the clean cooking market, which was mainly created by climate change financing programmes like CDM, REDD+, and carbon finance (cf. Chapter six). Availability of funding attracted entry of new firms in the technological field but some entrants were ill-equipped to benefit the system as would be expected. New entrants compound the problem of stove quality, and yet the capabilities of entrepreneurs that dominate the sector determine the pace and quality of the innovation generation sub-system (Wieczorek et al., 2012).

Based on in depth interview responses from UNREEA, BEETA, Ugastove, GIZ and Ministry of Energy and Mineral Development, in the strictest sense, incumbency in the improved cookstove sector relates to Ugastove as the first and sole producer of improved cookstoves from late 1980’s to mid-2000s. This research however, included all the firms that have been in existence for more than 5 years as incumbents. This is because some of these firms, such as SESSA, AES and FOWE were born out of Ugastove, while a majority of the others imitated Ugastove designs.

The improved cookstove innovation development in Uganda is driven by market demand, coupled with systemic catalysts like low entry costs, voluntary adherence to standards and carbon finance. What was eminent from the eight local proprietors of some of the biggest stove producing firms that were interviewed (AES, BM, FOWE, Josa, Masupa, SESSA, Humura Investments and Ugastove), was that stove production is mainly a response to the need for fuel saving innovations that are not complicated to operate, that do not significantly alter users’ cooking habits and are affordable. The baseline for comparison on efficiency, sophistication, compatibility and affordability is the traditional metallic stove or traditional three stone fire place.
Improved cookstoves manufactured by the different firms have no significant differences in quality or design. With the exception of Ugastove, the majority of stoves produced by local firms are between tier 0-2 and the designs are more or less the same – round, square, or rectangular shapes. The round shape is a replica of the traditional metallic stove with the added innovation of better insulation by clay liners and firebox and skilled engineering geometry. Stove production is still at small scale in all the local enterprises mainly because of limited financial capital to expand production and improve or introduce machinery.

In order to diversify stove designs and improve stove quality, Ugastove partnered with Design Without Borders in 2015 to come up with new stove designs. From this partnership, the Flame charcoal stove was made. This partnership was funded by EEP Africa and the grant’s main aim to design an efficient stove and automate its production process.

It also emerged that performance of a good quality stove can be compromised by the quality of fuel used. Firms mainly produce wood and charcoal stoves, though stoves that use briquettes have also started coming on the market. The higher the fuel’s moisture content, the lower the efficiency (both combustion and thermal) and the higher the emissions (GACC, 2017). In order to achieve the desired stove performance, the quality of fuel used is as important as the quality of the stove. Therefore, focusing only on optimising the engineering geometry and insulation of the cookstoves will not deliver grand results, especially on climate change mitigation. Having discussed the issues around stove typology and quality, we now turn to how these stoves are actually produced.

8.1.1.1 Improved Cookstove Making Process

Through direct observation of stove production process at BM, Ugastove, Fowe, AES and Masupa, I established that firms utilise more or less similar processes, except that
Ugastove has a documented, standardized process while others don’t. The other firms’ unstandardized processes directly affect product quality because there is limited room for quality control in the jumbled activity flows. From observing the different firms’ production systems as well as interviewing operators, it was constructed that the typical local household charcoal improved cookstove production goes through a process as illustrated in Figure 9 below;

Figure 9: The Improved Cookstove Value Chain in Uganda

Source: Author’s Illustration

Figure 9 shows that the improved cookstove production process has six stages, most of which are manual. These stages include; metal and clay assembly, metal cladding, clay moulding and liner making, liner baking, assembling and painting. The second main process, transport and marketing, works on retailing and distribution. Finally comes use of the stoves. Clay moulding/liner making and baking are the most critical processes in stove production because liners are a key determinant of efficiency and emission reduction.

a) Metal Cladding

This process involves fabrication of different metallic parts of the stoves including the frames, feet, handles, collar, pot stand, and door. Ugastove has mechanised this entire process for its size two round stove. Other firms like BM, FOWE, SESSA AES have mechanised some parts of the process while others remain manual. The quality of
materials used in this process varies significantly across different firms. The main determinants of material used are cost and availability. Some incumbent firms and new entrants use waste steel with varied levels of quality while others import plates to make the stove body. The quality of waste material differs depending on where it is generated from: Waste steel from steel mills is of better quality compared to waste from used products, and copycats use the latter. The quality and thickness of steel used directly affects the quality of the stove, especially its insulation and durability.

Sedighi and Salarian (2017) suggest that using steel in improved stove production is advantageous because it is conductive and quick to heat, low maintenance, sturdy and available. Perhaps what Sedighi and Salarian did not mention is that the quality of steel used largely determines what benefits can accrue from stove use. From my findings, poor quality steel, especially from waste material, was highly prone to rusting and compromised stove durability. Pictures 6, 7 and 8 show manual and automated systems for producing the different stove spare parts.
In addition to showing the activities taking place, pictures 6 and 7 show the health and safety risks artisans encounter in their work. Discussions with artisans revealed that some health and safety challenges associated with their work include back and chest pain, cuts, bruises, and as the pictures show, workers have no personal protective equipment to shield them from these risks. On the other hand, picture 8 shows a safer working environment.
Ugastove has a standardized workflow of the cladding process for each of the different stove components (Picture 9). Other firms like FOWE, BM, AES followed processes that are neither documented nor systematic. This is likely to affect the quality of the products produced since the casual workers who constitute the majority of employees in these firms do not have clear guidelines on what the end product should look like. Picture 9 shows a displayed workflow and quality control points and mechanisms for the body and collar stove components at Ugastove.

The Ugastove process flow chart for cladding of the stove body and collar in Picture 9 specifies, for example, the thickness of the rolled steel of each component with cold rolled steel of 1.2mm for the body and cold rolled steel of 0.8mm for the collar. It also specifies the time and how many workers each activity in the process flow chart takes. Points of quality control are well specified, including the control measures. These quality-controlled production procedures could be one explanation for why Ugastove produces stoves superior to other local manufacturers. On the other hand, other Ugandan producers relied on the memory and knowhow of the artisans in charge of
the different activities to control the quality of the processes. Other suppliers like Potential Energy import already produced stove components and assemble them in Uganda.

In automated production, each stove component has specific moulds that are used in its production. A hydraulic machine is used to cut the different shapes and sizes of the required components using the moulds. The body is produced with a circle cutter. Ugastove imported a CNC machine that makes a different stove shape to produce their Flame Stove (Picture 10), but it has not been used since its importation in 2016 because of lack of capacity to operate it. According to Ugastove, with mechanised production ten people can make over 1000 stove spare parts in a day while with manual production, 20 people produce 200 spare parts a day.

![Ugastove Flame stove](image)

**Picture 10: Ugastove Flame stove**

b) **Moulding**

This is the ceramic part of stove production and its starts with assembling clay and other materials like mica, sawdust, vermiculite and mixing them in the extruder machine. This process yields a mixture used to mould a liner. With the exception of Potential Energy’s BDS stove, which has no liner, all other firms confirmed that liner
moulding is still manual, with only clay mixing being mechanised. Firms like Masupa still retain an entirely manual liner moulding process, including clay mixing. A human being uses his legs, an iron rod and a spade to mix clay with other insulation materials. The moulding process is the most important stage for achieving the desired stove performance. A respondent from Ugastove emphasised the ceramics’ centrality:

(31) The ceramic part is the heart of the stove. If the right materials and proportions are not used, stove performance will be compromised. (Rehma Nakyazze, Ugastove)

The liner is the major components for insulation, which determines thermal efficiency and fuel saving. Therefore, getting the right materials, in appropriate portions and well mixed is very paramount to achieve a well performing stove. The quality of clay used and the quality and amount of minerals added to it are key determinants of a well-insulating liner. Ugastove works with the Ceramic Department at the Uganda Industrial Research Institute to scientifically test the stove liner clay for quality and fitness for purpose. Quality of clay also determines the ratio of minerals mixed in. BM, Masupa, JOSA, SESSA and FOWE on the other hand reported that they test clay quality and fitness for purpose using indigenous knowledge. This mechanism tests clay through observation and touching/feeling it, concluding that the goodness of clay is determined by its stickiness: the stickier, the better. This mechanism further confirms the strong influence of informal structures in the innovation process as already discussed in Chapter Seven. Regardless of the unstandardised processes however, locally manufactured stoves perform well on fuel saving. CREEC estimates that on average locally manufactured carbonised stoves save 40% of fuel relative to baseline while un carbonised ones save 50%.

Clay mixing was mechanised in 9 out of 10 firms studied, but liner moulding was manual in all cases except where no liners were needed, as with Potential Energy’s BDS stove. GIZ financed procurement of clay mixers for Ugastove, BM, Sessa, and
AES. Liners are sheltered to dry, taking between three to six weeks depending on thickness. Liner thickness is not standardised although width is through the use of liner moulds for the different stove models. Lack of standardisation on liner thickness also affects stove performance.

According to CREEC (2018) liners for Ugandan stoves are made very thick, larger than 2mm that is recommended for efficient improved cookstoves, which affects stove performance. Picture 11 shows the liner moulds that Ugastove uses for the different stove sizes and picture 12 shows a rack that is used to dry them. The ceramic parts of the stoves whose main purpose is to ensure insulation and durability make them heavy and as pointed out earlier, this affects their portability. It however emerged that using lighter materials like glass fibre increases the unit cost of the stove, eroding the affordability that buyers look for in stoves. A size two ceramic insulated stove costs between UGX 20,000 – 30,000 (£4 - 6) but with lighter insulation material, it could cost £10 or more.

Picture 11: Liner Moulds for different stove sizes

Picture 12: Liner drying rack
Furthermore, stove weight is not a standardised parameter according to UNBS. Yet, from FGDs, weight emerged as one of the main challenges users face with improved cookstoves. Most families in the city and towns cook on improved stoves on the veranda, shade or porch of the house, since detached kitchens are hardly there and those users who have kitchens inside the house prefer not to use the stoves from inside the kitchen because of the smoke especially when lighting the stove. Having to manually lift a 13 -15 kilogram stove daily, transferring it from the house to the veranda and back emerged as a disincentive for users. Stove users also raised the issue of improved cookstoves’ sluggish start. The main insulation material for local stoves is clay. And according the CREEC, ceramic liners of local stoves are thicker than recommended (2mm), which exacerbates the problem. As the liner is heated first before heat is transmitted to the cooking device, improved cookstoves are slower to cook than the traditional metallic ones. However, according to manufacturers, the stoves are only slow at the start but cook faster once the liner is heated up.

Like any product, stoves have to be used with care. This becomes paramount because the main components of cookstove construction and consequent determinants of their performance are made of clay. A well-made liner can last between 3 – 5 years according to Mubiru (BM), but this durability is not always achieved due to improper use. Users complain of fireboxes collapsing and liners cracking after a short period of use. Such complaints can be interpreted as issues of poor-quality stoves. However, the way users use the stoves contributes a lot to such problems as emphasized by a key informant;

(32) Stove performance and durability are hugely affected by improper use. Some users heap the stoves with charcoal beyond [the] required level, which affects efficiency. Others use big sticks or even stones to break the bulk charcoal into smaller pieces while already on the stove. Others heap the stove up to the collar and forcefully press the cooking pot down to break and condense the charcoal so that the pot can balance on the
The revelation in extract 32 shows that there are difficulties as far as proper stove use is concerned. Yet, there are no user guides in place to show the users how the stoves work, the dos and don’ts when operating them. In addition to engineering geometry and insulation, stove performance largely depends upon proper use, yet it is not given as much attention. Without user guidance from the manufacturers, the burden of guessing how to properly use the stove is left to the consumer, and they are in the end blamed for using the stove improperly. For example, according to the improved cookstove standard, the charcoal chamber is supposed to be \( \frac{3}{4} \) filled not full or heaped. But do all users know what \( \frac{3}{4} \) of charcoal in a charcoal chamber of any given stove model should look like? Dry liners are then baked in a kiln as explained in the next section.

c) Firing/Baking

Baking of liners takes place in a kiln (Picture 14). Kiln construction is one of the most expensive investments in the improved cookstove business. GIZ financed construction of kilns for Ugastove, BM, SESSA and FOWE. Kilns use wood to bake the liners. Liners (Picture 13) are baked for between 18 - 22 hours, depending on wood quality, at 900\(^\circ\) C. Liners are stocked in bulk because of their lengthy production process. Although its outside the scope of this research, it is inevitable to ponder on the net benefit of improved cookstoves in reducing deforestation and consequently mitigating climate change, when wood is used in producing stoves (liner baking) and wood and charcoal are the main fuels used in the stoves? According to Hajji Mubiru (BM Energy), a 7.5 tonne truck of wood bakes 3,000 liners and according to the Ministry of Energy and Mineral Development estimates 300,000 – 400,000 stoves are produced annually in Uganda. Baking liners for these stoves requires between 100-130 trucks of wood translating into 750 -975 tonnes of wood a year. How much forest
cover loss does this translate into? Doesn’t this make the improved cookstove’s grand promises of environmental sustainability an illusion?

In order to safeguard the quality of stoves and protect the market, organisations like the International Lifeline Fund (ILF) in addition to being stove producers, produce liners, which they sell to stove manufacturers. ILF is however based in northern Uganda, yet proliferation of stove firms is mainly in Kampala city and neighbouring towns. Replication of the ILF system of liner production by expert firms in Kampala city that can be sold to new entrants and other firms can improve the quality of stoves and gradually build specialisations in the cookstove value chain.

With the exception of clay mixing, all other liner making processes such as moulding, assembling and baking are manual. In all eight local stove firms, liner moulding was mostly done by women.

**Assembly**

This is the process of attaching the different parts/spares on the frame (pictures 15 and 16) and inserting the liners and cutting the firebox. This process was manual for 9 out of the 10 cases, and between 120 – 200 stoves are produced a day.
Figure 10 and Table 19 show the different stove components and their functions.

