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DETERMINANTS OF IMPROVED COOKSTOVE ADOPTION AND SUSTAINED USE TO REDUCE TRADITIONAL WOOD FUEL USE IN RURAL LESOTHO

by

Daphné Carliez

(2395575)

A research report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in

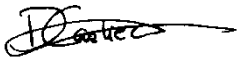
Environmental Sciences

Supervisor: Professor Wayne Twine

May 2021, Johannesburg

Declaration

I declare that this dissertation is my own, unaided work. It is being submitted for the Master of Science, Environmental Sciences, at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.



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31st day of May 2021 in Johannesburg

Abstract

In rural Sub-Saharan Africa, the implications of heavy traditional wood fuel dependency and its negative environmental and social impacts remain a grave concern. The reliance on wood fuel for cooking and heating prevails and is expected to remain the primary form of energy for many rural households. As a consequence, the region is witnessing natural resource depletion and has left households deprived of access to sustainable energy resources. To address this challenge, development stakeholders have long advocated the introduction of improved cookstoves (ICS). These solutions had been anticipated to address the challenges of cooking with solid biomass, but despite their potential benefits, a large number of barriers have stalled their uptake and sustained use. Neither these barriers nor enabling factors promoting adoption and sustained use are well understood. This is preventing further improvement of such technologies across the continent and risks the widespread roll out of unsustainable instruments and investments which may not yield the desired long term outcomes.

This research was undertaken to identify key barriers and enabling factors to the adoption and sustained use of ICS in rural Lesotho and similar contexts in Sub-Saharan Africa. Lesotho is a perfect example of the need to improve the understanding of ICS adoption and long-term use determinants in an effort to reduce traditional wood fuel use given its prevailing energy-access challenges and environmental vulnerabilities. The need to address these wood fuel challenges in Lesotho is high, while literature has largely excluded this nation from its research efforts in this field. The study findings contribute to the existing body of work by by uncovering the broad range of determinants and their relative importance for the adoption and long-term use of ICS in Sub-Saharan Africa and the extent to which regional drivers and barriers are transferrable to the context of Lesotho.

Three separate data-collection methodologies were used, including a literature meta-analysis (n=425), key-informant interviews (n=17) and a survey of experts (n=30), to understand the various determinants, perspectives and challenges in the region. The findings demonstrate a substantial gap between the existing body of work conducted on ICS adoption and the long-term use of these

technologies. Determinants that are essential for the adoption differed from those required to allow the sustained-use of these technologies at the household level. The variability found among contextual variables between Sub-Saharan Africa and Lesotho further emphasize the need for well-informed targeted approaches to stimulate and facilitate the ICS adoption process.

A number of technological, programmatic and policy factors which have received limited attention in existing ICS literature were found to be important determinants for the adoption and sustained use of ICS. In particular, policy and programmatic mechanisms should be utilized to address financial constraints at the household level. The study shows that increased consideration needs to be given to local household needs and cooking practices and the ICS' overall user-experience beyond fuel-efficiencies. In Lesotho specifically, the additional benefits people receive from their traditional cooking methods are often overlooked and not fully substituted by an ICS, rendering the technology ineffective as a substitute for traditional wood fuel use. The ambition to fully transition away from traditional cooking practices should be reconsidered and more emphasis needs to be placed on introducing context-appropriate and convenient wood fuel-reducing technologies that can become part of the household's cookstove and fuel portfolio instead.

Acknowledgements

I cannot express enough appreciation for the guidance, swift feedback and encouragement from my supervisor Professor Wayne Twine. His supervision has offered me invaluable advice and insights throughout the process with great learning opportunities to continuously improve my work.

I would also like to acknowledge Dr. Ruwadzano Matsika for her guidance during the research proposal development as her insights and knowledge on the subject greatly helped shape the vision for the research report.

I would also like to extend my sincerest thanks to the staff of The United Nations World Food Programme (WFP) Lesotho. I would like to thank in particular Marian Yun, Likeleli Phoolo and Nkopo Matseppe for their immense support in finding the information needed and facilitating connections with key experts in Lesotho.

Lastly, I would like to share my gratitude for the many experts and informants sharing their perspectives, knowledge and experiences without whom this research would not have been possible.

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Chapter 1 INTRODUCTION

This chapter provides the contextual background and rationale for this study. It also present the study aim and objectives, including the questions that this research seeks to answer.

1.1 Rationale for this study

The global dependency on wood fuel is a complex and burning energy-access issue rife with environmental challenges and social inequalities. Nearly three billion people, mostly in developing countries, are reliant on wood fuel as their primary source of energy. Sub-Saharan Africa has one of the lowest electrification rates in the world and as a result, one of the highest dependencies on wood fuel to meet household energy needs (World Bank, 2020). This wood fuel dependency has been a pressing issue of concern for numerous decades and while it can be a sustainable source of renewable energy, it is often cast as damaging to both people and their environments (Fullerton et al., 2008; Rudel, 2013; Sulaiman et al., 2017). Energy poverty in this part of the world is expected to worsen, partially due to its rapid growing population, as well as financial and technical limitations when it comes to connecting households to the grid (IEA, 2014, 2019). Although electrification rates in Africa marginally overtook its population growth recently, this trend is not visible in all countries and the lack of energy remains a major constraint, particularly for rural communities (IEA, 2019).

Rural electrification rates fall far behind Sub-Saharan Africa's national levels and even if connected, rural households face numerous challenges when it comes to the reliability and affordability of electricity, especially for cooking (World Bank, 2012, 2020). As a result, the majority of households in rural areas are mostly reliant on burning biomass, including wood fuel, agricultural waste and dung, on a three-stone open fire or traditional stove for cooking and heating (Kaygusuz, 2011; Putti et al., 2015). Using solid biomass fuels in this manner is very inefficient. It requires large amounts of fuel as a result thereof and can lead to negative health impacts from household air pollution, (localized) environmental degradation from wood fuel collection, and wood fuel scarcity (Fullerton et al., 2008; Putti et al., 2015; Bailis et al., 2017; Sulaiman et al., 2017; WHO, 2019).

Despite extensive research aimed at assessing and addressing the underlying issues of wood fuel dependency, few long-term successful innovations have been introduced to help solve the matter (Leach and Mearns, 2013; Caniato et al., 2017). The lack of alternative energy options and natural resource depletion stemming from high levels of wood fuel usage in the region leave many rural households without sufficient energy to prepare their meals (Putti et al., 2015). For many years, the introduction of Improved Cooking Solutions or Stoves (ICS) and 'clean' fuels were considered promising solutions to tackle or mitigate a number of challenges associated with traditional wood fuel use. However, the implementation of ICS programmes have largely been unsuccessful as the adoption and continued use of these technologies remain fairly low (Vahlne and Ahlgren, 2014; World Bank, 2014). In spite of decades of research and numerous development and government programmes aimed to increase the uptake of clean and improved cooking technologies, there is still limited agreement on the preferred models and methods for its dissemination as adoption barriers, drivers and suitable technologies tend to be situation and context specific (Ekouevi, 2013; Palit and Bhattacharyya, 2014; Vigolo et al., 2018). Instead of turning away from fuel-efficient and improved cookstoves after its previous failures, a closer look at the complexities of these technologies and household adoption barriers is warranted, especially given the fact that there are often limited alternative solutions. Special importance needs to be placed on understanding the variables leading to, and influencing, the initial uptake and the long-term primary use of improved cookstoves. The latter, the sustained use of ICS, has particularly received limited attention in research and programmatic efforts. Without the long-term primary use of ICS technologies, the envisioned wood fuel reductions will not materialize.

Measurements in assessing drivers and barriers for the initial adoption as well as the continued use of improved stoves have been largely inconsistent or even excluded in assessing the success of ICS programmes. This is mainly because of the fact that indicators vary widely based on the objectives of different ICS programmes e.g. increasing food security or reducing household air pollution and greenhouse gas (GHG) emissions (Ruiz-Mercado et al., 2011; Barbieri et al., 2017). To date, ICS programme interventions have mostly followed a top-down approach, addressing energy-access challenges without fully factoring in context-specific needs and the benefits people obtain from their

current cooking practices (Urmee and Gyamfi, 2014; Khandelwal et al., 2017). This resulted in a number of unsuccessful programmes due to an incomplete understanding of the broad range of factors determining the adoption of ICS technologies, why households are not making the step towards the long-term use of improved cookstoves, and how these factors differ in various contexts.

To change course, well-informed and concerted efforts are needed based on a thorough understanding of the current dynamics of wood fuel dependency and context-specific needs and solutions. Filling in the research gap on variables that drive the adoption process of improved cookstoves, both for the initial uptake as well as its long-term use, could help advance the outcomes of ICS interventions, design better programmes and technologies and ultimately, hopefully, reduce challenges in cooking energy access and related health and environmental concerns for rural wood fuel-dependent households. For this research, the focus lies on identifying such context-specific drivers and barriers for Lesotho, a country overlooked in ICS research despite its severe challenges surrounding wood fuel dependency. These factors are first determined in the regional context of Sub-Saharan Africa and are then narrowed further down to rural communities in Lesotho specifically.