Figure 10: Components of an Improved Charcoal Stove
Table 20: Stove Components and their Functions

<table>
<thead>
<tr>
<th>Component</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liner</td>
<td>Insulation, heat retention</td>
</tr>
<tr>
<td>Handle</td>
<td>For movability</td>
</tr>
<tr>
<td>Collar</td>
<td>To protect the liner</td>
</tr>
<tr>
<td>Pot Stand</td>
<td>To support the cooking device on the stove at an appropriate height</td>
</tr>
<tr>
<td>Body</td>
<td>To protect the firebox, liner and offering extra layer of insulation</td>
</tr>
<tr>
<td>Door</td>
<td>To allow air flow/circulation</td>
</tr>
<tr>
<td>Grate</td>
<td>To allow air circulation, repository for ash from the burning charcoal,</td>
</tr>
<tr>
<td>Foot</td>
<td>To support the stove</td>
</tr>
<tr>
<td>Firebox</td>
<td>To reduce heat escape</td>
</tr>
<tr>
<td>Charcoal Chamber</td>
<td>Loading charcoal/fuel</td>
</tr>
</tbody>
</table>

Source: Interviews and observation

Figure 10 and Table 20 show the key components of the stove. Indeed, as a key informant observed, “stove making is not just an assemblage of different parts together, it’s a science. Geometric parameters have to designed in such a way that allows the stove to meet performance expectations. Air flow and circulation, and heat regulation are part of the improved cookstove engineering geometry. Research (e.g., Memon et al., 2020) tells us that cookstove insulation is very important to improve performance, as it reduces heat loss through the heated walls. Sedighi and Salarian (2017) state that as the combustion chamber’s diameter determines the fuel burning rate, efficiency decreases when the height of chamber increases. Memon et al. (2020) further report that a grate can boost the efficiency and decrease pollutants by improving fuel-air mixing and that the size of the grate influences the fuel burning rate. This means that getting the improved cookstove science right is a prerequisite for generating high quality stoves. After assembling all spares together into a stove, the last stage is painting.
d) Painting

The last process in stove production is branding – painting (picture 17). Stove colour is the main symbol of identity and legitimacy among stove entrepreneurs, and indeed incumbent stove manufacturers are identified by the colour of their stoves. Leaving identity and brand legitimacy mainly to colour of paint has however been prone to abuse by competitors and copycats. Moreover, these colours are not registered or patented, therefore the firms do not own them in any actual or legal sense. This has encouraged copycats to continue producing low quality stoves and paint them with the big brand’s colour to confuse the unsuspecting consumers. Stove colour is also used as a weapon to fight competition among stove producers. SESSA claimed that its competitors used the firm’s colour of paint on stove factory rejects and poor quality stoves and distributed them in the market to purposely taint the firm’s brand.

![Picture 17: Stove colour spraying at BM Stoves](image)
In the face of increasing entry of new firms in the industry and existence of similar products, competition can only be expected to increase. Schallehn et al. (2014) offer that the constant growth of the number of brands, similar product offerings and imitation leads to high levels of brand similarity and increasing competition. The challenge in Uganda is that stove users remain largely unprotected from counterfeits and poor-quality stoves resulting from poorly developed branding systems. These challenges are worsened by the limited availability of and access to information and its poor communication to users. Having many counterfeits alongside genuine brands makes it difficult for users to obtain independent information, and to articulate their experiences and opinions about the products to both the manufacturers and the wider public. The issue of stove paint colour and the confusion surrounding it was prominent during FGDs.

It emerged that stove quality is associated with colour. Consumers know the colours of their preferred stove brands and these are the basis for recommendation to peers and family. Beyond the colour, users cannot differentiate between stoves from different firms since the sizes and shapes are largely the same. Copycats exploit the information gap to put substandard stoves on the market, which they paint with big brand colours. In one focus group discussion, a respondent shared this experience:

(33) I bought a maroon stove, which I thought was a BM stove because my neighbour has one and it serves her well on reducing charcoal use. I bought it at [UGX] 20,000 (≈£4) from a truck that was vending them. It took long to light and charcoal was not burning well all through the entire cooking period. It was smoky too. I had to discontinue using it. It might have been a fake one. (FGD Participant Nalumunye)

Quote 33 above suggests a case of a BM stove counterfeit, which the user could not detect at the time of buying the stove. The expression above shows that counterfeits cause customer dissatisfaction and ruin the reputation of genuine brands. Schallehn
et al., (ibd p.192) suggests that firms need to respond to the challenges of growing brand parity and competition by increasing communication efforts. Such communications can tell or show consumers how and why a product is used, where and when. Consumers can also learn about who makes the product and what the company and brand stand for (Keller, 2009).

It also emerged that, some firms produce stoves of more than one colour. For example, SESSA produces stoves in green, orange and gold with a black collar. It became apparent from the FGDs that this makes decision-making difficult for consumers on what choice of brand to go for based only on colour, yet some brands come in more than one colours and so do counterfeits. With limited information from the manufacturers, the cookstove market remains a complicated environment for consumers to navigate as revealed by the user in quotation 33 above. As observed by Keller (2009, p. 140), effective communication should succeed a strong brand in order to reap its benefits. This means that although product communication is an urgent need for stove producers in Uganda, building strong, authentic brands is even more urgent.

8.1.1.2 Scale of Production and Distribution
Improved cookstove production is at small to medium scale, with the majority of firms producing between 1,000 – 5,000 stoves a month. Ugastove is the largest and oldest improved cookstove business in the country, whose production stands at slightly over 5,000 stoves a month, its production processes are close to being fully mechanised, and with more diverse distribution systems. Figures include both household and institutional stoves for all cases. Stoves are largely produced for the local market and the level of production is insufficient to meet demand. The Ministry of Energy and Mineral Development estimates that on average a total 600,000 household stoves are needed a year and over 150,000 institutional stoves, yet between 300,000 – 400,000 stoves are currently produced. There was no authoritative documentation of
production level and the market’s extent apart from estimates given by a key informant at the Ministry of Energy and Mineral Development.

Ugastove exports stoves beyond the East African region to South Africa. It secured a first order in 2018 of 1,000 size 2 stoves and 50 size 3 charcoal stoves from Char, a South African briquette making company. Other firms like FOWE export to neighbouring countries such as Tanzania and Rwanda. With prospects of market expansion and partnerships beyond Uganda’s borders, putting in place mechanisms for quality and standards control, tax incentives and subsidies to boost production become critical. This need corresponds with system function 4 – Guidance of the search.

With the exception of Ugastove, which focuses on production and building distribution partnerships, the system is generally designed in such a way that individual firms perform all activities from product design, production of different stove components, painting and final assembly to delivery to the end user. Therefore, the value chain is not well developed. Ugastove is the only firm that does not deal with users directly; it operates a distribution network with companies like Eventure, Simoshi and Save Energy in addition to its own distribution outlets. Other firms like FOWE, SESSA opened up distribution points in different suburbs of Kampala city and neighbouring towns to increase accessibility and visibility of their products. Others like BM and AES distribute to retailers such as supermarkets, hardware shops, petrol stations as well as selling in different local markets using trucks (Picture 18).
The production process shows that most of the firms still grapple with quality control at the different stages of stove production because of lack of systematic production processes. This is exacerbated by extensive use of manual means of production, which are also associated with health issues like chest and back pain, and other accidents like cuts. Each individual stage of product development has sub-processes that have to be followed to ensure quality. The value chain is not well developed because most of the firms run all the processes more or less independently, which presents difficulties to build and expand knowledge bases and expertise. For all these reasons, locally manufactured stoves are largely classified as low quality by national standards and testing centres. Production processes are largely labour intensive with barely systematic and standardised procedures in most of the entrepreneurial activities. Stove designs are more or less the same across the industry with ceramics as the main insulation material. This leads us into examining the existing nature R&D in the innovation system.
8.1.2 F2: Knowledge Development

Hekkert et al. (2007) state that knowledge development is at the innovation process’ heart. I mapped the investments in research and development, including experiments that have occurred in the last ten years. Investment in R&D in the improved cookstove innovation system has been mainly spearheaded by GIZ and a host of other development agencies such as SNV.

In Uganda learning takes place mainly through informal mechanisms of learning by doing and interacting with users and distributors (cf. Section 6.5). Indeed, UNCTAD (2018) acknowledges that technological learning is not limited to formal mechanisms of research and development alone but takes other informal channels as is the case with Uganda’s improved cookstove entrepreneurs. Relying on informal mechanisms of learning and rudimentary experimentation however, presents systemic challenges for the innovation system, as it hinders development of the supportive knowledge base that is needed to foster learning at different levels and creating and strengthening firms.

Technology for production of the innovation is needed to improve the rudimentary means of production currently employed by majority of entrepreneurs. Only Ugastove is moving towards an entirely mechanised production process. The rest of the firms heavily rely on labour-intensive, basic ways to produce and assemble the different stove parts. Dependence on labour-intensive production techniques is largely a result of the limited financial resources that entrepreneurs have at their disposal, especially at start-up. All the enterprises that were studied in this research were started from personal savings.

Although Hekkert et al. (2007) argue that the entrepreneurs’ risky experiments are necessary to cope with the uncertainties that emerge from the new technological knowledge, applications and markets, Ugandan entrepreneurs are different. The risky
experiments are not necessarily a result of lack of technical knowledge nor part of the normal new technology learning curve, but rather are a result of entrepreneurs’ lack of requisite means and support to effectively go through the technology incubation process that can help minimise these risks. Each firm had their own way of developing prototypes, testing them and bringing products to the market. The key determinant in all these processes is cost-effectiveness and affordability to employ the necessary technical and financial resources. Therefore, informal learning or risky experimentation is not the challenge per se, but rather the environment in which it is done and the circumstances that dictate it.

No firm among the case studies had a patented product although some of them had stove prototypes and fuels that they innovated. Examples include the Flame Stove for Ugastove, and the Blue stove and Blue wave fuel (gas) for AES. The entrepreneurs did not know that the law on property rights and patents existed and what the process is to have innovations patented. Uganda signed the World Intellectual Property Organization’s Patent Law Treaty in 2000, but has not yet ratified it. The Uganda Registration Services Bureau is the agency responsible for the registration and protection of intellectual property and patents. Uganda enacted intellectual property and patent protection laws like the Trademarks Act (2010) and the Industrial Property Act (2014), which are relevant to innovations from small and medium enterprises like those I studied. There is however very limited awareness about their existence and benefits to stove manufacturers.

Researchers have a role to play in strengthening the industrial support system for improved cookstoves. They can provide various services in support of the different sub-systems of the innovation system like product testing, research and development and demonstration processes (UNCTAD 2018). Research actors in the cookstove innovation system include public institutes, NGOs and international organisations like GIZ, WWF and SNV. Local research actors like CREEC offer support to improved
cookstove development and promotion by offering testing services and research. The costs of testing are prohibitive and do not bring value to the entrepreneurs because no quality mark is given, but only a testing certificate. CREEC charges £853 for each stove model tested. As a test validity and quality control measure, stove tests are repeated three times before a report is issued. UNBS offers affordable testing services but for not emissions. Only CREEC has the laboratory and equipment to do so.

Research is not driven by the industry’s needs but rather by the funding priorities. For example, research interest is shifting to solar energy and LPG, leaving cookstoves at the periphery of funding and research portfolios of the different actors. This will affect the efforts to build a local knowledge base in the cookstove industry. There are a number of research outputs on clean cooking in general and a few on improved cookstoves. There are studies on consumer acceptance and willingness to pay, the national charcoal survey, a market intelligence study. UNACC and development agencies such as SNV have produced a few reports on behavioural change mechanisms for improved cookstoves, but research on user needs, actual benefits of improved cookstoves on the environment and impact evaluations on improved cookstove performance is lacking. We move now on to how the knowledge generated is shared and how learning takes places within the innovation system.

8.1.3 F3. Knowledge Exchange

Knowledge diffusion builds and strengthens networks and facilitates learning. This system function was analysed by mapping the workshops and conferences specifically on improved cookstoves that have happened in the last 10 years, and building on Chapter six, mapping network growth and activities over time. Other forms of communication, learning and information sharing are also analysed.

Workshops and conferences related to improved cookstoves are mainly organised by the Ministry of Energy and Mineral Development, mainly with funding from GIZ.
Energy Week is a flagship energy platform spearheaded by this Ministry that brings together more than 100 players engaged in clean energy promotion. The annual event, which started in 2005 is highlighted by exhibitions of the different types of stoves and other efficient energy related products, symposiums and dialogues on topical issues on efficient energy use. It also provides an avenue for creating awareness about energy conservation and efficient utilisation of energy resources. It has also become a platform where civil society organisations, private companies, government authorities, researchers and development partners interact and exchange ideas on the important issues pertaining to energy production and consumption. The event also provides an opportunity learning, marketing and selling of products by participating companies. Four local manufacturers who commented about this event said that their participation is motivated by mainly the exhibition and the sales that accrue from it than other activities such as symposiums and dialogues. A respondent from UNREEA reported that the Energy Week is increasingly becoming a ritual with no expected deliverables or engagements beyond the event’s week.

GIZ organised a clean cooking summit in 2018 (picture 19), the first of its kind. This summit, which I attended, brought together improved cookstove manufacturers in the country and similar players from other East African countries such as Kenya. Its chief aim was to deliberate on the best practices for development and promotion of clean cooking and for the summit run the first clean cooking award. The award, which focused on innovative improved cookstove distribution strategies was won by AVSI, an international NGO. Another avenue for knowledge sharing is social media, specifically WhatsApp, which is discussed in Section 6.5.
From these results, it can be seen that the key process on knowledge exchange is strongly driven by exogenous actors. Although the energy week is a government initiative, we see that funding for this flagship activity is provided by GIZ. Further, the establishment of networks and their activity portfolio (Chapter six) revealed a strong influence of exogenous actors. The first clean cooking summit was also financed by development agencies. This reveals that fulfilment of some of the key processes is almost entirely left to external players, raising questions of sustainability of such activities. System functions one, two and three have discussed what the actors are doing, how they are doing, how R&D takes place and how knowledge is diffused. Now we look at how the government supports the system growth.