Lesotho is a landlocked country in southern Africa, suffering from severe environmental degradation caused by a number of man-made impacts including overgrazing, over-cultivation, forest conversion and firewood collection (Mwangi, 2008; Qalabane and Chakela, 2014; FAO, 2015). Rural electrification rates in the nation are still low and mostly unaffordable for the majority of the population, leaving the country with very few remaining forest resources and high levels of wood fuel dependency for its energy needs (World Bank, 2017a; Mpholo et al., 2018a). The majority of Lesotho's rural household energy consumption is taken up by cooking, while the uptake of ICS in this region has been very low (Kapfudzaruwa et al., 2017). Addressing these wood fuel dependency challenges can have important multiplier effects that encompass improved food security, sustainable management of natural resources, small-scale employment generation, improved health outcomes for end users, and increased resilience in the face of climate change impacts and environmental challenges.

This research aims to shed light and provide detail on a small part of this complex issue, specifically related to the adoption of ICS technologies, to help inform and guide interventions as part of tackling the global wood fuel and energy poverty challenge. The study is partially developed in support of potential efforts by the United Nations World Food Programme Lesotho (WFP) to introduce alternative household cooking energy technologies in rural and vulnerable households. WFP's interventions seek to improve food security and introduce safer and more secure cooking energy access options and mitigate the harmful health and environmental impacts of traditional wood fuel use. With this, it is hoped that the study will provide beneficial insights to improve and expand efforts to increase the application of improved and clean cookstoves for biomass and firewood dependent households in rural Lesotho. There is a particular ambition that the outcomes captured in this study will increase the effectiveness of existing and future ICS programmes and contribute to the transformation of rural household energy use in Lesotho in line with its National Climate Change Policy (2017), the Lesotho Energy Policy (2015) and the Nationally Determined Contribution (2017).

1.2 Aim

This research aims to identify context-specific determinants of the adoption and sustained use of improved cooking energy technologies by rural households in Lesotho and to explore existing knowledge, policy and programmatic gaps and potential solutions in the current ICS landscape.

1.3 Objectives and research questions

The main objectives of this study are to:

1) Understand the primary enabling factors and barriers to the adoption and long-term use of ICS in rural development contexts in Sub-Saharan Africa.
   Research question 1.1: Which enabling factors and barriers are identified in the literature as main determinants for the adoption and sustained use of ICS in rural households in Sub-Saharan Africa?

Research question 1.2: Which policy, programmatic and regulatory barriers and enabling factors have been identified in support of the adoption and continued use of improved cookstoves for rural households in Sub-Saharan Africa?

2) Contextualize the current use, benefits and challenges of wood fuel energy and traditional cooking methods in rural households in Lesotho.

   Research question 2.1: In what manner and for which purposes is biomass or wood fuel currently used in rural households in Lesotho?

   Research question 2.2: What are the current challenges experienced by rural households in Lesotho with their biomass and firewood cooking fuel use and cooking methods?

3) Understand the context-specific determinants of the adoption and sustained use of ICS in rural households in Lesotho.

   Research question 3.1: Which prevailing barriers and enabling factors are identified that prevent or support the uptake and long-term use of ICS in rural households in Lesotho?

   Research question 3.2: Which ICS models have been introduced in Lesotho and have failed or succeeded to achieve adoption and sustained use?

4) Identify and analyse the effectiveness of existing policies, ICS programmes and private sector models aimed at increasing the adoption and sustained use of improved cookstove technologies in Lesotho.

   Research question 4.1: Which ICS policies, ICS dissemination models, financial schemes and regulations are in place that support or hinder the adoption and long-term use of improved and clean cooking solutions at household level in rural Lesotho?

   Research question 4.2: How well do these existing policies, ICS programmes, private sector models and regulations help overcome existing barriers and align with the needs of households to drive the adoption and continued use of ICS?

Chapter 2 LITERATURE REVIEW

The section includes a detailed literature review covering the research objectives and questions to be answered. It also provides additional background to the context and setting for the study in Lesotho, including an explanation of the relevance of this study in this particular region.

2.1 The dynamics of wood fuel challenges

Wood fuel is described as the use of biomass energy in the form of firewood or processed wood including charcoal, wood chips, pellets and saw dust. The first serious concerns about the sustainability of wood fuel and its impacts emerged in the 1970's on the heels of the 73'-74' oil crisis. New research described a looming wood fuel crisis by a predicted increased demand that would outpace the regrowth of natural resources at an alarming rate (Eckholm, 1975). This wood fuel gap projected disastrous impacts on the environment and the many people around the world dependent on it for their energy consumption. Anticipated shortages spearheaded research to understand the implications of this theory and to identify potential solutions to deter these ominous outcomes (Arnold et al., 2006; Leach and Mearns, 2013). As a result, widespread reforestation and wood fuel plantation programmes as well as fuel-efficient cookstove interventions were introduced as solutions to bring wood fuel demand and supply into balance, albeit with limited success (Arts et al., 2012). When the wood fuel crisis failed to materialize as the forecasts were proven to be erroneous, an improved understanding of wood fuel use and sustainability came to light. Most notably it became known that wood fuel was not only derived from forests but was mainly extracted from shrublands and savanna woodlands which regenerate after harvesting (De Wees, 1989; Twine and Holdo, 2016). In addition, the fact that communities depending on wood fuel adopted coping mechanisms in times of scarcity was not factored in sufficiently (Dewees, 1989; Trossero, 2002). In line with these findings, the urgency and interest in the topic tailed off resulting in less research and programmes dedicated to addressing wood fuel use challenges (Arnold et al., 2006).

Now almost half a century later, it is evident that deforestation is not the biggest concern linked to wood fuel dependency, but many social and environmental issues remain, admittedly in a different form than initially predicted. While an absolute global wood fuel scarcity is unlikely to take place in the near future, challenges related to the production and management of wood fuel, economic accessibility, toxic emissions and linked health implications for its users, wood fuel scarcity at village level and land degradation caused by unsustainable wood fuel extraction are still glaring problems today (Dewees, 1989; Trossero, 2002; Sola et al., 2017; IEA, 2019). The inclusion of energy as part of the Sustainable Development Goals (SDGs) and the impacts of clean and improved cooking solutions as contributor to a number of SDG Goals, including health and environmental protection, brings renewed interest and active support of delivering access to affordable and clean cooking energy (United Nations, 2015). In light of this there is a more comprehensive view emerging within the global research community on wood fuel use, underlining and recognizing its complex and multifaceted nature as it is deeply integrated in the broader landscape of energy-poverty, population growth, livelihood challenges, agricultural production, natural resource management and policy challenges (Dewees, 1989; Matsika, 2012; Leach and Mearns, 2013; Caniato et al., 2017).

2.2 Geographic disparities and environmental threats

Making the already convoluted wood fuel dilemma more complicated is the current climate change crisis which threatens to exacerbate ongoing environmental challenges with potential implications for wood fuel supplies. Although wood fuel dependency is not localized to the African continent, developing countries in the Southern Hemisphere are expected to suffer the most devastation with countries in Sub-Saharan Africa hit the hardest in the form of extreme weather events, overall decreased precipitation levels and estimated temperature increases rising far higher than the global average (Samson et al., 2011; Egoh et al., 2012; FAO, 2018; IEA, 2019). While most of the wood fuel in Sub-Saharan Africa is collected in resilient woodland savannas and shrublands, the predicted increased rainfall variability in the region and temperature increases can impact these ecosystems and their valuable ecosystem services (Flannigan et al., 2000; Lenihan et al., 2006; Zhai et al., 2018). Elimination and competition among species due to changes in climate and water availability, changes

in soil-moisture levels affecting plant growth as well as disturbances such as increased wild fires and droughts can impact the amount of woody biomass available including for wood fuel to meet energy needs (Flannigan et al., 2000; Scheffer et al., 2005; Kreuzwieser and Gessler, 2010; Allen et al., 2010; Ostberg et al., 2018).

Adding to these environmental and climatic stresses in Africa are regional annual deforestation rates that greatly surpass the world average (Kebede et al., 2010; Yalew, 2015; MacDicken, 2015; IEA, 2019). Although agricultural conversion is the main cause of global deforestation, accounting for some 80% of total forest loss, in Africa, unsustainable wood fuel extraction remains an important driver of forest and land degradation and constitutes for as much as half thereof (Kissinger et al., 2012; Jabbour and Hunsberger, 2014; FAO, 2016; Sulaiman et al., 2017). Forest cover loss can also lead to disruptions in important local ecosystem services; e.g. trees support agriculture through regulation of water flow, soil stabilization and soil fertility and provide energy necessary to cook and consume meals in the form of wood fuel or charcoal (Krieger, 2001; FAO, 2016). These changes in ecosystem services are of particular concern in Sub-Saharan Africa which is characterized by a high dependency on wood fuel as a response to steep chronic energy insecurity levels (Sulaiman et al., 2017; IEA, 2019). In the case of Lesotho, which is already one of the least forested countries in the region with limited agricultural land and a high wood fuel dependency, such stresses further highlight the need for more sustainable wood fuel usage.

An extensive range of policy measures aimed to increase the sustainability of wood fuel sourcing have been introduced in the Sub-Saharan African region, often including a complete ban on wood fuel extraction (FAO, 2017a). For example, in Malawi, where the majority of the population is reliant on charcoal and firewood for household energy consumption, there is a statutory ban on non-commercial and unsustainable wood fuel extraction (Zulu, 2010). As part of this legislation, many wood fuel producers remain unsupported and marginalized and these conditions leave little space for active engagement with producers. It limits motivation for investments in more sustainable production methods for producers as a result thereof. At the same time Malawi's energy policy advocates for an energy transition from wood fuel to electricity even while this has proven to be a difficult feat and

does not align with local realities on the ground (Openshaw, 1997; Zulu, 2010; IEA, 2019). Given the continued need for wood fuel for the foreseeable future in this part of the world, these bans have been proven ineffective in achieving the desired results.