8.1.4 F4. Guidance of the Search

This function relates to mapping the supporting infrastructure to reduce uncertainties in the TIS, including regulatory, policy and financial infrastructure. Data for this function was obtained from in-depth interviews with key informants in the Ministry

Although scaling up the distribution of improved cookstoves at household and institutional levels remains a priority target in the key policy documents and strategies, including but not limited to: 1) Uganda Vision 2040, 2) Uganda’s Sustainable Energy For All (SE4All) Initiative Action Agenda (2030), 3) the second National Development Plan (NDPII 2015/16 – 2019/2020), 4) the Uganda Green Growth Strategy (2017/18 – 2030/31), 5) the Uganda National Climate Change Policy 2015, and 6) the National Determined Contributions for climate change mitigation and adaption, the commitment lacks corresponding targets and requisite funding.

Not only that but also other key issues like awareness, marketing and taxation are not well addressed as far as improved cookstove promotion is concerned. For example, the Green Growth Strategy explicitly mentions scaling up improved cookstove use in the country as a key activity under the core strategy intervention area “energy for green economy”, but it falls short of stating practical targets for this activity as well as attaching the financial investment required to achieve widespread distribution and use of improved cookstoves.

In the SE4All Initiative Action Agenda (2030), Uganda commits to cut national wood consumption by 40%, to disperse 5.4 million household improved cookstoves and an undisclosed number of institutional improved stoves to hotels and restaurants by 2030. These targets however are not collaborated with requisite funding. However, the current national development plan 2020/21 – 2024/25 focus shifted from improved cookstoves to LPG and biogas (NDP III, 2020), and this policy change presents what I have called a structural shock to the system because this policy shift will directly affect planning, implementation and financing of improved cookstove activities in Uganda.
This finding concurs with Markard’s (2020) prediction that contextual changes such as policy priority shifts affect the focal TIS.

Despite abundant acknowledgement of improved cookstoves’ role in achieving the various sustainable energy goals in the country as reflected in the key policy and strategic documents, it remains more of lip service than actual, practical promotion. There is a lack of practical commitment for the promotion of improved cookstoves in terms of policy, financing, awareness raising and capacity building. The mismatch between acknowledging the need to scale up improved cookstove use and implementation of concrete actions to promote the same was echoed by both government officials and networks leaders. Acknowledging the importance of improved cookstove use in both households and institutions as one of the means to achieve sustainable development without setting goals and the financial investment required cannot stimulate private ambition to invest in the sector. Worse still, the absence of a clean cooking policy leaves improved cookstoves promotion without a clear road map for investment and growth.

This therefore presents a lacuna in terms of clear policy implementation arrangements including clarity on clean cooking governance, proper collaboration and coordination for clean cooking among the various relevant sectoral agencies to ensure that efforts to promote clean cooking are well leveraged and synergised, to limit duplication of efforts and harness benefits from all implemented clean cooking actions. Absence of a clean cooking policy presents an obstacle in translating the clean cooking priorities identified in other policy and strategic documents into tangible improved cookstove access and utilisation.

8.1.5 F5. Market Formation
This function is aimed at creating protected spaces for the new technology by incentivising its promotion and distribution. It is widely understood that new
technologies are not fit for purpose at the time they are first introduced on the market (cf. Hekkert et al., 2007). To understand how this function is being fulfilled, I mapped efforts at subsidisation, tax incentives, standardisation and regulatory reforms and market activation efforts over the years. Also, in-depth interviews with entrepreneurs and government officials were conducted to extrapolate how market formation efforts have been perceived.

Tax exemption for stove-making machines would have been expected to act as a stimulus for improving the means of production, which is one key setback in the industry, but not all players are aware of this incentive and those that do acquire machines lack capacity to operate them. Ugastove’s CNC machine was imported from China in 2016 and has not been used to date because of lack of expertise to operate it and the huge cost of bringing in a Chinese expert. Iron and steel used in stove making are taxed, though not solely used for stove-making but also other functions like construction of houses. Voluntary standardisation and lack of a certification label for stoves by UNBS allows counterfeits to proliferate, which affects quality and consequently compromises the intended and expected benefits of improved cookstoves.

All 31 key informants reported that diffusion and adoption is higher among households in urban areas compared to rural households. This finding concurs with existing studies in Africa (Kapfudzaruwa et al., 2017; Hiemstra-van der Horst & Hovorka, 2008). These studies attribute this imbalance in diffusion and adoption of improved cookstoves to higher poverty in rural communities and lower affordability of stoves relative to urban households. My findings however show that this view sheds limited light on Uganda and technological specific innovation system dynamics. The imbalance in diffusion and adoption of improved cookstoves between urban and rural setting is not only because of financial challenges but also the limited involvement of distributor companies and other stove dispersal conduits in the stove
distribution process (cf. section 5.3.2). Stove manufacturing companies are concentrated in Kampala city and its suburbs, with only a few identifiable companies like ILF operating in rural towns. Some local manufacturers like FOWE and SESSA have distributing outlets, but these are still in Kampala or neighbouring towns. This means that even if a rural household needs a stove and can afford it, stove availability remains a hindrance to acquisition. Therefore, my findings suggest it is not rural poverty that is slowing down diffusion, but also other factors related to accessibility.

Related to accessibility is the issue of unfulfilled promises with regard to after-sale services. One benefit of stove acquisition and sustained use, especially under carbon financed stove projects, is the offer of after-sale services to users. Such services are typically repairs and stove maintenance. The stove distribution model employed by GIZ to support manufacturers in reaching new markets involves providing logistical support like providing transport to manufacturers to move to agreed districts and towns for an agreed number of days and vend stoves. Although this model creates opportunities for diffusion of stoves in areas that were underserved, consumers who buy stoves under this model never get to interact with the sellers/ manufacturers again and as such miss out on after-sale services. Although it was beyond the scope of this research, this study wonders the extent to which this marketing model contributes to discouraging would-be stove adopters and users.

What these results show us is that the system function of market formation too seems to be dictated by foreign funders rather than local conditions, leading to an ever-shifting landscape.

8.1.6 F6. Resource Mobilisation

Financial, human and physical resources are necessary to fulfil not only the different system functions but also to build and maintain the TIS itself. Therefore, the state of resource availability, access and use is a crucial determinant for the performance of
the innovation system from idea generation to implementation and acceleration. In order to understand how this function is fulfilled in Uganda’s bioenergy improved cookstove development, financing opportunities earmarked for research and development, including testing, were mapped. In addition, through in-depth interviews, informants were asked about their perception of resource availability and access and whether it is a challenge to their innovation efforts.

8.1.6.1 Financial Resources: The Complexities and Challenges of funding in the Improved Cookstove Innovation System

Local manufacturers rely on personal savings to start up cookstove production enterprises. Along the way, some firms attract activity specific funding from different funding agencies. All eight local manufacturers that were part of this study confirmed receiving external funding at least twice. As related in Section 5.3 however, the funding architecture is increasingly changing from grants to co-financing and result-based financing. Funding has primarily been to acquire machinery, skilling and marketing. What, then, is co-financing?

8.1.6.1.1 Co-Financing

Co-financing is another instrument that GIZ uses to support improved cookstove development and promotion, although some firms did not understand it this way. They took it as a grant. GIZ subsidises an investment in equipment by contributing to the investment cost. However, local firms like BM reported that this co-financing mechanism has stretched them beyond their capacity, leading to unplanned debts. This financing scheme works in a way that a firm responds to a call for proposals for technical support, including purchasing capital goods, and GIZ determines how much it will contribute to each proposed activity. For BM, when they proposed to construct a kiln and buy a truck for stove transportation, they expected GIZ to underwrite the majority, if not all, of the costs.
GIZ offered UGX 24 million (£5,000) for a five-tonne truck, whose actual cost was UGX 62 million (£13,000) and offered UGX 25 million (£5,200) for a standard kiln whose actual cost was UGX 48 million (£10,000). BM was expected to top-up on GIZ finances and implement the agreed activities. According to BM’s proprietor, Hajji Mubiru, the company was not ready for such a big investment and expansion yet they had signed a contract to buy the equipment and distribute thousands of stoves every month. He resorted to borrowing, which caused set his business back. It later recovered and currently produces about 5,000 stoves a month. BM became one of the biggest stove producers in the country, more than tripling their pre-partnership output of 1,500 per month in 2015. It has started to open up stove outlets in other parts of the country, such as northern Uganda, which will improve stove dissemination and adoption.

This experience shows that co-financing can work and be a sustainable but can be designed in a more user-friendly format to align with manufacturers’ capabilities to meet their end of the bargain. Conversely, it also shows a lack of understanding about and exposure to the requirements and expectations of different funding models. Co-financing is a rather new model in Uganda, firms having been accustomed to grants where the beneficiary only submits activity reports to guaranty accountability. Therefore, it is not surprising that some manufacturers can assume that all funding is a grant and therefore do not pay attention to the details of the requirements of different funding schemes. This knowledge gap reflects a challenge of local manufacturers’ limited information about and exposure to the requirements of the different funding models and credit finance management in general and the limited existence of external technical support with regards to funding proposal development and management.
8.1.6.1.2 Result-Based Financing

Result-based financing (RBF) approaches are becoming popular tools for supporting development projects. There are different approaches to RBF, but what all these approaches have in common is that the arrangement for project implementation involves a funder (the principal) who makes payments to an agent (project implementer) to achieve pre-agreed results (Grittner, 2013; Pearson, 2011). The payment however does not happen immediately after the delivery of pre-determined results, but upon their independent verification (World Bank, 2013; Musgrove, 2011). Another important feature of this financing model is the requirement for verification to be done by an independent third party, and in some cases ex ante verification (before payment) can be complemented by ex-post assessment (Musgrove, 2011). The objective of this funding model is to achieve effectiveness and efficiency of funding (Grittner, 2013), and is a way of linking funding more closely to measurable results (Pearson, 2011).

RBF approaches were pioneered in the health sector but were later implemented in the energy sector, specifically to promote private sector investment in low-carbon energy sector opportunities (World Bank, 2013). This work was commissioned by the Energy Sector Management Assistance Program (ESMAP) in 2012, as an initiative to test the potential of the use results-based approaches (RBAs) in the energy sector in developing countries (ibid, pg.9). The World Bank views RBF as a funding approach which involves a national or sub-national government body as the principal and a range of possible agents (individuals, NGOs, sub national government) (Pearson, 2011). This forms the origin of the World Bank-funded improved cookstove project through Private Sector Foundation Uganda (PSFU).

In the Ugandan cookstove project’s case, PSFU contracted with cookstove companies as the principal to distribute tier 3 and 4 stoves in the country. The RBF approach for this project involved three conditions, including: 1) incentives are directed only to
providers, not beneficiaries; 2) payments for pre-determined services were purely financial; and 3) payment depended on the degree to which products are of approved quality and quantity. Musgrove (2011) refers to this RBF approach as Performance-Based Financing (PBF).

Under the World Bank RBF model for cookstoves, the project primarily subsidises stove distribution (the project refunds 50% and distributors pay 50% of each stove order). The model works in such a way that the agent is required to partner with stove distributors who pay the manufacturer a commitment fee of 10% of the total order, and also agree on the terms of payment for the remaining 40%. The manufacturer produces and delivers the stock to the distributors, and upon verification by KPMG, the manufacturer then requests 50% of the total order cost from the principal (PSFU). A total of 2,500 units is the threshold for support, and only tier 3 and 4 stoves qualify under this scheme. It is also a requirement that a manufacturer has an organised distribution network. Almost all locally manufactured stoves could not qualify as they met neither condition, stove quality nor organised distribution. Unlike carbon finance direct price subsidies, which negatively affected the cookstove businesses, the World Bank RBF is an indirect subsidy, which operates a refund system on stove sales. In addition, the project operates an inventory grant where, upon verification of results on stove use, durability and numbers distributed, the subsidy refunds distributors 20% for tier 3 and 30% of verified sales for tier 4 stoves. Ex-post results verification is done by KPMG (stock verification) and CIRCODU (field tests for quality, usage, durability). In addition, the project provides marketing support, which is paid to the distributors upon verification of results.

Beneficiary manufacturers are not required to reduce stove prices below the market rates in order to meet the distribution targets because the aim of the funding is to boost their production and distribution capacity. Nakyazze reported that Ugastove, which
nearly collapsed due to the direct price subsidy of the carbon financing model, has recovered due to this project’s indirect subsidy.

The challenge, however, is that fewer distribution companies deal in improved stoves mainly because of their fragility, weight and also limited knowledge of cookstove marketing. As explained by Kasirye of FOWE, finding a distribution company to partner with is an uphill task, because in addition to the disadvantageous stove attributes of weight and fragility, the road transport system in peri-urban and rural areas is bad, rendering operation almost impossible in the wet season.

The project design also limited both distributors and stove manufacturers’ capacity to meet targets. Both producers and suppliers that enrolled on the project struggled to finance the pre-agreed project activities. The distributors are required to raise 10% of the total order placed while the manufacturer is expected to produce and deliver stoves upon receipt of commitment fees, and only requisition for a 50% refund from the principal after delivery of the stock and upon verification. Local manufacturers and distributors however struggle with working capital, which makes implementation of project expectations difficult. There is a lot of preparation, logistics and processes that go into generating and selling a stove to the user.