Taking note of the challenges that are linked to the transition of energy use and wood fuel extraction bans, there has also been an uptake in policy work that addresses the rising needs of wood fuel products through wood lot creation and afforestation. Granted that a number of these policies have been successful in supporting the development of sustainable wood fuel products, in many instances these wood lots are exploited for logging as a more lucrative activity or caused significant environmental harm to existing eco-systems (Dewees, 1989; Chamshama, 2011; Matsika, 2012). For example, in a number of Sub-Saharan countries, the fast-growing invasive *Eucalyptus* species is widely grown and promoted to prevent soil erosion and meet growing needs for forest products including charcoal and firewood. Although this species can be cultivated with minimal inputs and provide a rapid return on investment, its negative environmental aspects, including its high water consumption and competition for space with indigenous species, have been widely documented (Chanie et al., 2013; Abebe and Tadesse, 2014). In Ethiopia, where over 90% of all total planted forests consists of this tree species, concerns have also been raised over this mono-cropping approach due to the arrival of insect pests that are specifically targeting Eucalyptus seedlings (Gezahgne et al., 2005; Bekele, 2011; Lemenih and Kassa, 2014; Aylward et al., 2018). Ill-advised policies and programmes and the lack of effective wood fuel policies, regulatory measures and subsequent forest tenure insecurity further drives inefficient natural resource management and forest degradation, adding to the challenges of wood fuel dependency in the region (Bassey, 2008; FAO, 2017a; GIZ HERA, 2018). While strict bans for wood fuel extraction have not been introduced in Lesotho, and despite the development of a holistic energy policy framework to support the more sustainable use of wood fuel and energy access, the lack of wood fuel availability still presents a serious concern for the majority of its population (LMS, 2015).

2.3 Energy consumption

Sub-Saharan Africa has access to a wide variety of energy sources, including oil, gas and coal reserves, powerful river systems to generate hydropower, uranium that can be utilized for nuclear energy production and a vast potential for solar energy (Kebede et al., 2010). These energy sources, however, are unevenly available to its inhabitants, especially to those living in rural settings who are therefore mostly dependent on biomass for cooking. The level of biomass dependency and the share of wood fuel used in the energy-mix in this region has hardly changed over the past couple of decades (Leach and Mearns, 2013; IEA, 2019). Currently some 600 million people here lack access to electricity and around 70% of the population is deprived of clean cooking solutions. Cookstoves or cooking fuels are deemed 'clean' when they meet WHO's guidelines on emissions. This includes electricity as well as gas, ethanol, solar power and high performing biomass cookstoves. As access to, and use of, these technologies and fuels are minimal in Sub-Saharan African, most households remain reliant on traditional biomass and rudimentary stoves for their energy needs. This in turn is resulting in high levels of household air pollution and inefficient wood fuel use (WHO, 2014). In spite of significant progress at the global scale to increase clean energy access, the modernization of the wood energy sector and electrification in Africa has lagged behind (Kebede et al., 2010; IEA, 2019). With a 45% household electrification rate, the region ranks lowest in the world and has almost 900 million people dependent on biomass, firewood and charcoal to prepare meals and heat their homes (Hafner et al., 2018; IEA, 2019). This lack of energy provision is especially delayed in rural communities which make up some 60% of the total population in Sub-Saharan Africa, leaving only 6% of rural households with access to clean cooking solutions (World Bank, 2017b; Bos et al., 2018; World Bank, 2018). Similar discrepancies are seen in Lesotho. Here, inadequate electricity infrastructure and lack of clean cooking solutions result in high wood fuel dependency levels, especially among rural household (LMS, 2015; Mpholo, 2018).

As demonstrated by the numbers, access to electricity does not always imply access to clean cooking solutions. According to the 2019 Africa Energy Outlook, electricity access encompasses at a minimum, sufficient power to run a number of lightbulbs and charge a fan, radio, television or phone,

but does not include electricity-services aimed to power cooking technologies (IEA, 2019). At the same time, access to clean cooking solutions means access to, and the primary use of, clean cooking fuels, including electricity, and stove technologies that can utilize these fuels. Not all households with access to electricity hold access to electric powered cookstoves, have sufficient and stable electricity to power cooking, or are unable or unwilling to make such a switch for various economic or cultural reasons (Madubansi and Shackleton, 2007; IEA, 2019). While numerous investments and policy changes that support the efforts of electrification up-scaling are anticipated to increase energy-security across the continent, it is important to note that newly connected households often do not tend to use electricity to meet their cooking needs. In Lesotho, where only 5,5% of its rural population has access to electricity, similar constraints have been identified where only a small part of that population would use electricity to prepare their meals (Mpholo, 2018). Rural populations in Sub-Saharan Arica may continue to be reliant on wood fuels for a number of household energy requirements, meaning that the number of households dependent on traditional wood-based fuels are still expected to rise with growing populations (Twine et al., 2003; Madubansi and Shackleton, 2006; Matsika et al., 2013; IEA, 2014, 2019).

As the impacts of climate change worsen and the population size continues to grow faster than the rate of electrification and access to clean cooking, the pressure on existing biomass energy services in this part of the world will grow further. In addition, the region will likely feel the heat of climate change through the additional demand for cooling and irrigation further adding pressures to local energy demands (Parkes et al., 2019; Van Ruijven et al., 2019). It is estimated that by the year 2040, the amount of biomass used in Sub-Saharan Africa will account for half of the global consumption, rising to 60% if South Africa is excluded (IEA, 2014; Lambe et al., 2015; Caniato et al, 2017; IEA, 2019). The recent COVID 19 pandemic and its negative economic impacts might further drive firewood use as households transition from LPG or electricity to more affordable wood fuel to prepare their meals and warm their home. In Kenya, this trend has already become visible with rural households switching back to cheaper fuel sources such as firewood and charcoal in the wake of the pandemic

(Njagi, 2020). Rural households in Lesotho may soon find themselves in a similar situation as the COVID pandemic is expected to further fuel high levels of biomass dependency (IEA, 2020).

2.4 Wood fuel use at the household level

The bulk of energy needs in rural households is Sub-Saharan Africa, including Lesotho, are attributed to cooking, heating and lighting of homes (Kebede et al., 2010; IEA, 2019). The use of biomass for households to meet these energy needs does not only stem from necessity, but wood fuel is at times also favoured to prepare meals and heat homes. This preference stems from the fact that wood fuel is available in a wide number of eco-systems, can be free of cost, is often easy to obtain, simple in use and constitutes as a form of renewable energy due to its regenerative capacities, among other cultural, climate and location specific reasons (Abbot et al., 1997; Akintan et al., 2018; Jiménez-Escobar and Martínez, 2019). People may prefer the flavour of food that is cooked on firewood, it can be an important cultural tradition to prepare meals this way, or firewood collection can even be an important opportunity to spend time in nature or bond with other community members (Cocks et al., 2012; Akintan et al., 2018). However, it comes with its own set of challenges and a preference for traditional wood fuel or biomass use is not supported across communities (Mbaka et al., 2019). Firewood is not always widely available or easy to obtain and use. Increasing pressures on firewood resources have resulted in localized natural resource depletion, leaving local households with firewood shortages and challenges to cook (WFP, 2012; Putti et al., 2015; Caniato et al., 2017). Firewood substitutions, if available, such as agricultural waste or dung, make it more challenging to maintain high temperatures for long periods of time, and can result in people skipping meals (Caniato et al., 2017).

One of the most researched complications related to wood fuel use at the household level is the adverse health impact of burning solid biomass, including firewood, in a three stone open fire or rudimentary stove, particularly when used indoors. Studies consistently show how the health-damaging emissions released during the combustion process are extremely harmful to people using these solid fuels to heat their homes and cook their meals (Naeher et al., 2007; Pope et al., 2015; WHO, 2016). The resulting high levels of indoor household air pollution are responsible for some 3.8

million deaths globally per year with people in developing countries and rural households in Sub-Saharan Africa, the Western Pacific South and East Asia experiencing the highest burden (WHO, 2016). In Sub-Saharan Africa, this form of air pollution is the most serious health risk for women and girls as the traditional role divide leaves them mostly solely responsible for fuel collection, cooking and tending the fire (Torres-Duque et al., 2008; Lim et al., 2012). This detrimental health impact is not the only risk for women and girls when it comes to wood fuel use. While burning these solid biomass fuels in traditional stoves or open fires poses severe damage to their health, in rural areas, the burden of collecting wood fuel also often falls on women and girls. Wood fuel collection can take up to multiple hours a day and can expose them to substantial dangers during this process including Gender Based Violence (GBV) and wild animal attacks. It also significantly impacts the time available to them to partake in education or productive work, limiting their development as well as their potential economic contribution to the household (Bizzarri et al., 2009; Jan and Pervez, 2015).