In reference to this particular project, Rehma (Ugastove) reported, “selling a stove is not as easy as people think............. people do not value them so much because there are many alternatives... marketing takes time and other resources.” This means that the project was designed with incomplete information about stove manufacturing and distribution. The financial viability of the agent and the distributors to implement RBF activities also needed to be put in consideration. Indeed, as Pearson (2011) cautions, the presence of incomplete information or information asymmetry, such as the agent being the only one who knows how challenging any results are and how hard they would have to work to achieve them, makes both establishing a sound principal-agent
relationship and setting appropriate incentives extremely difficult. This lack of appreciation of what goes into stove manufacturing and distribution forced distributors to borrow funds to pre-finance the project yet the project took two and a half months to make refunds, putting strain on their businesses.

Another case of incomplete information was in auditing and stock verification. The company earmarked for this job (KPMG) had no experience in stove marketing and distribution. This meant that project distributors found it difficult to get verification approvals from the verification agency especially on marketing and distribution strategies employed, which sometimes delayed refunds. For example, one distributor invested in a tuk-tuk (3 wheeled motorised cycle) to make delivery of stoves quicker and easier, while another branded aprons with stoves and other messages about stove benefits and whoever bought a stove got a free apron. The verification agency however required specific results of stove sales attached to the tuk-tuk and aprons, which distributors had not captured. Such audit queries brought about delays in refund processing. And considering that some distributors borrowed funds to pre-finance the project activities, such delays further affected effective project implementation. Rehma estimates that about half of the project funds were not used because the way it was designed made it very difficult for especially distributors to join the project and even those who did, could not effectively deliver on the project activities. The project lasted four years and ended in 2020.

Due to the fact that only tier 3 and 4 stoves qualified for funding under this scheme, only Ugastove qualified among the local enterprises. In order to meet project targets, the principal (PSFU) extended the subsidy to imported stoves – such as Burn Manufacturers and Environfit to market and distribute stoves in Uganda. Providing an import subsidy in a country where the stove sector is struggling with different structural rigidities ranging from production challenges to marketing and distribution is to further disadvantage local actors. This decision also goes against the Uganda
government policy of Buy Uganda - Build Uganda (BUBU). The pertinent question that arises from this is, how can local manufacturers be supported to produce quality stoves and distributors supported to overcome some of the marketing challenges so that local players can participate in financing schemes, instead of alienating them from the very support that they need?

Despite these shortcomings, Ugastove confirmed that the project funding model was instrumental in the company’s recovery process, especially since the company was struggling to relaunch their unsubsidised products. Having organised distribution systems is important for stove distribution, reduces transaction costs for manufacturers, and risks are also spread between manufacturers and distributors. This study is therefore convinced that RBF can be an effective and efficient financing model that more directly links funding with results to promote private sector investment in low-carbon energy sector opportunities if such a scheme is adapted to the needs of the technological field.

8.1.6.1.3 Carbon Finance

Stevens et al., (2020) laud the role of carbon financing in accelerating diffusion and adoption of improved stoves in Uganda thusly:

> Carbon finance has been more widely available in the Ugandan context than in Kenya or Tanzania, thanks largely to the presence of Impact Carbon which acts as an intermediary linking local producers with the voluntary carbon market. The injection of carbon credits has helped to reduce the sales price of better-quality stoves.

While it is true that carbon finance played a big role in accelerating diffusion and acquisition of improved stoves in Uganda, this is but only part of the intricate story. Beyond the commendation, Stevens and his colleagues do not tell us the complexities and challenges that characterised this funding scheme, which nearly brought the
cookstove sector in Uganda to a halt as established by this research. In the Ugandan cookstove industry, carbon finance applied a direct subsidy to the stove’s price. While it can be credited for boosting production and distribution of improved cookstove, its characteristic system of price subsidisation led to market distortion.

As another approach to RBF, the carbon finance model works in such a way that carbon credits are earned after delivery of a pre-determined output, for example reduced emissions (Lambe et al., 2015). For this reason, the focus in Uganda was to use all means possible to massively distribute stoves to earn the carbon credits. Targets of how many stoves produced and distributed every month were set and Impact Carbon would pre-finance some stove production activities. The produced stoves were supposed to be subsidised by 40% for the users. Ugastove was the first carbon financed cookstove project in Uganda under the Gold Standard certification, which is part of the voluntary carbon market in 2007, and this was achieved through partnering with Impact Carbon. Through this partnership, Ugastove produced and distributed hundreds of thousands of stoves every year. Before then, Ugastove was producing between 1,000-2,000 stoves a month. Production capacity rapidly expanded to meet the high stove distribution targets for carbon credits. This growth necessitated recruitment of more artisans and professional workers. The contract required Ugastove to produce and sell stove volumes and capture end user and other details for monitoring purposes. Distributing stoves to the end user ultimately made the unit cost of the stove more expensive than what financing offered.

This meant that Ugastove had to distribute the stoves up to the end user because Impact Carbon monitored stove usage for two years. Ugastove was the stove producer and distributor, yet it had an inadequate distribution network in place to distribute the monthly stove volumes. As a result, Ugastove recruited many marketers and opened many distribution networks across the country. This inevitably increased the cost of production of stoves beyond what the project offered. This coupled with
the fact that the price of the stove was subsidised, Ugastove was not operating with the profit margins it had envisioned, although this was not realised until much later when the business started collapsing under the weight of unmet and unaccounted for overhead, production and distribution costs. The Ugastove experience exposes the inadequate capacity of local enterprises to negotiate and implement complex international business financing schemes like carbon finance on one hand and a lack of advisory services to support local actors in technical matters like contracts on the other. It is also indicative of rapid growth and expansion without proper strategic planning on the part of the local firm.

Still failing to meet the stove targets with Ugastove, Impact Carbon partnered with other manufacturers to produce and distribute stoves under the auspices of Ugastove, the only qualified carbon project for cookstoves in Uganda at the time. Those firms that worked under this arrangement had to give 10% of their carbon emission sales to Ugastove but this was later reduced to 1% without explanation, according to Nakyazze. Ugastove claims that the partnership with Impact Carbon was marred by lack of transparency and concealment of vital information, yet the many non-disclosure clauses in the contract, which mainly favoured Impact Carbon gave Ugastove limited opportunity to seek advice from professionals when disagreements cropped up. For example, Ugastove claims that between 2007 - 2012, emission reduction invoices that showed how many carbon emission sales were made were never given to them, despite persistent requests.

Although Ugastove ceased work with Impact Carbon in 2012, the contract gives Impact Carbon exclusive rights over the Ugastove brand until 2028. This kind of monopoly makes Ugastove an enterprise in captivity for carbon trade, and as such cannot partner or transact business with any other carbon projects until 2028. Noteworthy though, the Impact Carbon PoA under the Ugastove brand is still
running but with different stove producers, and Ugastove does not benefit from these carbon emission sales at all.

Carbon finance is one of the biggest funding opportunities for the improved cookstove sector: therefore, Ugastove not having access to it caused a huge setback to the business, which it had yet to fully recover from at the time of research. Ugastove went into restructuring and laid off 80% of its workers with accumulated salary arrears and unpaid bills from suppliers. According to Nakyazze, the Managing Director of Ugastove, the 2011 death of the proprietor and founder of Ugastove, the late Kawere, due to a heart attack is attributed to the extreme pressure the company went through due to financial disagreements that characterised the carbon finance partnership, and later realising that he had “unknowingly franchised\textsuperscript{20}” the company’s brand for carbon business to Impact Carbon. For Ugastove, the end of carbon financing portended a complete business shutdown because of huge unmet financial obligations and the uphill task of relaunching the stove products afresh on the market without subsidies.

Worse still, during 2007-2012, Ugastove stoves were sold at a price lower than the actual production cost because of the carbon finance subsidy. Therefore, when carbon finance ended, Ugastove was faced with a challenge of selling unsubsidized stoves on the market because consumers resisted new higher prices for the same products. This further derailed business recovery. Ugastove was at the time of research benefitting from the World Bank RBF scheme to increase marketing and distribution of stoves, and this project has been key in supporting Ugastove to reintroduce its unsubsidised stove products to the market.

\textsuperscript{20} Unknowingly because the proprietor was an artisan of very limited formal education and did not engage professional advisory services during the partnership’s formative stages.
The conflict that resulted from Ugastove and Impact Carbon carbon finance partnership reveals the complexity of partnership building, more importantly equitable partnerships. Broto et al (2015) opine that equitable partnerships entail not just agreeing to deliver common action in relation to each partner’s capacities but, rather, the fulfilment of an agreed common goal, the sharing both of responsibilities and of risks and the transfer of skills and know-how between partners. Brinkerhoff (2002) further argues that in order for partnerships to pursue equity, they need to achieve high levels of mutuality (in terms of recognising and responding to the interests of each partner) and high levels of organisational identity (in terms of maintaining the original purpose for the partners involved). Considering the principles of equitable partnerships as advanced by Broto et al and Brinkerhoff, the Ugastove/Impact Carbon partnership offers salient lessons for future carbon finance partnership building.

As a key player in carbon finance in the country, I sought out the opinion of Impact Carbon on carbon finance experience in Uganda, but the key informant accepted to discuss only currently running projects and declined to talk about past partnerships. This means that I could not get Impact Carbon’s side of the story in relation to the Ugastove conflict. Impact Carbon, which now operates under the name Impact Water Limited still runs a carbon financing project with two local manufacturers as stove suppliers (AES and EUF) and according to Kalcic, the Impact Carbon Country Office Advisor, carbon finances are used to strengthen both manufacturers’ production and marketing capacity including awareness raising through radio and TV campaigns. This information was corroborated with AES reports on the role carbon finance plays in their stove production and distribution processes. This means that Impact Carbon changed from direct subsidy that was employed at first with Ugastove to indirect subsidies with the current partners.
After the launch of Impact Carbon/Ugastove partnership, more project developers for stove carbon finance projects such as Up Energy, Climate Care, Living Goods, and the Uganda Carbon Bureau also got involved. Entry of new carbon finance actors brought about a huge surge in demand for stoves, albeit artificially, which local manufacturers struggled to meet. Incumbent firms could not meet the demand and this served as an opportunity for artisans to start stove manufacturing enterprises. It also presented an opportunity for imported good quality stoves to join the market. Some project developers charged enrolment fees in order for local manufacturers to distribute stoves with their carbon project. Other players just bought stoves from established stove producers, branded and distributed them under carbon finance activities. Project developers scrambled for stoves to meet their targets and this inflated the demand and market for stoves. In a desperate bid to meet the carbon emission sales targets, project developers like Living Goods would buy stoves from different manufacturers and sell them at dumping prices.

UNREEEA reported that there were also cases where participating organisations bought stoves and donated them to users. This report was corroborated with responses from a key informant from CIRCODU. The main target was massive distribution of stoves, yet it greatly distorted the market. Firms were mainly producing for carbon finance and when the prices fell in 2017/2018, project developers scaled down operations while others closed down. Manufacturers struggled to reintroduce their unsubsidized stoves to the market amidst many counterfeits that are sometimes priced lower. This struggle to sell unsubsidised stoves signifies that the wide adoption experienced was not a result of users appreciating the value of an improved cookstove but rather because stoves were made very cheap by the subsidy.

Another peculiar issue with carbon finance was that, in some cases, manufacturers benefitting from it would sell stoves at the same price as those without finance, hence making abnormal profits while at the same time exploiting users. Purchasers were
required to sign warranty cards transferring their carbon finance benefits to the manufacturer in exchange for a subsidised stove and after-sale services. Therefore, if a manufacturer benefiting from carbon finance sold a stove at an unsubsidised price, yet the buyer signs a warranty card giving away their benefits to the manufacturer, in exchange for a stove subsidy and after-sale services, then the consumer actually pays more than double for each unit purchased. As emphasized by network leaders like Noah of UNREEA, Virginia of BEETA and Ugastove and Joseph of CIRCODU, one of the biggest setbacks for carbon finance was the lack of after-sale services, yet they were part of the finance contract and one of the reasons why users transferred their carbon finance benefits to the manufacturers. Instead, manufacturers concentrated on distributing as many stoves as possible without offering any maintenance or repair services to the users.

Prior to carbon finance, the stove market in Uganda was getting established and stoves were sold without subsidies. Stove manufacturing was taking place on a small scale with primarily local producers as the major suppliers. Carbon finance brought significant shifts in the improved cookstove TIS by expanding the structure by attracting new actors (suppliers – local and importers, assemblers and distributors), creating artificial demand, upscaling stove distribution, distorting the budding stove market and nearly bankrupting the first local enterprise to qualify as a PoA under the carbon finance scheme. After the first wave of carbon finance, the innovation system had to undergo a long period of restructuring at the firm level in order to circumvent the direct subsidy’s effects. At the time of research, carbon finance activities had considerably reduced due to a fall in voluntary carbon credit, the main financing scheme for improved cookstoves. This presents a second structural shock in the system from national policy shift, and it will have an effect on stove fabrication and dispersal.
In addition to dwindling carbon finance, clean cooking external funding at the time of research was shifting to solar and LPG. All the network leaders that were interviewed for this study confirmed this change in the funding landscape.

(34) Improved cookstoves now face stiff funding competition from solar and LPG, because these are the new priorities for funding for some financiers (Birungi, formerly of UNACC).

Noah Asinga (UNREEEA), partly attributed this change of funding focus to the vigorous and effective lobbying and mobilisation efforts of the Uganda Solar Energy Association (USEA)21. What all this confirms is that the improved cookstove financing landscape is unstable, causing vulnerabilities in the system. We now turn to the human resources in the system.