2.5 Emerging energy technologies

The growing energy demand on the African continent and severe wood fuel related challenges are creating a push to explore and exploit new energy policies, models, resources and technologies (IEA, 2019). Where on one hand a massive expansion of power systems is needed to be able to produce sufficient electricity, the lack of access to clean cooking solutions remains a largely separate and extremely complex concern (IEA, 2019). The principal use of biomass and wood fuel for many rural households is to cook food, often in combination with traditional cooking methods including the three-stone open fire or a simple stove (Lambe et al., 2015; Hafner et al., 2018; Mpholo et al., 2018b; IEA, 2019). Depending on the experience level of the user and external circumstances, including the moisture content of the wood and combustion ventilation, these cooking technologies offer extremely limited fuel efficiencies. Most of the wood, biomass or charcoal energy content is lost due to insufficient combustion or isolation, and fuel efficiency rates can be as low as 10-15% (Ballard-Tremeer and Jawurek, 1996; Von Schirnding et al., 2002). This is the main reason for large quantities of firewood or other forms of biomass needed on a daily basis, increasing pressure on natural

resources and amplifying environmental and household challenges associated with wood fuel cooking.

Over the decades, technologies have been explored and developed to overcome such gaps and improve fuel efficiency, or scale up access to clean cooking technologies and fuels. ICS were the first technologies to be introduced in the seventies in an attempt to reduce wood fuel use, address environmental concerns, decrease greenhouse gas emissions and improve the health of the end-users (Urmee and Gyamfi, 2014). A selection of these improved cookstoves still mainly use biomass in the form of firewood, charcoal or agricultural waste, but are designed to maximise both thermal and fuel efficiency, reducing the amount of fuel needed and limiting toxic emissions (Urmee and Gyamfi, 2014; Putti et al., 2015). The ICS technologies vary from simple designs with small functional improvements over traditional cooking methodologies, to more advanced stoves with a higher improved fuel efficiency (Fig. 1). Whereas improved stoves are designed to reduce the use and inefficiency of burning solid biomass fuels, clean cooking solutions also fall under this umbrella term but provide different benefits.



Figure 1. An overview of different improved cookstove technologies implemented in the Sub-Saharan Africa region (from left to right: the Envirofit rocket stove for firewood, the ACE1 smokeless biomass stove, the Briketi Ecostove for charcoal or briquettes and the CleanCook Aluminium One-Burner using ethanol and alcohol).

Clean cooking solutions focus on low particulate emission technology that aim to reduce, or even completely eliminate, smoke emissions from burning wood fuels or move away from wood fuel all together. Thanks to more recent technological advances, clean cooking solutions also include advanced improved stove designs such as gasifier stoves developed for pellet or briquette use, modern fuel stoves designed for LPG or electricity, or stoves functioning on renewable energy sources including biogas, ethanol or solar energy (World Bank, 2014; WHO, 2014). Although the efficiency and success of ICS and clean fuels vary greatly depending on user accessibility, adoption, training provided and a number of external factors, improved and clean cookstoves have been recognized as an important tool to address both energy poverty and reduce a number of negative environmental and health impacts of traditional wood fuel use. If these solutions are accepted and used correctly, they can reduce household air pollution, (local) environmental degradation, food insecurity, energy- and time-poverty as well as provide livelihood diversification opportunities for wood fuel dependent livelihoods (Hutton et al., 2007; Caniato et al., 2017; Gibbs-Flournoy et al., 2018).

Tremendous progress has been made in terms of developing improved and clean cookstoves technologies and fuels to help move away from habitually environmentally taxing and challenging traditional firewood use for cooking. Yet despite many apparent environmental, climate and health benefits, the widespread application of these technologies has been fairly limited with only 11% of African households using clean stoves (Vahlne and Ahlgren, 2014; World Bank, 2014). Decades of experience and research on ICS dissemination revealed that a lack of sustained use and lower stove performance outside of laboratory settings has hindered its success (Ruiz-Mercado et al., 2013). While many ICS technologies prove to be effective in controlled settings, targeted audiences have either failed to adopt these or were unable to create similar fuel efficiencies in the real world. Environmental and health related technologies, such as improved cookstoves, attribute their benefits from its sustained and correct use driven by individual actions and behaviours (Hanna et al., 2016). To understand if an improved stove or alternative fuel programme can be successful therefore does not rely merely on the technology alone, but encompasses many household and external characteristics

that influence both the initial adoption and its long-term and correct use (Vahlne and Ahlgren, 2014; Hanna et al., 2016; Pailman et al., 2018).

2.6 Technology adoption

It has become apparent that many of the proposed cookstove interventions cannot be seen as stand-alone solutions in this complex wood fuel landscape. Fuel-efficient or clean stove and fuel interventions have proven to be largely unsuccessful due to limited uptake and sustained primary use (Burwen and Levine, 2012; Putti et al., 2015; Hanna et al., 2016; Khandelwal et al., 2017). Many institutions, development agencies and local governments have tried to increase the use of ICS technologies for decades but a large number of barriers that stunt the adoption of ICS in developing countries remain in place (Vigolo et al., 2018). Without people actually willing and starting to use these stoves, ICS programme and dissemination efforts remain without purpose. Studies that examine these adoption barriers and enablers often include limited contextual variables and lean heavily on socio-economic and demographic data, whereas the long-term success of ICS interventions relies on a number of interlinked factors that both stimulate and facilitate the ICS adoption process (Ruiz-Mercado et al., 2011; Lewis and Pattanayak, 2012).

Several theoretical models exist that aim to understand the adoption process and the factors that drive this initial uptake and long-term use or the rejection of a technology. These models are based on the straightforward concept that beliefs and attitudes heavily influence a person's behavioural intention which subsequently influences their actual behaviour (Fishbein and Ajzen, 1975; Ajzen, 1991). Understanding those personal assumptions and convictions towards new stove technologies are important to predict and adjust ICS interventions to achieve adoption as without intention no purchase or use will take place. In addition to these beliefs and attitudes, there are a number of external factors that influence people's ability and willingness to adopt and keep using an improved cookstove. The diffusion of innovations (DOI) theory is a well-known process identifying different sets of product characteristics as determinants to new technology adoption (Rogers, 2010). This adoption process follows several steps encompassing the awareness, interest, evaluation, trial and complete adoption of

a product. The latter of which is addressed as sustained use in this study. Rogers (2010) states that "unless a product is highly compatible with the users' needs and resources, it will not be used for the long-term.". A major pitfall that has consistently interfered with achieving complete adoption of improved or clean cookstoves is the lack of understanding of context-specific complexities, product characteristics and limited focus on last two processes of the diffusion theory i.e. product trial and its sustained use (Putti et al., 2015; Dickinson et al., 2019). Without achieving initial uptake and long-term primary use of ICS solutions, the potential benefits in terms of cleaner cooking as well as wood fuel reductions cannot be obtained. Research shows that a disproportionate focus has been placed on understanding the initial adoption of ICS technologies compared to its long-term use (Lewis and Pattanayak, 2012). For ICS to become a realistic solution to the wood fuel problem, in Sub-Saharan Africa and Lesotho more specifically, it is not only essential to understand the determinants for households to adopt a fuel-efficient cooking technology, it is pertinent to understand how these determinants differ between initial adoption and sustained use.

2.7 Determinants of ICS adoption

Improved and clean cooking solutions are mostly designed in laboratory settings in an attempt to optimise efficiency without fully considering practical realities, user convenience, affordability and cultural practices (Urmee and Gyamfi, 2014). Noting that wood fuel and traditional cooking methods are often free or cheap, making a switch that involves costs becomes more challenging and often less desirable (Terrado and Eitel, 2005; Puzzolo et al., 2016). Many rural households do not have the financial means to pay for their electricity consumption or alternative technologies and fuels and there are often some additional practical, social and cultural barriers to overcome to move away from wood fuel use (Madubansi and Shackleton, 2007; World Bank, 2014; Putti et al., 2015; Pailman et al., 2018). Costs associated with ICS can become an important barrier for households to use or purchase such improved stoves or compatible fuels. So far, financial schemes in support of these technologies have not been able to overcome all limitations for successful adoption and the cost barrier involved (Palit and Bhattacharyya, 2014). Similarly, improved cookstove programmes and enterprises relying on a stove or fuels' technical abilities alone have failed to achieve demand and sustained adoption

(Ruiz-Mercado et al., 2011; Caniato et al., 2017). Technologically advanced stoves can be unsuitable for certain areas or cooking habits. Some types of food require short spans of high heat whereas other dishes need to be able to simmer on low heat for a long time. In areas where people prepare meals early in the morning, solar powered stoves are rendered useless and traditional pots and pans for certain dishes, for example the injera bread in Ethiopia, cannot be used on all stoves due to their large size. This demonstrates just how complex and location specific even the dimensions, type of heat and the technical abilities of a stove are, and a 'one stove fit all' solution can never be the answer.

It must also be noted that traditional biomass stoves or a three-stone open fire provide additional services and benefits to people in rural areas. These benefits can encompass energy to heat their homes, the protection from insects and the ability to use a variety of fuels depending on the season. All these additional benefits expected from a stove or cooking methodology can also influence peoples' willingness to adopt new cooking technologies if similar benefits cannot be obtained with the improved cookstove (Barnes et al., 1994; Pailman et al., 2018). Gains in one area can set a household back in another, and a new technology can prove difficult to meet the same needs traditional fuels and stoves have provided.

Where the initial uptake of the ICS technologies hinges on one set of barriers and enabling factors such as awareness, perceived benefits and affordability, the continued and primary use of these stoves often depend on a distinctively different set of features (Vahlne and Ahlgren, 2014; Hanna et al., 2016). Even after initial adoption, factors including lack of training on how to maximize and achieve the potential stove benefits in terms of savings and fuel efficiency, stove repair costs, and changing fuel prices can result in the ultimate rejection of the technology even after initial adoption was successful (Ruiz-Mercado et al., 2011; Shankar et al., 2014; Catalán-Vázquez et al., 2018). In areas where improved cookstoves are utilized, they rarely fully replace traditional cooking technologies and are supplemented with traditional cooking methods and fuels, a phenomenon described as *fuel or stove stacking* (Ruiz-Mercado et al., 2011; World Bank, 2014; Putti et al., 2015; Shankar et al., 2020). Under this approach, new fuels and technologies can be the primary cooking method, used sporadically or very rarely and eventually even be phased out completely if they do not meet the

households needs or become too costly in comparison (Ruiz-Mercado et al., 2011; Hanna et al., 2016; Puzzolo et al., 2016).

The assumption predating many improved or clean cookstoves initiatives is that with increased household wealth, time and access to alternative forms of cooking technologies, people would adopt and continue to use modern fuels and cookstoves (Van der Kroon et al., 2013). While it seems obvious to assume that the use of wood fuel and traditional cooking methods stems from a lack of access to modern fuel and stove choices, using wood fuel on an open fire or rudimentary stove obtains a number of very specific benefits for its users that can be difficult to meet with ICS technologies. Dismissing wood fuel altogether as a viable form of potential renewable household energy to cook and heat homes is disregarding the fact that the future for alternative sources of energy for many rural households are often bleak and likely unaffordable. It could also take away certain important social or cultural aspects linked to traditional wood fuel cooking practices. Completely moving away from wood fuel use can therefore be challenging and is not always preferred by households (Akintan et al., 2018).

It is not unsurprising that the majority of ICS programmes still use wood fuel as their main source of cooking fuel. However, most of the research and programme interventions by humanitarian and development agencies remain focused on addressing cooking energy access challenges from an expert point of view, failing to understand the household perspective. For example, UNHCR led an ICS programme in refugee camps in Rwanda where stoves were freely distributed among households. However, in the first year alone, 69% of the disseminated cookstoves were sold off as most beneficiaries indicated that they did not to see the benefit of the stove, even though the households were experiencing energy shortages (Gebre Egziabher and Marara, 2016). It is clear that this top-down approach does not fully allow a solid understanding of the benefits people receive from their current cooking practices when trying to facilitate a fuel or stove switch at the household level (Urmee and Gyamfi, 2014; Khandelwal et al., 2017).

2.8 Institutional and policy barriers

Environmental and energy policies in Sub-Saharan Africa occasionally include the up-scaling of improved cookstoves, but are often limited or contain no specific policies, regulations or incentives to help increase the long-term adoption of these technologies (Lambe et al., 2015; LMS, 2015; Putti et al., 2015; IEA, 2019). Understanding the determinants to the initial uptake and sustained use are one part of the equation, whereas the development of enabling policy and programmatic frameworks are also required. Both have the ability to overcome certain bottlenecks to adoption and can help households to fully and sustainably obtain the benefits of improved cookstoves, a feat many ICS programmes have been trying to achieve for so long (Ruiz-Mercado et al., 2011; Putti et al., 2015). Where household access to ICS technology is necessary to transition away from rudimentary cookstoves and reduce traditional wood fuel use, without people actually using these technologies a push for ICS renders no results. Effective policies tailored to the local economy, markets, traditions, consumer habits and needs can tackle a number of existing barriers faced by the end-user and provide an enabling environment to expedite the access and adoption of ICS (WHO, 2020). Many ICS development programmes are designed to distribute free stoves without sufficient training on using these stoves or provision of extension services where people can repair the stoves in case they break. An example of an improved cookstove programme in a rural community in Michoacán, Mexico demonstrated the importance of these services and limitations in the sustainability and success of ICS programmes. The programme led by the Interdisciplinary Group on Appropriate Rural Technology (GIRA) and the Institute for Ecosystem and Sustainability Research at the National Autonomous University of Mexico (UNAM) initially saw a high uptake of the distributed stoves. However, after about four years, the mean lifespan of the improved cookstove, half of the stoves were no longer in use. The stoves had needed repair or replacement and no services were put in place to facilitate this for the beneficiary households (Schilmann et al., 2019).

A profound understanding on context-specific determinants is needed to support the adequate planning and development of policies, programmes and frameworks to enhance and enable the uptake of ICS for those currently reliant on rudimentary stoves or open fires (Rehfuess et al., 2014; Lambe et

al., 2015; Vigolo et al., 2018). There should be more efforts dedicated to analyse the reluctance, resistance and challenges when using improved cookstoves perceived by household decision-makers or those responsible for meal preparation. This includes identifying and better understanding the barriers and enabling factors at the household level that influence the adoption and long-term use, gaps in policy and challenges faced by programme makers and private sector aimed to scale up ICS dissemination (Caniato et al., 2017; IEA, 2019).

2.9 The case of Lesotho

The Kingdom of Lesotho is one of the many countries in Sub-Saharan Africa where a high level of wood fuel dependency for cooking and heating and limited access and uptake of improved or clean cooking solutions have resulted in number of challenges for a major part of its population. Especially in rural areas concerns are surfacing regarding the sustainability of its chronic wood fuel dependency (FAO, 2015; CIAT; World Bank, 2018). At least 90% of the energy consumption of rural households consists of firewood, shrubs, crop residues and animal waste, causing localized depletion of woody plants (UNDP, 2014). This nation is already one of the least forested in Africa. Various estimates of its forest cover exist, and depending on the definition of forest resources, this ranges between just a couple of percentage points of Lesotho's total land cover. Taking only natural or planted forest into account, with trees that stand at least 5 meters in situ, the current forest cover estimation varies between 1.4% and 1.6% (Qalabane and Chakela, 2014; World Bank, 2016). Even considering the most favourable count encompassing government owned tree plantations, indigenous trees, woody shrubland and private tree lots, the country still has just a small cover of woody vegetation (FAO, n.d.; Leslie, 1991). Unlike many of the savanna woodlands found in neighbouring countries, Lesotho's mountainous terrain consists mostly of grassland which supports very few trees. The limited patches of natural forest and more abundantly available shrubby woodlands remain a valuable resource to its rural population depending on this 'free' energy to cook and heat their homes. (FAO, 2015, 2017b).

In spite of the great strides made by the Government of Lesotho to increase electrification rates across the country and shift the dependence on solid biomass use, just over one third of households are connected to the grid and only 19% of its rural population has access to electricity (World Bank, 2017a). The Rural Electrification Unit (REU) tasked by the Government of Lesotho to expand the grid to service rural areas is faced with numerous obstacles. The low household purchasing power of rural households, the nation's mountainous landscape and scattered villages have resulted in logistical difficulties and low economic returns which are necessary to support the capital infrastructure for expansion (Mpholo et al., 2018). Rural zones that do have access to electricity mostly use this for powering radio, TV and lights and not so much for cooking or heating due to its perceived or actual higher cost compared to biomass fuels, even if these are purchased (Taele et al., 2012; Mpholo et al., 2018b). These unbalanced needs and resources result in a heavy reliance on the import of electricity and some of its fuelwood for household energy consumption (LMS, 2015; Government of Lesotho, 2017).

Ongoing energy challenges are compounded by current climate change trends and human interference, increasing the vulnerability of Lesotho which has already been facing an increased frequency of natural disasters and environmental challenges (LMS, 2017a; World Bank Climate Change Knowledge portal, 2020). Lesotho's environment is defined by a number of environmental problems potentially impacting its wood fuel availability further in the form of frail soil formation, decline in soil quality, biodiversity loss and grassland, shrubland, woodland and wetland decline. This is caused in part by the combined pressures of climate change impacts, over-cultivation, forest conversion, overgrazing, urbanization, deforestation and wood fuel extraction (Mwangi, 2008; Qalabane and Chakela, 2014; FAO, 2015). The impacts of climate change in Lesotho are expected to lead to a rise in temperature, diminishing rainfalls and chronic drought. These changes could shift the availability of present forests as woodland may transition to shrubland under drier conditions and changes in climate can limit plant species distribution (Allen et al., 2010; World Bank Climate Change Knowledge portal, 2020). Recurrent droughts and changing precipitation patterns also negatively affect groundwater recharge ability and the growth and regenerative capacity of woodland

resources (Allen et al., 2010; FAO, 2015; LMS, n.d.; Zhang et al., 2018). These anticipated impacts together with the widespread over-harvesting of wood fuel and grazing by livestock that cuts regrowth at an early stage, cause wood fuel to become increasingly scarce. In addition, many woodlands in Lesotho are publicly or privately reserved, making wood fuel accessibility limited while biomass fuels (fuel wood, shrubs, crop residue and animal dung) count for some 66% of the total energy consumed in Lesotho (FAO, 2015; LMS, 2015, 2017a).

To combat a number of threats related to energy poverty, environmental degradation and climate change impacts, Lesotho rolled out the National Climate Change Policy (2017), the Lesotho Energy Policy (2015) and the National Climate Change Implementation Strategy (2017) aimed to build climate change resilience, protect its fragile environments, harness the potential of renewable energy sources and facilitate the substitution of wood fuels (LMS, 2015, 2017a, 2017c). Fortunately, Lesotho harbours an abundance of renewable energy potential in the form of solar, hydropower and wind, and the exploitation of this will play a significant role to achieve the policy objectives. Increased electrification in the country through renewable energy sources will tremendously benefit its economic development, inhabitants and environment but will not immediately address the cooking energy needs, particularly for rural population's needs (Twine et al., 2003; Madubansi and Shackleton, 2006; Matsika et al., 2013; IEA, 2014).