8.1.6.2 Human Resources

The industry also suffers from founder syndrome, which may limit growth and expansion beyond the founder’s capability and vision. Most stove enterprises are run as family enterprises regardless of the capabilities of the family members. Ugastove for example was founded by the late Kawere who was a primary school dropout and is currently run by his sister (a graduate) and Kawere’s sons. Hajji Bulaim Mubiru, the proprietor and CEO of BM Energy, is semi-illiterate; his daughter, a fresh University graduate, is in charge of operations while his sons, whose education does not go beyond secondary school, are in marketing and distribution. Ugastove and BM

21 USEA is an entrepreneur-led industrial association, and one of the strongest among the clean cooking networks. It brings together players in the solar energy business. Established in 2016, this association has achieved milestones for solar promotion in Uganda including huge government investment, policy support and wider uptake (Avellino et al., 2018).

According to UNREEEA, an alliance of which USEA is a member, USEA is effective in enforcing standards and quality assurance, have an effective pay as you go payment system for users, developed a solar credit facility.
Energy are some of the biggest stove producers in Uganda. The sector is also dominated by stove producers with limited capacity to utilise and absorb new knowledge and transform it into innovation ideas. The Proprietors of AES, FOWE, SESSA, JOSA, MASUPA all possess college level formal education.

8.1.7 F7. Legitimacy Creation
Local organising for improved cookstoves is still weak and uncoordinated. Although there are three associations that bring suppliers together, they struggle with technical capacity, conflicts of interest, limited funding and low membership engagement. Some manufacturers believe that these associations do not understand their needs and therefore do not serve their interests. Some government agencies like UNBS reported facing a challenge of working with the different, uncoordinated associations.

The conflicting roles of improved cookstove advocacy NGOs impedes progressive advocacy for desirable policy changes. UNACC and BEETA, the key advocacy NGOs still have challenges defining what exactly each player should be doing. They behave more like competitors than partners in the promotion of improved bioenergy cookstoves. NGOs also experience very limited independence, if any. For example, the Commissioner of Ministry of Energy and Mineral Development and GIZ officials are part of the governing board of UNACC. This presents a conflict of interest because UNACC cannot pursue pro-entrepreneurial policy changes if they are not in tandem with government and GIZ interests.

8.1.7.1 Improved Cookstove Behaviour Change Strategies
Advocacy groups have mainly engaged in behaviour change campaigns for cookstoves. This research sought to understand what drives adoption of clean cookstoves and the findings showed that the drivers are twofold (Figure 11). There are those drivers that influence immediate decision-making about the adoption of improved cookstoves, which this study calls proximate drivers, and there are others
that allowed the proximate drivers to develop, which this study refers to as the underlying drivers.

![Diagram of Drivers of Improved Cookstove Adoption](source)

**Figure 11: Drivers of Improved Cookstove Adoption**  
*Source: Author’s Illustration*

Proximate drivers relate to behaviour change mechanisms that are implemented to influence cooking habits whereas underlying drivers are connected to cooking and environmental challenges that cookstoves users face, e.g., indoor air pollution, fuelwood scarcity/deforestation, risks of burns, longer time spent on cooking activities, dirty cooking atmosphere, and expenditure on fuel.

**Table 21: Behaviour Change Techniques Employed in the Improved Cookstove TIS in Uganda**

<table>
<thead>
<tr>
<th>Driver</th>
<th>BCTs</th>
<th>Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advertising</td>
<td>Shaping Knowledge</td>
<td>TV/Radio, print posters</td>
</tr>
<tr>
<td>Cooking Demonstration</td>
<td>Shaping knowledge, comparisons, Social Support</td>
<td>Cooking demonstrations by trainers in marketplaces and villages</td>
</tr>
<tr>
<td>Free stoves</td>
<td>Rewards and Threat</td>
<td></td>
</tr>
<tr>
<td>Establishing financing mechanisms</td>
<td></td>
<td></td>
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</tbody>
</table>
Awareness raising and stove promotion | Shaping knowledge, social support, comparisons

From the FGDs, it was evident that although stove users had the desire to change from traditional to more efficient and improved cooking technologies, this desire only transformed into action after behaviour change interventions. Users effectively acquired improved cookstoves after they were incentivised through different means like adverts, cooking demonstrations and camps, favourable financing mechanisms, and free stove offers, among others (Table 21). It can therefore be deduced that for wider adoption and dissemination of improved cookstoves to take place, more behaviour change interventions must be implemented. The question therefore is no longer whether behaviour change is necessary for bioenergy improved cookstove promotion but rather how behaviour change programmes can be integrated into their development and endorsement for widespread adoption and diffusion. The importance of behaviour change campaigns was emphasised during FGDs as advanced below;

(35) I heard over the village public announcement system that there will be a cooking demonstration for improved cookstoves at the community centre. Out of curiosity, I went to see what the demonstration, the first of its kind in our community, was all about. We were sensitised about what the stove can do, shown how it works and how we can maintain it. I was happy to learn that the stove will considerably reduce the amount of charcoal and smoke. I ended up buying one, which I use currently. Ever since, I have not gone back to the metallic stove. The stove has served me for one year and still counting. (FGD Participant – Wandegeya).

(36) Although it was not one of the things that I was losing sleep about, the idea of replacing my metallic charcoal stove with a more efficient and multipurpose stove was tempting. I can use small wood pieces and also charge my phone using the stove. The
offer of instalment payment for the stove over a 6 months’ period was an extra incentive to me, which encouraged me to buy an improved cookstove. (FGD Participant – Kajjansi)

The discussion on the improved cookstove functional pattern has revealed that like the structure, the key processes are dictated by exogenous actors rather than local conditions, leading to an ever-shifting landscape. We turn now to the systemic weaknesses in the system.
8.2 Systemic Weaknesses of the Improved Cookstove Innovation System

Systemic weaknesses in the improved cookstove innovation system were identified while analysing the structural elements and their activities. These weaknesses constitute what Bergek et al. (2008a) and Chaminade et al., (2012) conceptualise as blocking mechanisms or systemic problems.

Table 22: Systemic Weaknesses in the Improved Cookstove TIS

<table>
<thead>
<tr>
<th>Systemic Weaknesses (failures of actors)</th>
<th>Manifestation</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capability Problem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited use of research knowledge</td>
<td></td>
<td>Sector is dominated by stove producers with limited technical capacity</td>
</tr>
<tr>
<td>Limited capacity to produce high quality stoves</td>
<td>Limited research in the sector</td>
<td></td>
</tr>
<tr>
<td>Homogeneity of stove designs and quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited knowledge transfer and interactive learning</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Network Problems (interaction failure)   |               |        |
| Weak, captive and uncoordinated networks | Strong government and donor influence on networks |
| Limited relevant and up to date information. | Financial dependence |
| Limited transfer of knowledge             |               |        |
| Limited incentive to share knowledge     |               |        |
| Low legitimacy among manufacturers       |               |        |

| Institutional Problems (institutional failures) | Inappropriate and voluntary standards | Weak and uncoordinated networks |
| Lack of policy on clean cooking             | Limited information on the performance and potential of the improved cookstove sector |
| Coordination for improved cookstove promotion scattered in different government offices | | 
Low capacity to comply with standards

### Infrastructure Problems (technology failures)

<table>
<thead>
<tr>
<th>Limited research and testing centres</th>
<th>Limited funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substandard stove manufacturing environment</td>
<td></td>
</tr>
</tbody>
</table>

**Source:** Interviews and observation

### 8.2.1 Capability Problems

These relate to enterprises’ inability to absorb the knowledge generated by other actors in the system like research and testing centres, NGOs and industrial associations. Cookstove enterprises are not guided by findings from research and development organisations but rather by their informal research mechanisms. Local manufacturers conduct applied research to learn about their products’ performance and fitness for purpose. These informal mechanisms include seeking feedback about stove performance, including experimentation by family and friends who use the product. Local stove manufacturers try to keep in contact with the users through their distribution systems. Samuel from JOSA reported that he tested a charcoal household stove with his family. For the institutional stove, he constructed one free of charge for a local school and asked them to record the performance indicators that he gave them. He used this feedback to improve on the stoves before putting them on the market.

> (37) I experimented my first stove design with my wife and two sisters. I gave them a list of performance parameters to look out for and assess. I told them to specifically observe fuel consumption, smoke, time taken to cook. I used their feedback to make improvements. After a couple of experiments, I launched the product on the market.

(Samuel, CEO JOSA).

Through feedback from stove users, local manufacturers have improved on some stove aspects like providing the ashtray, installing wooden handles instead of metallic
ones, and supporting stoves with stronger feet. Therefore, knowledge absorption takes place at the micro level, which means that stove producers are guided more by the stove users’ “standard” than the national standard. Although applied research is key to understanding how science (innovation) works in real life, it needs to be complemented with other forms of research in order to achieve completeness in understanding how knowledge can be used to improve innovation development.

It was also pointed out by the CEO of FOWE that important research outputs are written and presented in formats that are not user friendly for manufacturers. He gave an example of testing reports that can hardly be interpreted by the local manufacturers. They are written in highly technical language, and as a result, they end up not serving one of the important purposes for which they are intended – to improve stove performance (see an exemplary test report in Appendix 8). According to the Managing Director of CREEC, manufacturers are interested more in fuel saving than other parameters and therefore, do not express willingness to improve stove designs where fuel saving is 40% and above. This again emphasises the local manufacturers perception about the key role of an improved cook stove (save fuel), and what drives their innovation.

The research infrastructure is not well coordinated, with very limited involvement of universities in improved cookstove development and promotion. The networks, which act as the main research centres in addition to CREEC and international NGOs like WWF, SNV, and GIZ, work independently and none are linked to any university in the country. Therefore, the few existing research outputs remain scattered in the various organisations that conducted them. Some of these products are only available in hard copy and many remain hardly unused. This stifles knowledge transfer and interactive learning in the sector.
8.2.2 Network Problems

These mainly refer to the nature and intensity of linkages between the different actors. Networks like UNACC grapple with legitimacy issues among their membership on one hand and high influence from government and development partners on the other. UNACC is supposed to be a network, a civil society organisation, that brings together all organisations that engage in clean cooking promotion. However, its policy direction is determined by government and GIZ, SNV and WWF as the founding organisations. UNACC’s contradicting formation, role and governance stifles its ability to support improved cookstove associations’ advocacy agendas.

Networks’ activity portfolio is determined by donor priority rather than improved cookstove sector needs. This has meant that networks implement only those activities for which they can secure funding from donors and for a specific period of time. There is a challenge of securing multi-year funding to ensure tangible outcome and impact.

8.2.3 Institutional Problems

These mainly relate to weak formal rules that guide the innovation system processes, for example regulations, laws, policies and standards. The biggest institutional challenges as far as improved cookstoves are concerned are two-fold – the voluntary standard and lack of an autonomous coordination unit. The recently reviewed standard in force is voluntary, meaning there are no ramifications for non-compliance. A voluntary standard cannot solve one of the biggest sector problems, which is proliferation of poor-quality stoves.

Secondly, coordination for improved cookstove promotion is scattered in the different government agencies and ministries like Ministry of Energy and Mineral Development, Ministry of Water and Environment, and the Climate Change Division. Improved cookstove promotion is treated as a crosscutting issue, which disadvantageously relegates it to the periphery of sector-specific plans.
8.3 Conclusion

Improved cookstove innovation development in Uganda is largely driven by external actors, in addition to systemic catalysts like low entry costs, voluntary adherence to standards and carbon finance. With the complexities and challenges that are associated with the current and past funding schemes, funding for research and development in the improved cookstove sector is declining. Indeed, Mugwagwa and Banda (2021) describe the current funding architecture in both developing and developed countries as declining or stagnant. While Kaya (2009) established that research and development funding initiatives in Africa is not only weak but also sporadic. This means that shrinking of funding for research, development and innovation is not only associated with the improved cookstove innovation system, it is a universal challenge. The resultant effect of this declining and sporadic funding is a stiffer competition for the available declining financial resources, which will necessitate building new institutions and effective mechanisms of interactions to cope with the changing global funding trend.

There is an issue of standardisation at different levels. Production processes are not standardised in most firms except Ugastove. Stove sizes and weights are also not standardised. Stove standardisation is voluntary at the national level, which presents compliance problems. In addition, the level of innovation is low as evidenced by the fact that improved cookstoves manufactured by different firms lack significant differences in both quality and design. The sector is dominated by stove producers whose technical capacity to innovate to the expected standard is limited. Yet, there is limited involvement of the universities in research and development for the cookstove industry. All this makes knowledge generation and transfer and interactive learning a big challenge for the sector.
In a nutshell, fulfilment of the system functions is largely driven by external players, which makes the system vulnerable to external actors’ ever-shifting priorities. The government’s role in the improved cookstove TIS building remains peripheral, with its major institutional support being the publication of the inappropriate biomass stove standard. Even the flagship annual energy week, which is organised by the Ministry of Energy and Mineral Development is funded by GIZ. R&D activities are not only largely funded by funding agencies such as GIZ, SNV, WWF, ACC and the World Bank but also in some cases these activities are spearheaded by these agencies. The system grapples with capability problems (related to limited research to inform entrepreneurial activities and quality of firms), network problems (related to dependency and legitimacy issues) and institutional problems (inadequate regulation).
CHAPTER NINE: DISCUSSION AND CONCLUSION

9.0 Introduction

In this research, I set out to answer four research questions: 1) Who is active in the improved bioenergy cookstove innovation system, why and the environment in which they operate? 2) How is knowledge shared and how does learning take place within the improved cookstove innovation system? 3) How does the improved cookstove innovation system in Uganda work? 4) What implication does the current innovation system set up have for diffusion and adoption of improved cookstoves technologies? Chapters Five, Six and Seven answered research questions 1 and 2, while Chapter Eight answered research question 3 and the current Chapter will answer research question 4.