To tackle energy poverty across the board and its negative environmental and social impacts, energy access must go beyond electrification through renewable energy sources and explore potential solutions for cooking and heating for rural households dependent on traditional cooking methods and fuels. In an effort to overcome these obstacles, the policies include an intensified focus on wood fuel-based energy management, increased use of and access to sustainable bio-energy resources and interventions aimed to reduce the pressure on natural resources through wood fuel substitution and the promotion of energy efficient, improved and clean cook stoves (LMS, 2015).

The promotion of improved and clean stoves has been at the forefront of efforts to address the challenges of cooking and heating with solid biomass in Lesotho. The Lesotho Nationally Determined

Contribution (NDC) under the United Nations Framework Convention on Climate Change to reduce GHG emissions and identify climate change priorities of the country include: 1) the dissemination of efficient cookstoves with a penetration rate of 30% by 2030, 2) the endeavour to progressively replace firewood use with LPG for heating by 10% by the year 2030 and 3), to disseminate clean cookstoves to reach 15% of the non-electrified population by 2030. (Danish Energy Management & Esbensen, 2017; LMS, 2017b). Currently, manufacturers and distributors of ICS in Lesotho are few and include Fairtrade International (FLO), Atmosfair and ACE (Danish Energy Management & Esbensen, 2017). Not surprisingly, and in line with global results, the national ICS adoption rate has been slow, especially within rural populations (Kapfudzaruwa et al., 2017). While the dilemma of wood fuel dependency and its challenges cannot be solved with a one-stop solution, understanding how some tried and failed solutions may benefit from a new perspective in the broader context of the problem, can potentially contribute to effectively tackling a part of the equation.

Decades of promoting ICS in rural areas in an attempt to minimize or move away from traditional wood fuel energy use has proven a difficult feat, and a gap in understanding situation-specific factors that influence a household's decision making is slowing down adoption rates. For Lesotho, to achieve the ambitions set forth for increased and sustained use of improved cookstoves, switch to cleaner forms of fuel or change the currently mostly unsustainable traditional wood fuel use dependency, it needs to align policies, ICS programmes, technologies and private sector models with local households needs and abilities to overcome existing barriers. This research aims to fill in the knowledge gap on such context-specific determinants for cookstove adoption and the long-term use for rural households in Lesotho to reduce the country's rural household energy poverty and environmental pressures stemming from high levels of wood fuel dependence.

Chapter 3 METHODOLOGY

This chapter presents an overview of the study setting, research methodology and design, data collection process, ethical considerations and analysis followed for this research.

3.1 Study setting

The study is set in the Kingdom of Lesotho and specifically focusses on rural villages in the lowlands of the country that are dependent on biomass fuel and traditional cooking methods. The area of interest encompasses the six lowland districts of Berea, Leribe, Maseru, Mafeteng, Mohale's Hoek and Quthing (LMS, 2015; WFP Lesotho, 2015). These districts, located at a level of some 1500-1800 meters above sea level, are part of the major agricultural zones causing the indigenous grasslands, forest patches and shrubby woodlands of these regions to be heavily fragmented as a result thereof. The focus on these districts comes as a result of the high dependency on biomass fuel, mostly wood fuel, its limited and dwindling natural resources, low levels of household electrification and the presence of cookstove interventions in parts of these districts. These zones also fall under WFP's operations and could potentially be part of future household energy access activities.

Although Lesotho saw a decline in poverty over the past 15 years due to economic investments, improvements in education and increases in income, the poverty levels in these rural zones where some 85% of the population lives only decreased marginally from 61.3% to 60.7% (WFP, 2018; World Bank, 2019). Here, the majority of the population still faces high levels of unemployment, poverty and inequality. This makes switching or supplementing cookstoves or cooking fuels more challenging as traditional alternatives, such as the three-stone open fire and use of solid biomass fuels, are largely free. Villages in these districts are largely homogenous in terms of geographical similarities, climate, livelihoods, poverty and income levels, energy use and socio-cultural characteristics. Most households in these districts are depending on wood, cow dung, maize straws and in very small areas some electricity and gas for household energy consumption. Paraffin is used at times for lighting. Livelihoods focus mainly on animal farming and maize productions well as the

production and sales of livestock, other vegetables and firewood. Remittances from family members in South Africa and casual labour are also an substantial part of household incomes, which considering the COVID19 pandemic were impinged (Finmark Trust, 2020).

3.2 Study design and data collection

The principal goal of this study is to assess which enabling factors and barriers are in place for the adoption and sustained use of improved cookstoves for rural households in Sub-Saharan Africa and particularly in Lesotho. To provide answers to the research questions proposed under the individual research objectives, this study relies on a mix of methods and combines semi-quantitative and qualitative research tools. To identify the most influential variables to the adoption and sustained use of improved cooking technologies, these factors are examined through a systematic literature review, key-informant interviews and a survey of experts.

First, a literature review encompassing the current use of wood fuel and associated challenges experienced by rural households in Lesotho and ICS adoption theory was carried out followed by an in-depth meta-analysis of relevant literature on ICS adoption and sustained use obstacles and incentives in Sub-Saharan Africa. This provided inputs to research question 1 and partially research question 2 and 4 through a qualitative and semi-quantitative research synthesis. The aim of this systematic literature review was to provide academic knowledge on the topic and identify key drivers and barriers to the uptake and use of ICS at household level. Drivers and adoption barriers derived from this analysis that have proven to be significant in previous studies were incorporated in the interview questions for the key informants as well as the survey design for experts to help understand if similar significance among variables could be found for rural households in Lesotho.

Second, key-informant interviews were conducted via phone, Zoom and Skype to help finalize and conceivably add to the list of identified enabling factors and adoption barriers derived from the systematic literature review. All interviews took place between October 2020 and November 2020 and were recorded with permission of the participants. The interviews lasted between 25 minutes and

two hours and were transcribed in full. The interviews followed a semi-structured predetermined outline which focussed on the research objectives and the themes and variables derived from the meta-analysis and literature review. This approach allowed for data collection goals to be set while ensuring flexibility for the conversations to change direction where needed (Vaughn and Turner, 2016). Primary questions were kept to a minimum and included 5 items. To allow more in-depth exploration of topics or issues within the informants' expertise, a limited number of secondary questions were added resulting in a cumulative item score of 10 or 12 questions (Kumar, 1989). Depending on the key informants' knowledge and field, the interview guide was adapted to extract the most relevant and reliable information (Annex II). This provided inputs to research question 1-4 at a qualitative level and detail and nuance to the outcomes of the literature meta-analysis.

The interviews aimed to derive information on enabling factors and barriers to the adoption and sustained use of improved cookstoves in rural households in developing countries and incentives or gaps in ICS policy and programmes based on the individuals' knowledge, experiences and beliefs. In addition, the interviews with key informants in Lesotho included a focus on extracting contextual knowledge on the importance of each of these variables, investigated social norms and cultural values, and aimed to improve the understanding of behaviours, challenges and viewpoints towards ICS interventions and wood fuel issues. It also set out to understand ICS successes and failures in Lesotho or similar settings, and challenges and best practices concerning existing ICS policies and programmes. This qualitative research method collected information from an expert group of persons by drawing from their experience and opinions. To this end, the outcomes of the key-informant interview provided insightful information to narrow down the variables to be included in the semi-quantitative research methodology in line with other similar studies (Agbokey et al., 2019; Prah et al., 2019).

Third, the combined findings from the literature review and the qualitative exploratory research helped finalize the design of the online survey and ensured informed and relevant categories and questions were proposed. The survey was conducted among Lesotho-based ICS experts, relevant private sector, development agencies working on ICS and policy makers to help answer research

question 2-4. This method provided a semi-quantitative analysis of the barriers and enabling factors to the adoption and sustained use for ICS and compatible fuels in rural Lesotho. The survey data helped to understand if and how identified drivers and barriers of previous ICS adoption research were transferrable to households in rural Lesotho, including the comparative importance of these variables despite differences in context.

Key decision-factors in choosing the most appropriate survey data collection tool included the current challenges due to the COVID19 pandemic to conduct in-person survey collection, the speed of data collection and ease of data transformation. Based on this background, the survey was carried out via a web-based questionnaire program: surveyplanet.com. This program offers software to create and evaluate surveys online and can easily be distributed to targeted respondents via e-mail. The advantage of this online surveying methodology is the reduced social pressure associated with a face-to-face survey collection method and can therefore mitigate false responses and circumvent movement restrictions.

A total of ten questions were developed based on the variables extracted from the meta-analysis and themes derived from the key-informant interviews to allow comparable outcomes and standardized results. Answers were collected using multiple choice at the nominal level and the Likert scale, which measures attitudes at an ordinal level. The Likert scale is the most widely used and accepted method to assess attitudes and beliefs for the purpose of research. This method uses different measuring points ranging from high to low based on which the participant indicates the extent to which they agree or disagree with a series statements provided in the survey (Likert, 1932). For this research, a 5-point Likert scale was used as it limited the response choices and possible misunderstanding of the choices provided and provides a neutral option given its uneven numbering. For the Likert scale measured questions, respondents were given choices on a continuum such as strongly disagree to strongly agree. These answers were coded from 1-5, with strongly agree, very high and very important receiving a 5 score and strongly disagree, very low and not at all important receiving the lowest score of 1. For the multiple choice questions respondents were able to provide additional inputs if their answer was not incorporated in the survey. This allowed the inclusion of variables that did not, or not strongly,

emerged from the literature meta-analysis and interviews. These answered were recorded separately and presented in the results section.

3.3 Sample size and sampling procedure

The key informants were selected at a global and local level consisting of individuals with specific expertise and experience with ICS in Sub-Saharan Africa or Lesotho. The selection for the key-informant interviews included a wide range of informants from different backgrounds to ensure that a sufficient broad perspective and different points of views were captured in the data collection. Firstly, appropriate groups were identified based on the members of the Safe Access to Fuel and Energy Global Working Group hosted by the Clean Cooking Alliance as well as with the support of WFP Lesotho. From this list, candidates were selected and approached for interviews. Using the snowballing effect, more than the initially planned 15 candidates were identified through further recommendations from these original selected informants. A total of 17 informants were included in the final study in line with the recommended sampling size for key-informant interviews (Kumar, 1989; Gilchrist, 1992). Four of the key-informants were experts on the issue in Lesotho, whereas the remaining thirteen participants had extensive knowledge on the subject matter in the region of Sub-Saharan Africa. Participants for the interview were screened and selected based on their knowledge and expertise and encompassed individuals from UN agencies (4), International NGO's (4), technical improved cookstove experts (2), ICS policy and decisionmakers (2), energy related interventions and ICS researchers (2), and manufacturers (3). Each of the candidates interviewed had a broad range knowledge on ICS implementation strategies or technology design and were able to provide informed perspectives on the determinants to the adoption and sustained use of improved cookstoves in rural households in developing countries.

For the semi-quantitative data collection, an online expert survey was conducted among Lesotho-based informants and ICS experts. To obtain sufficient respondents, similarly to the key-informant interviews, candidates were selected from a number of different groups with the support of WFP Lesotho and based on recommendations from key informants. The participants of the survey

encompassed experts from local NGO's, relevant ministry departments, humanitarian and development agencies, field monitors working on ICS programmes and relevant private sector. The snowballing method was utilized to obtain a significant sample by requesting respondents to recommend appropriate candidates to extend the survey invitation too. Initial respondents were appointed via e-mail and directed to the online survey location. Here they were asked to complete the survey, received background information to the purpose of the survey and provided consent to have their data used for the stated purpose anonymously. While there was limited understanding of the magnitude of ICS experts and policy and programme makers in Lesotho, the research had aimed and managed to obtain 30 respondents to fill in the online survey. This allowed for a comprehensive perspective on the topic while ensuring the quality of the respondents.

3.4 Ethics

Data collection for both the key-informant interviews and the survey was informed by a sound understanding of cultural, religious and social sensitivities, values and traditions obtained through literature review and discussion with the World Food Programme Lesotho office. The data collection was conducted in adherence of the WFP SAFE Handbook to exclude unnecessary sensitive topics and ensure the confidentiality of the participants as well as the subjects in the study by warranting the anonymity of both groups (WFP, 2012). During the data collection and interviews, the principles of 'Do no Harm' were utilized, and will maintain compliant with these principles for the future dissemination of the study findings (Sim and Waterfield, 2019). An ethical clearance (protocol number HA2002) was obtained from the University of Witwatersrand human subjects research ethics committee prior to the data collection via key-informant interviews and survey methods. The participants of the study for the key-informant interview received a participant information document and consent form to explain the purpose of the research, provide information about the voluntary nature of the study and their rights. It also functioned to obtain their consent to be included in the study anonymously and to have the interview recorded for transcribing purposes (Annex I). The consent forms were signed and returned via email or signed *per procurationem* after providing oral consent during the interview.

For the online survey, participants received a participant information document explaining the purpose of the research, their rights, how the data would be utilized and a link to the online survey. The respondents' consent was obtained on the first two pages of the online survey indicating their approval to partake in the exercise and have their provided information used anonymously for the purposes of this research (Annex I). Confidentiality was ensured at all times during data collection and names and addresses were not collected on the survey. While names, profession and organization were collected for the key-informant interviews, this personal information provided during the interviews and any personal information disclosed during the online survey, was not shared in the research itself.

3.5 Data analysis

First, the literature meta-analysis was performed among the most relevant published scientific studies addressing the barriers and enabling factors for the adoption and sustained use of improved cookstoves. Peer reviewed publications were scoped using Google Scholar, JSTOR and the ScienceDirect databases and identified via key word searches encompassing; clean cooking technologies; improved cooking technologies; adoption barriers to clean OR improved cooking technologies; drivers of adoption of clean OR improved cooking technologies; drivers of and barriers to sustained improved cookstove use; adoption of clean OR improved cooking technologies in Lesotho; improved OR clean cookstove policies; improved OR clean cookstoves programmes; and, technology acceptance and adoption theory models. Using a statistical approach to combine the findings from numerous studies provided a higher statistical power and a more robust result. The studies identified through the keyword search function using Boolean operators, were evaluated against a set of inclusion and exclusion criteria and eliminated or included by logical reasoning following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) model (Moher et al., 2009). After the complete literature search a total of 425 papers were identified (Fig. 2). All selected studies were gathered into the Zotero reference manager and duplicates were eliminated, resulting in 159 records for further screening. Each record was assessed on predetermined criteria which encompassed a title and abstract search where any records that did not consider the use or

adoption of ICS in Sub-Saharan Africa were excluded for the study. This resulted in a total of 64 studies to be eligible for a full-text review (Appendix A). To be included in the quantitative synthesis for the final study, the studies selected were then screened against the following criteria: 1) considers the adoption or use of ICS as an outcome, 2) includes at minimum three determinants from the socio-economic, demographic, market, geographic, or institutional domain, 3) uses household as the unit of measurement, 4) is conducted in Sub-Saharan Africa and 5), uses a statistical analysis indicating if the variables had a significant or insignificant positive or negative relation to the adoption or sustained use of ICS (Lewis and Pattanayak, 2012).

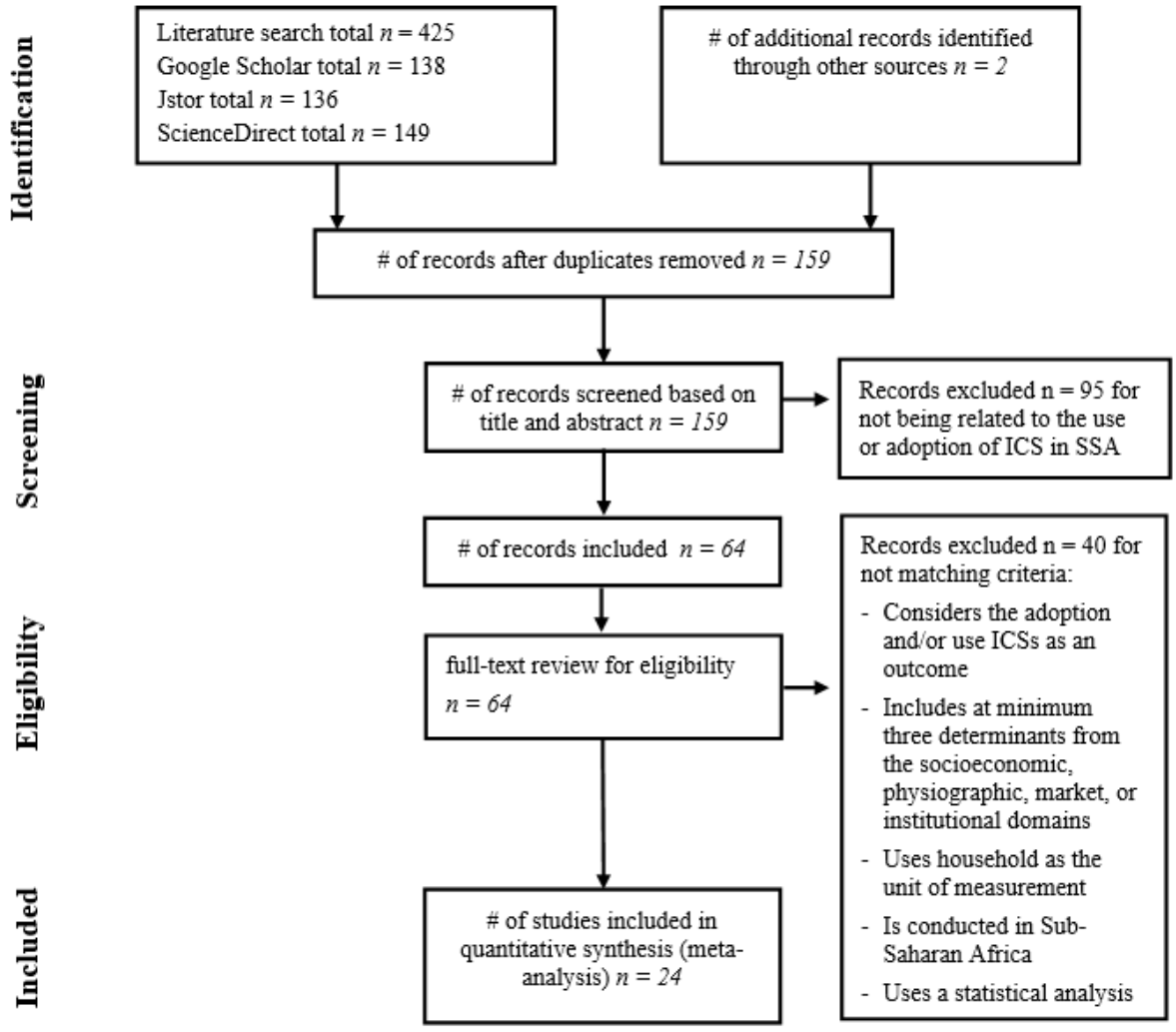


Figure 2. Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) flow diagram through the different phases of the systematic review for ICS adoption and sustained use determinants (Moher et al., 2009).