Despite the fact that improved bioenergy cookstoves have been a topic of research for more than 40 years (Kshirsagar and Kalamkar, 2014), 2.5 billion people in the world still rely on the traditional use of solid bioenergy to cook their meals, and in Sub-Saharan Africa almost 80% of the population cooks with solid bioenergy (IEA, 2017). This study was inspired by the paradox surrounding improved cookstoves’ grand promises on one hand (such as reducing pressure on forests by sinking demand for wood fuel, improving both cooking atmosphere and the efficiency with which traditional fuels such as wood and charcoal are produced and used, saving energy and cooking time and money, reducing risk of burns to the user, generate income) and their slow diffusion and adoption on the other. Using the technological innovation systems model of analysis, this research sought to contribute to deeper understanding of the factors responsible for this trend by examining the system, which generates, diffuses and uses these technologies. This research departed from the analysis that situates the problem of slow progress of diffusion and adoption of stoves in the characteristics of the users and attributes of the technology, and sought to interrogate systemic and institutional factors’ role in this paradox.
9.1 Discussion

The previous four chapters presented the empirical evidence on the structure, environment, and key processes of the improved cookstoves TIS in Uganda. My interpretation and analysis has been supported with substantial reference and comparison with theory and literature. This section therefore focuses on pulling together only the major findings and briefly discussing them. The synthesis is presented in two sections: the structural configuration and functional pattern.

9.1.1 Structural configuration

The structure is the foundation of the TIS, supported by three pillars including: actors, institutions and networks. An equally important part of the TIS structure is also the focal technology.

Entrepreneurs

My findings (cf. section 5.3.1) show that entry of firms in the innovation system does not generate system inducement because of the entrants’ capability challenges and opportunistic intentions. This makes firms, especially new entrants, into blocking rather than inducement mechanisms, contrary to Bergek et al.’s (2008a) given wisdom. In their paper, “Innovation Systems Research: An Agenda for Developing Countries”, Egbetokun and colleagues (2017) suggest that firms are the main actors in the TIS and go on to elaborately explain how their competences and capabilities impact TIS building especially in developing countries. Carlsson and Stankiewicz (1991) too place entrepreneurs at the core of the innovation system saying that;

*The role of the entrepreneur is to provide the vision that turns a network into a development block. He must be able to see beyond that which currently exists to what is possible in the future. He has to perceive the (future) need, identify the necessary ingredients, secure the resources that may be missing initially, and*
communicate his vision to the relevant agents (Carlsson and Stankiewicz, 1991: pg. 106).

To a large extent, stove entrepreneurs in Uganda seemed not to assume such big leadership role in building the improved cookstove TIS. The core actors in the TIS are mainly external actors. This lack of strong engagement on the part of entrepreneurs in Uganda can be attributed to many factors including motivation behind participation in the system, resource constraints (financial and technical), weak mechanisms of interaction and limited government support. An entrepreneur’s capability is a function of the resources at their disposal and their ability to create value from those resources, for example by developing innovative technologies (Egbetokun et al., 2017). Grant (2001) makes a similar observation saying that the nature of resources (quality, quantity and type) available to firms have a direct effect on what they can do. While the views of Egbetokun and Grant on resources and capabilities were to an extent evident in the findings of this study (cf. section 8.1.6), I argue that entrepreneur capability is only part of the story. In Uganda’s case, although limited resource availability, for example, is partially responsible for poor quality stoves, the opportunistic and sometimes dubious intentions of especially entrants was largely responsible for compromising stove quality. Entrepreneur capability is therefore not just a function of resource availability, but also the intentions of the firms. My finding further show that the Ugandan consumers’ capability to demand for standardised stoves is almost non-existent because they are neither aware of the existence of the standard nor its use (cf. section 5.4.2). This consumer capability challenge was confirmed by a network leader saying that;

*The problem we have is that stove users are not aware that stoves are standardised. So they cannot help in pushing for the implementation of the standard. (Virginia, BEETA).*
This therefore suggests that to achieve successful innovation system building, the discussion on capabilities of entrepreneurs should focus on users as well. After all, the UNCTAD report (2018) observes that the success of innovation systems is determined by the capabilities of the different actors, interaction among them, and the enabling environment for the innovation they create.

Research (e.g., Egbetokun et al., 2017) further suggest that if capabilities of new entrants are built, they can eventually evolve from being imitators to innovators. To achieve this, however, firms have to engage in technological learning in which interaction with information and knowledge generating actors such as universities plays a crucial role (Bell and Pavitt, 1993). With the current limited involvement of universities in the improved cookstove TIS therefore, transformation of firms’ capabilities remains a huge challenge. Secondly, the focal technology (improved cookstove) TIS was created and shaped with limited, if any, linkage and learning from existing industries (cf. section 5.2). Although Markard (2020), predicted that in the formative phase the TIS heavily depends on context structures such as universities, R&D programmes, existing industries and larger societal trends, and it builds its legitimacy based on these, my findings show that these context structures have a very limited role in the improved cookstove TIS building. External actors notably the donors play the biggest role.

**Institutional Framework**

One of the key findings of this study is that the key institution in the improved cookstove TIS: the improved cookstove standard and testing protocols are misaligned from local firms’ innovation focus and user habits and preferences (cf. sections 5.4.2 and 7.1), yet Freeman and Louca (2002) tell us that institutions need to be adjusted, or “aligned”, to a new technology, if it is to diffuse. In his seminal paper about the role of institutions in economic development, North (1994) defined institutions as human-devised constraints that structure economic, social and political interaction, which
consist of both formal and informal rules. North continues to say that rules are devised to create order and reduce uncertainty. TIS researchers do not differ from North’s seminal work in new institutional economics in their view of what institutions are and their role in innovation system building. For example, Markard (2020), Bento and Wilson (2016), Hekkert et al. (2011), and Bergek et al. (2008b) define institutions as formal structures such as legal and regulatory aspects and informal structures such as norms and cognitive rules that regulate interactions between actors, define the value base of various segments in society, influence firms’ decisions and structure learning processes. Institutions are therefore the rules of the game in innovation system building. Without them or with inappropriate institutions in place, like the case is with Uganda (cf. section 5.4.2), the system is bound to face challenges fulfilling key processes. Misaligned institutions can neither create order nor reduce uncertainty in the system.

**Networks**

Network activities, and even their establishment, are heavily influenced by donor priorities. Networks like other NGOs in Uganda do not have any independent source of funding. They rely on funding agencies for survival, and Shviji (2007) states that in such a case the degree of independence they can exercise in relation to donor agendas is limited. This dependence restricts the network’s capacity to implement activities at system level (cf. sections 6.2 and 6.3). My results show that networks engage more in technical roles such as training, sensitization and awareness creation than in political activities such as lobbying and advocacy, which limits attempts at system-level change. This has in turn affected network’s legitimacy among member firms (cf. section 6.4) and derailed achieving necessary institutional changes. Papaioannou et al. (2014) argue that industry associations should play an important role in shaping government policies on innovation, establishing governance institutions and strengthening the enforcement mechanisms. Delivering on such roles requires a good
degree of independence on choosing activities to implement and the duration of implementation depending on the prevailing circumstances, which Ugandan networks do not have.

On the other hand, Markard et al. (2016) emphasise the importance of legitimacy, especially in resource mobilisation for both new and established technologies, yet it remains a challenge for improved cookstove networks in Uganda. In their earlier work, Woolthuis et al. (2005) suggested that successful innovation is a function of close interaction between technologies and actors, and when this connectivity among these elements is poor, learning and innovation may be inhibited. Weak legitimacy means that the connectivity that Woolthuis and colleagues talk about is weak as well. Both networks leaders and local manufacturers concurred that networks largely drive the agenda of development agencies than local sector needs. A network leader reported that; *For us to survive, our project priorities have to be in line with financiers’ priorities and not necessarily the pressing needs of the sector.* On the same note, a local manufacturer observed that; *We cannot do much with the current networks. Their agendas are dictated in board rooms where we hardly have a voice. We need to mobilise ourselves into a home-grown network like the solar business community where our needs take priority.* These two voices further express the magnitude of networks’ donor dependence on one hand and the weak legitimacy among local entrepreneurs on the other.

Such sentiments depict networks as vulnerable entities and, as such face difficulties to build assets like legitimacy and collective voice, and capacity to mobilise for collective action, which are necessary to bring about institutional changes as well as strengthening enforcement mechanisms. But do the structural elements even agree on the contextual definition of an improved cookstove innovation?
Technological Frames

My findings in Chapter Seven reveal that there are significant differences in the technological frames of local innovators, users and external promoters on the improved cookstove innovation. Local users and innovators perceive stove innovation in terms of fuel saving, affordability and fitness for purpose while external actors focus on emission reduction among other international parameters. For Orlikowski and Gash (1994), technological frames refer to the shared assumptions, knowledge and expectations about the purpose, context and importance of a technology. These have a strong influence over choices concerning the design and use of technologies. This includes not only the nature and role of the technology itself, but the specific conditions, applications, and consequences of that technology in particular contexts of use. Orlikowski and Gash (ibid) further argue that where the technological frames of key groups are significantly different, difficulties and conflict around the development, use, and change of technology may result. In the Ugandan improved cookstove TIS, the differing technological frames are manifested in the divergence of perception on what an improved cookstove should be. Actors in Uganda do not agree on what constitutes an improved cookstove innovation, and while the international qualification of stove innovation is what is promoted by the external actors as well as the government, local entrepreneurs and users pursue a different set of stove qualifications that are context specific to Uganda. Reflecting the spirit of the importance of context-specificity, Altenburg (2009) suggests that the choice of technology depends on the socio-economic conditions. In other words, socio-economic realities should be the drivers of innovation. Where external factors instead become the drivers of innovation development as is the case in Uganda, then tension as it is experienced in the improved cookstove TIS is likely to happen.

My results (cf. section 7.1) also reveal that when users acquired sophisticated and more efficient, imported stoves like the biolite, they discontinued using it and reverted
to the locally made improved stove because the former did not meet their needs, whereas the latter does. This means that the priorities and expectations of the climate change push factor have not successfully influenced local innovators’ focus and users’ preferences and by extension users’ frames.

Some studies suggest that heterogeneity in frames may be inconsequential or even beneficial in some circumstances (Walsh *et al.*, 1988 in Davidson and Pai 2004). However, in the improved cookstove TIS, failure to include fuel saving as a standardised performance parameter has negative repercussions on technological diffusion because it is the overriding attribute stove users look for in an improved cookstove. The national and international standards emphasise thermal efficiency, and in Uganda’s case this is done only at high power.

Efficiency at high power doesn’t reveal the true picture of improved stoves’ efficiency, because in Uganda cooking takes place at all three power levels – high, medium and low power. In responding to the problem of climate change, exogenous actors have tended to prioritise their own concerns over those of local stove users in Uganda. This finding confirms what earlier studies (e.g. Sesan, 2014) suggested that the priorities and policies of exogenous actors have always taken centre stage in driving development and dissemination of improved cookstove technologies in developing countries.

Behavioural change campaigns geared towards influencing user frames to mirror those of external actors have been implemented, but on a small scale. According to Davidson and Pai (2004), technological frames develop and change through experience, education, and sometimes through planned interventions. This therefore means that achieving congruent technological frames for improved cookstoves among the different actors will require more education and specific interventions to generate homogenous frames. Further, the study established a prominent use of indigenous
knowledge in some of the improved cookstove generation and use processes such as clay testing, ceramic baking, and firepower adjustment. Yet, research hardly exists on the role of indigenous knowledge in building the innovation system in developing countries (Jauhiainen and Hooli, 2017; Kaya, 2009).

Smith (2009) suggests that indigenous knowledge is often conceived as something quite distinct from scientific or Western knowledge and that, how we perceive knowledge as scientific or indigenous fundamentally shapes how we interact with it, which consequently may result in creation of artificial boundaries. My findings bring in another realisation that indigenous knowledge can be useful in understanding user needs and preferences that scientific knowledge can utilise to generate appropriate innovations.

9.1.2 Functional Pattern
The results of this study indicate that fulfilment of the innovation system functions is faced with many complexities and challenges related to stove quality, an inappropriate standard and decreasing funding (cf. sections 8.1.6.1 and 5.4.2). This research established that the government plays a token role in building the improved cookstove TIS, leaving the biggest responsibility to external actors: donor agencies (cf. section 8.1.4). Indeed, during this study, it was widely acknowledged that, “You cannot talk about the improved cookstove sector in Uganda without mentioning GIZ”. GIZ has consistently financed and provided technical support to the improved cookstove TIS in Uganda for close to two decades. Although other financiers came on board along the way (cf. 5.3.4), GIZ remains one of the principal promoters.

There is a global acknowledgement of the role of innovation and technological change in economic development and as such, governments around the world prioritise promotion of innovative activities within their economies to create an enabling innovation environment (Egbetokun et al., 2017). Bergek (2011) offers that the role of
the government in fostering innovativeness includes: market stimulation, provision of relevant institutions and other infrastructure and giving firms incentives to invest in innovation. On the other hand, Carlsson and Stankiewicz (1991) suggested that the role of the government in the innovation system building is to establish and maintain the institutional arrangements conducive to achieve dynamic efficiency in the system. This means that Government of Uganda’s lip service to improved cookstove promotion (cf. sections 8.1.4 and 8.3) coupled with inappropriate institutional framework exposes the system to the vulnerabilities of the ever-shifting external promotion landscape. Yet, evidence from Barbados solar water heater TIS shows that there are greater benefits in strong government support for emerging technologies (Rogers, 2016).

Exogenous catalysts, specifically climate change, brought not only a shift in the improved cookstove TIS landscape in Uganda, but were tsunamis that swept renewable energy technology innovation systems in other countries. An earlier study by Westhoff and Germann (1995) asserts that since the beginning of the 1980s, improvement and dissemination of cookstoves has been centre-stage for global development programmes and projects that focus on energy and environmental problems. “The co-evolution of innovation systems and context: Offshore wind in Norway and the Netherlands” (Loos et al., 2021) established that when climate change topped the public agenda in 2007, it culminated in prioritising wind energy for the Norwegian energy mix. An energy council was formed to study and report on the wind energy potential of Norway, and this later led to policy development in favour of support for research and development and demonstration of offshore wind energy. On the other hand, Tigabu et al. (2015) report that biogas energy development received what they called a “special momentum” for countrywide biogas programme in 2008, and this momentum is attributed to an inspiration gained from a conference in Kenya on the potential of biogas in the region. Although Tigabu and his colleagues do not mention
climate change as a driver of the new biogas momentum, the year 2008 in which the special momentum happened coincide with the climate change push factor, therefore it could be possible that it indeed played a role.

In Uganda, climate change concerns brought significant shifts in the growth of the improved cookstove TIS. It brought new impetus to the structure and key processes. What is apparent, however, is that although this big exogenous push led to acceleration of cookstove generation and diffusion in the short run, it disrupted the evolutionary growth trajectory and caused negative feedbacks in the system. For example, limited control of entry and exit of the actors has compromised stove quality. Lack of regulation on funding schemes like carbon finance led to the introduction of the destructive direct subsidies on stoves, which consequently caused market distortion (cf. section 8.1.6.1.3). Therefore, climate change finance in Uganda was to a large extent what I have termed a disruptive push factor than a stimulus in the improved cookstove TIS. Research (e.g. Altenburg, 2009) already suggested that technological learning is a cumulative undertaking, whose decisions taken at the start of the evolutionary processes determine the technological development trajectory. In Uganda, we can see that climate change finance disrupted the evolutionary trajectory of the improved cookstove TIS, including technological learning, hence causing shocks and damage in the system.

With the current structural shocks (change of government priority and decreased external funding (cf. sections 8.1.4 and 8.1.6.1), the TIS presently stands at crossroads. This stage is characterised by reduced activity caused by what I have termed structural thinning, or a state where the TIS experiences loss of key structural elements such as policy support and key actors like financiers at a formative stage. Structural thinning can also mean premature disengagement of key structural elements from the TIS. Once this premature disengagement happens for example loss of funding for research and development resulting from changing donor priorities, this destabilises key
processes such as knowledge development, market formation, resource mobilisation and legitimacy creation in a young innovation system. On the other hand, structural shocks in the system represent responses to abrupt actions of the key actors such as change of government priority from improved cookstoves to LPG and disengagement of funders. Structural shocks are a result of structural thinning.

Existing literature theorises that low entry and exit of actors is one of the characteristics of a TIS in its formative stage (Markard, 2020; Bento and Wilson, 2016; Bergek et al., 2008a), therefore losing critical actors like financiers in Uganda where government funding is limited presents challenges to further research and development, capacity building, and market activation.

Findings of this study suggest that the quality of structural elements is important in determining the quality of activities implemented in the system. In Uganda, firm entry is associated with poor stove quality, contrary to suggestions by Bergek et al. (2008a) saying firm entry is beneficial to the system because it brings new knowledge and bridges gaps in the system. Secondly, institutions that are disconnected from the TIS’ needs have proved, in Uganda’s case, inadequate in addressing pertinent issues like stove quality. Although Bergek et al. (2008a) and Kieft et al. (2017) suggest that it is difficult to measure how good or bad the structure of an innovation system is unless it is measured against the functions they fulfil, and that it is not feasible to tell how many elements are sufficient, evidence from Uganda shows that indeed the way the structure is organised, including motivation for participation in the system can give insight into the state of the TIS.

Relatedly, Woolsthuis et al. (2005) emphasised the importance of the structure of the TIS in determining its performance, and indeed suggested that system problems are structural (capabilities failures (actors), interaction failure (networks), institutional failures (institutions) and infrastructural failures (actors and artifacts)). More recent
studies for example by Wieczorek and Hekkert (2012) and Kieft et al. (2017) suggest that instead of applying them individually, the structural and functional analyses should be combined to create a comprehensive picture of the performance of the innovation system and identify where problems lie.

**Nascent or Stunted TIS?**

The TIS of the improved cookstoves is still in formative stage and presents characteristics such as volatile market and diffusion being limited to urban areas, distorted pricing systems, limited quality control, low levels of economic activity and diffusion compared to estimated potential, small number of actors along the value chain, high entry and exit of actors, unclear performance parameters, low structuration, reliance on informal institutions like collective expectations. Markard’s paper “The Life Cycle of Technological Innovation Systems” (2020) depicts nascent TIS as having similar characteristics as found in the improved cookstoves TIS in Uganda, although some attributes don’t fully match. For example, Markard says a nascent TIS depends on context structures such as universities and existing industries, but this was not the case with the improved cookstove TIS in Uganda. There was very limited evidence of interaction between universities and research institutes and manufacturers except for testing purposes and this could affect knowledge development. Further, the divergent technological frames on what stove innovation is in Uganda (cf. section 7.1) generates conflicts and tension in the system, hence inhibiting wider generation and adoption of these technologies. These negative systemic feedbacks can be attributed to rapid expansion of the structure and acceleration of system functions with weak institutional support.

Although Bergek et al. (2008a) warn that analysts should not judge an innovation system in formative phase based on the volume of economic activities because this phase is characterised by small volume of activities and more experimentation, I argue that ensuring quality of whatever volume of economic activities being implemented
is essential for effective innovation system building. Following Kieft and colleagues (2017), I argue that the quality of whatever activities the structural elements engage in is an essential indicator of effectiveness of the structure of the innovation system and growth. Considering therefore that the improved cookstove innovation system is about 35 years old but still grappling with issues of stove quality, a weak institutional framework characterised by an inappropriate standard and a lack of policy on clean cooking, limited technology dissemination, ineffective stove testing, weak networks, R&D financing not adjusted to the needs of the system, points more to stunted, as Bergek et al. (2008a) refer to it, than a young system.

9.2 CONCLUSION

There is limited literature on the TIS analysis in developing countries (Edsand, 2019; Jauhiainen and Hooli, 2017; Lundvall et al., 2009). Most of the existing literature focuses on National Innovation System analysis (e.g. Mugwagwa and Banda, 2021; Yongabo and Göransson, 2020; Maloney, 2017; Papaioannou et al., 2014; Chataway et al., 2009; Altenburg, 2009; Kaya, 2009). The limited research on technological innovation systems in African countries mainly focuses on evaluative, functional analysis of the different elements in the innovation system, for example bio-digestion technology innovation system in Rwanda (Tigabu et al., 2015a), bio-digestion innovation system functioning in Rwanda and Kenya (Tigabu et al., 2015b), solar PV systems in Ethiopia (Kebede and Mitsufuju, 2017), and innovation system perspective in analysing adoption and diffusion of renewable energy technologies in Africa (Tigabu, 2018). Employing both structural and functional analysis, this study has therefore made contribution to the knowledge of how the systemic factors influence diffusion and adoption of cookstove technologies in Uganda. While criticising the TIS analytical limitations, Edsand (2017) says that the functional analysis largely focuses on the influence of endogenous factors (inward looking) on the functional performance of the innovation system with limited attention to exogenous factors.
This study has partly addressed this criticism by providing evidence on the influence of exogenous factors such as climate change and external actors on the improved cookstove TIS growth in Uganda.

Although factors responsible for slow rate of uptake and diffusion of improved cookstoves in developing countries, and specifically Africa, may superficially look homogenous (financial and affordability challenges, low levels of awareness of stove users, cultural rigidity, stove attributes and performance) as mainly presented in literature (e.g., Kapfudzaruwa et al., 2017; Kumar et al., 2016; Kshirsagar & Kalamkar, 2014; Lewis & Pattanayak, 2012; Sovacool, 2012; Oyedepo, 2012; Kaygusuz, 2012; Kaygusuz, 2011; Haselip et al., 2011; Mondal et al., 2010; Karekezi et al., 2008), intricacies and local dynamics in each individual country’s innovation system inform variations in the pace of diffusion and adoption of these technologies. The heterogeneity of country contexts and innovation system build-up therefore calls for more critical interrogation of the challenge of slow diffusion and adoption of cookstove technologies in developing countries than what is currently obtained in a vast swathes of the technical literature.

From my research findings, I conclude that the improved cookstove TIS in Uganda has been a phased process and largely externally induced. It is heavily influenced by external factors than local conditions, and has largely pursued an exclusionary innovation trajectory. The voices of some actors especially the local entrepreneurs and users are largely muted in preference for external actors’ interests and objectives. This not only exposes the system to an ever-shifting external actors landscape of interests and priorities, but also misaligns the system from the socio-economic realities in Uganda. Although it brought about some positive feedback in the system in the short run (e.g. acceleration of cookstove generation and diffusion through funding and capacity building), externally engineered system building has proved to generate vulnerabilities in both the structure (e.g. a standard that seeks to meet international
parameters than local needs, climate finance direct subsidies disrupting the existence of some of the local enterprises, networks’ activities being largely donor driven) and key processes of the system (climate change finance distorting the market). Although Chataway et al. (2014, pg 34) tend to suggest that exclusionary innovation trajectories are mainly a thing of the past, my results show that innovation system dynamics still lead to such negative outcomes even today.

The priorities and preferences of Ugandan stove users and local manufacturers innovation objectives are subordinated to the priorities and policies of the external promoters of improved cookstoves. As Davidson and Pai (2004) suggested, technologies are social artifacts, and as such their material form and function will embody their sponsors' and developers' objectives, values, interests, and knowledge regarding that technology. Confirming Davidson and Pai’s suggestion, indeed the improved cookstove TIS in Uganda seeks to fulfill the objectives and interests of external actors than local priorities. Not only that but also there exists contention on what constitutes an improved stove innovation in Uganda. If actors cannot agree on such a crucial component of the innovation process, then how will consensus on the focus and direction of the TIS be built? In a nutshell therefore, my study has revealed that indeed the improved cookstove promise stands like an illusion in the practical landscape.

In addition to generating rich insight into how the innovation system works in a developing country context with specific reference to Uganda, this study has also developed new concepts (Table 23) as well as contributed to theory building. This study has contributed to theory building by explaining the role of qualitative characteristics of structural elements in system building, providing evidence on the extent to which external actors can influence innovation system building, and how a system experiences structural thinning and structural shock and the possible consequences of such systemic changes.
Table 23: New Concepts from this Research

<table>
<thead>
<tr>
<th>Concept</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Pre-adoption Bias</td>
<td>The inherent fear users have about adopting a new technology.</td>
</tr>
<tr>
<td>Post–adoption Bias</td>
<td>The negative attitude users develop about a new technology after adopting it.</td>
</tr>
<tr>
<td>Structural Thinning</td>
<td>A state where the TIS experiences loss of key structural elements such as policy support or key actors like financiers at a formative stage.</td>
</tr>
<tr>
<td></td>
<td>It can also refer to premature disengagement of key structural elements from the TIS.</td>
</tr>
<tr>
<td>Structural Shock</td>
<td>An abrupt significant change in the structuration of the innovation system, possibly resulting from structural thinning.</td>
</tr>
</tbody>
</table>
9.3 RECOMMENDATIONS FOR POLICY MAKERS, LOCAL FIRMS AND NETWORKS

This study recommends *structural alignment* in order to absorb the current *structural shocks* and also create a better institutional environment friendly to growth of the TIS in Uganda. Specifically, standards need to be reconciled with country-specific needs, and also need to be involuntary to curb stoves counterfeiting. There is a need for a policy guidance on clean cooking and clear coordination and implementation focal points in government agencies. Structural alignment also speaks about reorganisation of networks.

There is need for a reinvention of the vehicles of formal interaction in order to cope with the changing context. Networks for improved cookstoves in Uganda were established by professionals and funding agencies and none were created by stove manufacturers. Findings of this study highlighted legitimacy challenges of these networks among local manufacturers (cf. section 6.4). There was limited sense of belonging to these networks. With the changing context, local manufacturers need to mobilise themselves into an industrial network that can advocate and lobby for their focal technology. Government focus is now on LPG whose rate of dissemination is at 1% compared to 15% for improved cookstoves in urban areas (NDP III, 2020). Considering the cooking habits and user technological frames for improved cookstoves, with vigorous advocacy and lobbying coupled with improving stove quality, the improved cookstove TIS stands a chance of earning back government support.

The same way there are indicators of functional performance of the different TIS functions, there is a need to generate indicators of quality of structural elements quality. My findings show that the quality (capability) and intentions of structural elements affects fulfilment of the TIS functions. I therefore infer that qualitative characteristics of structural elements are key to a strong and efficacious TIS structure.
Interrogating the motivation behind for example firm entry, networks establishment and standards generation can provide insight into the qualitative power of such structural elements to the system.

9.4 IMPLICATIONS FOR POLICY

From the findings of this study, it was evident that there is a need to align institutions to the needs of the system, especially the local manufacturers’ innovation focus, and user preferences and cooking habits. An involuntary standard is likely to be more effective in dealing with the issue of counterfeit stoves and stove quality in general. Secondly, a policy framework to streamline and adapt R&D funding to the needs of the system would shield the system from the vulnerabilities of unregulated funding schemes.

There is a need for deliberate efforts by local entrepreneurs to mobilise internal agency to create home-grown, entrepreneur-driven networks that can become the main mechanisms of interaction. Based on the evidence of the successful entrepreneur-driven water solar heaters innovation development in Barbados (Rogers, 2016), and the experiences of USEA in Uganda (cf. section 8.1.6.1), and the key role research places on entrepreneurs (e.g., Egbetokun et al., 2017; Carlsson and Stankiewicz, 1991), I am inclined to suggest that a strong entrepreneur-driven industrial network can exercise some degree of independence in relation to donor agendas, than it is possible for donor driven networks. It can also possibly become an avenue of interaction which includes stove users in the TIS building since this research shows that there exists a weak linkage between the private and public sectors, and entrepreneurs seem to understand user needs and preferences better.

9.5 FUTURE RESEARCH

Results from this study alluded to the possibility that that there is a strong correlation between fitness for purpose and intensity and sustained use of the improved stove.
detailed interrogation on improved cookstove use patterns and intensity is important because over time, as Pine et al. (2011) suggest, new products develop one of four patterns of use: i) intense use (product has both high rate and high variety of use); ii) specialized use (product becomes a specialized tool that is used at a high rate for only one or two tasks); iii) non-specialized use (product has a high variety of uses but low rate of use); and iv) limited use (product has few if any worthwhile uses and thus rate of usage is also low, possibly to the point of discontinuance). Patterns and intensity of improved cookstove use therefore need to be explored in order to understand better a number of issues, including: 1) actual contribution of these technologies to emission reduction and fuel saving, and 2) determinants of intense use of improved cookstoves.

This research was focused on understanding how the improved cookstove innovation system works in Uganda. The findings are primarily about the structural configuration of the improved cookstove TIS as well as the functional pattern of the key processes. This study therefore did not comprehensively evaluate the performance of the improved cookstove TIS. A comprehensive evaluation of the functional performance of the improved cookstove innovation system, which analyses the systemic problems (blockages) would be useful to inform broader policy reform in the system.

There is need to explore in more detail the concept of technological frames and provide a concrete illustration of its application and value in generation, adoption and use of improved cookstoves. My findings show that technological frames and interaction of the frames can help explain the adoption and use of improved cookstoves.

There is a need for comprehensive study of the informal interaction mechanisms employed by the different actors. Research finding (cf. section 6.5) revealed that actors interacted in other informal ways including social media and off-the-record
interactions. There is a need for better understanding of these informal structures of interaction and how they influence decision making in the system.

In the face of decreasing funding from mainstream funders (cf. Chapter Eight), there is need for research on the plausibility of innovative financing for the renewable energy technologies in general and improved cookstove technologies in particular in Uganda. This will involve studying the non-traditional applications of solidarity, Public Private Partnerships (PPPs) and catalytic mechanisms that (i) support fundraising by tapping new sources and engaging investors beyond the financial dimension of transactions, as partners and stakeholders in development; or (ii) deliver longer term and more predictable financial solutions to development problems on the ground.

Research on incremental improvements on improved cookstoves is necessary in order to achieve significant progress on emission reductions (both indoor and outdoor) among other targeted achievements such as fitness for purpose. This research has demonstrated in Chapter Five how the improved cookstove sector grapples with low stove quality, which directly affects emission reduction targets on one hand and some stove technologies do not meet user expectations (Chapter Seven). Incremental innovation research on improved cookstove will help to generate an appropriate innovation that meets both emission and end user expectations.
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World Bank (2014). Clean and Improved Cooking in Sub-Saharan Africa: A Landscape Report


APPENDIX 1: INFORMED CONSENT FORM

University of Edinburgh
School of Social and Political Science
Chrystal Macmillan Building
15a George Square
Edinburgh EH8 9LD UK
Dear Sir/Madam,

Re: Informed Consent for the study of “Understanding Diffusion and Adoption of Improved Cookstove Technologies through the TIS”

You have been identified as a participant in the above titled study. It seeks to interrogate the institutional context of renewable energy technologies and how it influences diffusion and adoption of these technologies in a developing country context. The study is inspired by the growing interest in renewable energy as the best and possibly the only choice for achieving sustainable development on one hand, and the concern over low diffusion and adoption of renewable energy technologies on the other.

Please note that as a participant, if at any point you decide to withdraw from the research, you will be free to do so. Also note that information given will be treated with confidentiality. And on no account will any other person apart from me and my supervisor have access to the information. If as a participant you wish to remain anonymous, it will be respected and pseudo names will be used.

Participant’s Name________________________________________________
Participant’s signature_______________________________ Date _____________

PhD student Contact Information Supervisors’ Contact Information
Annet Nakyeyune Prof James Smith
Email: Dr Jean-Benoit Falisse
Tel: +256 772575779
APPENDIX 2 – INTERVIEW SCHEDULE FOR TOP MANAGERS/ ENTREPRENEURS
1. What was your motivation to venture into cleaner bioenergy cookstove development/promotion?
2. Describe the technologies you are developing or implementing and their possible application.
3. What is the possible impact of your technologies on for example fuelwood use, emission (indoor), meeting the cooking needs of the users? How do you measure this impact?
4. Describe the stage you are currently at with your technological innovation(s) – (Discovery, incubation, acceleration, commercialisation/dissemination).
5. How did the innovation develop through the different stages?
6. Explain the stakeholders that are important in the development and implementation of the technological innovation(s). (disaggregate by stage of development)
7. Why are these stakeholders important and how do they affect the development process of your technology(ies)?
   How did/do you interact with them?
8. Explain the process you go through to successfully develop and disseminate your technologies.
9. *Present and explain the Technological Innovation System functions.* Are these processes all in place in the improved cookstove field? Or should they actually be?
   From an entrepreneur point of view, is any process missing?
10. In which way are the processes in the development of cleaner bioenergy cookstoves not working well? Why?
11. How do you think the development process of bioenergy cookstoves can be improved?

APPENDIX 3 - INTERVIEW SCHEDULE FOR TECHNICAL STAFF
F1 Entrepreneurial activities
1. What is the typology of cleaner bioenergy stoves developed or implemented? Why these particular types?
2. At what scale is the production of your technologies?
3. How does the current operation scale affect development and dissemination of technologies?

F2 Knowledge development
4. At what rate does the sector attract new entrants?
5. How do you promote your technologies?
6. How do you assess the demand for and impact of the technologies?
7. How do you ensure that the technologies meet standards and needs of users?
8. What capacity building activities do you engage in?
9. How does the quality and quantity of existing knowledge affect development and diffusion of the technologies?

F3 Knowledge diffusion
10. How do you create awareness about the technologies you develop?
11. How does the current knowledge availability and dissemination affect the development and dissemination of the technologies?

F4 Guidance of the search
12. What is the vision of the cleaner bioenergy industry and market in terms of growth, technological design, expectations regarding the technological field, goals? Is this a shared vision?
13. How does this (or lack of) shared vision affect the development and diffusion of the technologies?

**F5 Market Formation**
14. What is the current and expected market size for cleaner bioenergy cookstoves?
15. How does the market size affect the development and diffusion of the technologies?

**F6 Resource Mobilization**
17. What kind of human capacity do you have? Is it sufficient?
18. What is the nature of your financial envelop? Is it sufficient?
19. What kind of resource constraints are you faced with that impede successful development and dissemination of the technologies?
20. Do you have the physical infrastructure needed to develop and disseminate the technologies?

**F7 Creation of legitimacy**
21. How long does the technology take from designing to dissemination?
22. How do you influence acceptance of your technology?
23. What kind of resistance is your technologies faced with? How does it affect development and dissemination of the technologies?
24. From a technical point of view, is any process missing to achieve successful development and dissemination of technologies?
APPENDIX 4 - INTERVIEW SCHEDULE FOR NEW ENTRANTS

1. What was your motivation to venture into cleaner bioenergy cookstove development/promotion?
2. Describe the technologies you are developing or implementing and their possible application.
3. What is the possible impact of your technologies on for example fuelwood use, emission (indoor), meeting the cooking needs of the users?
4. Describe the state you are currently at with your technological innovation (s) – (Discovery, incubation, acceleration commercialisation/dissemination).
   How did the innovation develop through the different phases?
5. Explain the stakeholders that are important in the development and implementation of the technological innovation (s).
6. Why are these stakeholders important and how do they affect the development process of your technology (ies)?
   How did you interact with them?
7. Explain the process you go through to successfully develop and disseminate your technologies.
8. Present and explain the Technological Innovation System functions. Are these processes all in place in the cleaner bioenergy cookstove field? Or should they actually be?
   From an entrepreneur point of view, is any process missing?
9. In which way are the processes in the development of cleaner bioenergy cookstoves not working well? Why?
10. How do you thing the development process of bioenergy cookstoves can be improved?
APPENDIX 5 - INTERVIEW SCHEDULE FOR QUITTERS

1. Why did you leave the cleaner bioenergy sector?
2. Who are the key stakeholders in the sector and what is their role?
3. In which ways do the stakeholders interact? Where are the gaps?
4. From your experience, what are the major contributing factors to the successful development and dissemination of the technologies?
5. What are the major impediments to the successful implementation of cleaner bioenergy cookstove activities?
6. How can these impediments be overcome?
7. How do you see the future of the bioenergy sector in terms of production of technologies and their dissemination?
APPENDIX 6 - FOCUS GROUP DISCUSSION GUIDE FOR USERS

1. Why did you adopt a cleaner cookstove? How did you learn about availability and benefits of cleaner cookstoves?

2. What do you look out for in a stove? Which type of stove (s) do you prefer and why?

3. To what extent do the promoted stoves meet your needs? How often do you use the acquired stove (rate and variety of use)?

4. What do you perceive as the impact of cleaner cookstove technologies? (on IAP, fuelwood use, money, time, safety, technology transfer, cleanliness)

5. Have you ever participated in the development of these stoves?

6. How would you like to be involved in the cleaner cookstove development process?

7. How can adoption and dissemination of cleaner cookstoves be improved?
### APPENDIX 7 – OBSERVATION GUIDE

<table>
<thead>
<tr>
<th>Aspect of Observation</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>General environment</td>
<td>Factory structure, organisation, workers</td>
</tr>
<tr>
<td>Materials</td>
<td>Stove fabrication materials, liner making materials</td>
</tr>
<tr>
<td>Processes</td>
<td>Clay mixing, liner moulding, liner baking, fabrication of different stove parts, attaching spare parts, stove body painting</td>
</tr>
<tr>
<td>Equipment</td>
<td>For different processes</td>
</tr>
<tr>
<td>Products</td>
<td>Different stove types and sizes, complimentary products</td>
</tr>
</tbody>
</table>
APPENDIX 8 – STOVE TEST REPORT

ISO/IEC 17025:2005 LABORATORY MANAGEMENT SYSTEM

STOVE TEST REPORT
TEMPLATE USING FDUS
761:2018

Document No.: CRC/FORM/ON-56
Issue No.: 01
Revision No.: 00
Date of issue: 20 May, 2018
Next review date: June, 2020

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TEST REPORT
Report No: B/TR/2018/019

Name of stove: BM Energy Saving stove size II
Type of stove: Ceramic charcoal stove

Manufacturer: BM Energy Saving Equipment

<table>
<thead>
<tr>
<th>Sample laboratory code</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2018/B084</td>
<td>2018/B089</td>
<td>2018/B090</td>
</tr>
</tbody>
</table>

Number of test repetitions: 3
Fuel type: Charcoal
Water content: 5.9%
Low heating value (LHV): 30.717 KJ/kg

Stove description and physical characteristics

Test site: CREEC RTKC Laboratory
Test date: 28 – 30 May 2018

Standard referred: Final Draft Uganda Standard FDUS 761.2015 Household biomass stoves - Requirements

Test environment conditions:
- Ambient temperature: 21°C-24°C
- Humidity: 56%-65%
- Wind speed: No wind

Test equipment:
- Weighing scale: LEMS
- Gravimetric

Model:
- Class 111
- 2029
- CX 285

Serial no/asset no:
- CRC/BL/050
- CRC/BL/001
- CRC/BL/065

Date of calibration:
- Dec 2017
- Aug 2017
- Dec 2017

Test items

<table>
<thead>
<tr>
<th>Test items</th>
<th>Units</th>
<th>Average</th>
<th>Standard deviation</th>
<th>Classification 1</th>
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<tbody>
<tr>
<td>Thermal performance</td>
<td>Cooking power, $P_c$ (kW)</td>
<td>0.7</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>High power Thermal efficiency, $\eta_h$ (%)</td>
<td>31</td>
<td>0.02</td>
<td>Class 3</td>
<td></td>
</tr>
<tr>
<td>Emission factor</td>
<td>$PM_{10}$ (mg/MJ)</td>
<td>8</td>
<td>3.24</td>
<td>Class 1</td>
</tr>
<tr>
<td></td>
<td>CO (g/MJ)</td>
<td>26</td>
<td>4.36</td>
<td>Not rated</td>
</tr>
<tr>
<td>Safety score</td>
<td>Points</td>
<td>88</td>
<td>Class 2</td>
<td></td>
</tr>
<tr>
<td>Durability score</td>
<td>Points</td>
<td>88</td>
<td>Class 2</td>
<td></td>
</tr>
</tbody>
</table>

Recommendations:
The stove is in class 3 for thermal performance and is not rated for Carbon monoxide (CO). There is need to improve the stove design to reduce especially on the CO emissions that are quite high as well as improve on thermal performance. This requires more technical discussion upon request from the manufacturer. The stove is in class 2 for both safety and emissions.

Test institution: Centre for Research in Energy and Energy Conservation (CREEC)

Name of Tester: Derrick Kivana
Date: Jul 7, 2018

Name of Supervisor: Agnes Natuwa
Date: Jul 7, 2018

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1 Refer to the classification criteria in annex 1

B/TR/2018/019
### Annex 1: Classification Criteria of carbonized biomass fuel stoves as per FDUS 761:2018

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Efficiency, %</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Emission Factor</td>
<td>PM_{2.5} mg/MJ</td>
</tr>
<tr>
<td></td>
<td>CO g/MJ</td>
</tr>
<tr>
<td>Safety %</td>
<td>≥95</td>
</tr>
<tr>
<td>Durability %</td>
<td>≥94</td>
</tr>
</tbody>
</table>

Note. The values are determined in accordance with the test method in the FDUS standard 761 and should be corrected to nearest whole number.

Class 3 → Improving Performance → Class 1