Data synthesis was conducted for a total of 24 studies on both the barriers and enabling factors of ICS adoption and the sustained use. None of the studies identified addressed the specific determinants for Lesotho. This lack of existing context-specific research further underlined the importance of this study and allowed the results to be utilized as regional determinants. These regional determinants verified through the key-informant interviews and Lesotho-specific experts in the form of the online survey to answer the research questions proposed.

From the final number of 24 studies, a broad number of internally homogenous factors were determined to allow the results of the different studies to be standardized and grouped where relevant (Lipsey and Wilson, 2001; Tewari, 2014). Each of these factors were further categorized under broader thematic topics that included Financial, Technological, Market, Cultural, Knowledge, Socio-economic or Demographic related items. For each of the studies it was assessed if a variable identified as part of the predetermined groups was included in the research and if this variable was found to have a statistically positive or negative influence on the adoption or sustained use of ICS. These results were summarized using Excel with the sole purpose to categorize and further analyse the collected data (Appendix B). A vote-counting exercise for the individual variables identified in the studies was conducted to extract the general relationship for each variable, the proportion of studies that identified a significant positive of negative effect for each variable and the percentage of the studies that mention each variable to identify the most referenced determinants (Lewis and Pattanayak, 2012). The total scores were visualized in a series of graphs included in the results section.

Second, for the key-informant interviews, a combined deductive and inductive approach was taken for the qualitative data analysis, merging theory-driven and data-driven coding and categorization of the interview transcripts (Fereday and Muir-Cochrane, 2006). After the data preparation, data analysis included assessing the most common themes that emerged in the interviews, identifying differences in responses and extracting of noticeable responses and linkages that provided relevant information to the research questions (Davis, 2019). These main ideas from the interviews were noted to understand recurring ideas and perceptions. Together with the information derived from the literature meta-

analysis, relevant themes were identified to provide a broad idea of the key categories under which further coding could take place.

Using the open access data analysis programme QDA miner, an emergent coding technique was used to identify all barriers and enablers factors mentioned in the interview transcripts for the adoption and sustained use of ICS. Where responses did not align with any of the predetermined categories, other structures were identified to map relations within the existing categories, new categories where added, or answers were excluded if not deemed relevant. Exclusion categories were developed at the onset of the data preparation to have a standardized approach in eliminating responses from different questions where needed (Vaughn and Turner, 2016). These exclusion criteria consisted of any comments unrelated to determinants of ICS or related fuels and challenges regarding electrification of rural areas as this does not fall under the scope of this study.

The QDA Miner coding process allows words and text passages to be assigned codes reflecting particular concepts which accumulated in a total of 231 separate variables under various categories (Lewis and Maas, 2007). These derived variables were used to finalize organizing the categories and codes resulting in a total of 136 codes, categorized among eight separate themes in the subsections:1) Barriers to adoption of ICS, 2) Enablers to the adoption of ICS, 3) Barriers to the sustained use of ICS and 4) Enablers to the sustained use of ICS (Appendix C). For each code, a vote count and frequency percentage was provided indicating how often the variable was mentioned across the interview transcripts, as well as a vote count and percentage for the number of cases each variable recurred in. These results are discussed in Chapter 5.

Lastly, for the expert-survey as an initial step the responses were scanned for missing data. There were no incomplete questionnaires detected and all thirty survey responses were included in the final study. Questions that required reverse scoring were adjusted to ensure that all variables are measured with the same directionality in terms of barriers and enabling factors and are comparable. Descriptive statistics were calculated for the Likert scale responses for the identified variables to provide initial information about the sample. These included a frequency distribution, percentage frequency

distribution and the central tendency using the mode and median for the ordinal data. The results derived from the nominal data were presented in a pie-chart. The data collected through the Likert scale required additional data preparation to allow the data to be visualized in a diverging stacked bar chart to present the distribution of the answers provided. This included the divide of neutral answers (3) for the negative/low and the positive/high side of the chart to show the spread of reactions ranging from very low to very high or strongly disagree to strongly agree.

Based on the survey outcomes, the trends and the importance of each item was categorized. The relative importance of the variables was derived from the numbers of answers, or Likert item scores, each variable received. This method allowed for the ranking of the different identified variables contributing to, or hindering, the adoption and sustained use of ICS and its perceived importance within the total set of variables. Ranking these variables could provide important information for policy and decisionmakers in terms of assigning priority to help overcome certain barriers, include enabling factors or adjust targeting strategies.

The data were then compared to the results from the meta-analysis and key-informant interviews allowing the identification of the key barriers and enabling factors for households in Lesotho. The comparison helped to understand if the three datasets supported similar determinants to ICS adoption and long-term use as well as the importance of each of these factors across Sub-Saharan African contexts and rural households in Lesotho. This also permitted the discovery of discrepancies between the determinants of the different datasets. The findings from the data-analysis for all three data-collection methods are synthesized and discussed in Chapter 5.

3.6 Study limitations

As the study aimed to understand the determinants for the adoption and sustained use for improved cookstoves in an effort to reduce or substitute wood fuel in rural households in Lesotho, the current methodology provided a specific outline of existing literature and experts understanding of these enabling factors and barriers. Unfortunately, the COVID19 pandemic did not allow field work to

undertake a quantitative survey and collect information directly from rural households in Lesotho. This type of direct data collection would help identify adoption barriers and enabling factors in more detail among targeted households and test the outcomes of this study. It must be noted that while the key-informant interviews and expert surveys provided expert knowledge on the subject and data that could not be obtained via other methods, the literature meta-analysis did not find any research conducted in Lesotho on this topic, and just four of the key-informants were experts on the topic in Lesotho. In addition, the findings collected through the interviews could be biased by the informant's personal beliefs or through interviewer bias. The use of an online data collection tool for the survey also limited respondents to those with access the internet online, although it was expected that the majority of subject matter experts could be reached online and no feedback was received on such technical issues. The study does not include the predicted economic decline, loss of incomes, market failures and so forth due to the COVID19 pandemic which might alter the prominence of certain variables including financial access. Further research is required to understand if identified influencing factors truly predict the adoption and long-term use of wood fuel dependent households in rural Lesotho. Ultimately, where the outcomes of this study help inform policy and decisionmakers to successfully design and regulate ICS efforts, the true importance of each of the determinants and the anticipated adoption behaviour can only be validated through longitudinal monitoring and research.

Chapter 4 RESULTS

This chapter presents the results from the literature meta-analysis, key-informant interviews and the survey conducted among experts. The results describe identified determinants, encompassing enabling factors and barriers, for improved cookstove adoption and sustained use for rural households in Sub-Saharan Africa. These results are further defined for rural households in Lesotho specifically.

4.1 Literature meta-analysis

The literature meta-analysis set out to identify and evaluate the inclusion of primary barriers and enabling factors pertaining to the drivers and hindering factors that influence the success of ICS in rural households in Sub-Saharan Africa. The results from the literature analysis are quantified, and for each variable the statistically significant positive, negative or insignificant relationship towards adoption and long-term use is presented.

4.1.1 Variable identification, categorization and magnitude

A total of 24 studies were included in the final data set that focused on initial adoption and sustained use determinants. None of the literature reviewed included such research for the country of Lesotho, hence the results were utilized as a proxy based on regionally identified trends among similar rural groups in the Sub-Saharan African region.

An overall number of 51 determining factors for the adoption and sustained use of ICS were identified through the literature meta-analysis which were grouped under Financial, Knowledge, Market, Cultural, Technological, Demographic or Socio-economic categories. For the purpose of context, income was classified under Financial factors, whilst Socio-economic factors focussed on age, assets, education and the gender and decision-making power of the head of the household. A total of 11 separate variables were identified as barriers to the adoption of ICS, 7 variables for the barriers to the sustained use of ICS, 21 variables considered the enabling factors for ICS adoption and 8 variables

recognized the enabling factors for the sustained use. The grouping of individual variables as demonstrated in Fig. 3-6 presents the findings per category for the barriers and enablers for ICS uptake and its sustained use in Sub-Saharan Africa. Barriers and enabling factors for long-term stove use were noticeably less often considered in the studies consulted compared to the determinants of ICS adoption.

Across the identified barriers and enablers for the adoption and sustained use of ICS, Financial, Demographic, Socio-economic and Technological factors most often emerged as having a strong influence on the uptake and long-term use of the stoves. Barriers to the adoption of ICS most often identified Financial and Technological factors as hindering the ICS uptake (Fig.3). Correspondingly, Socio-economic, Financial as well as Technological factors clearly stood out among the selected studies as enabling factors for the adoption of ICS (Fig.5). There were no categories that stood out substantially with respect to sustained ICS use barriers, however, Technological and Demographic factors were mentioned slightly more frequent (Fig.4). Similarly, few enabling factors to the sustained use of ICS appeared to be included in the studies. Despite limited entries, Technological factors visibly surfaced as being the most influential in aiding the long-term use of ICS (Fig. 6).

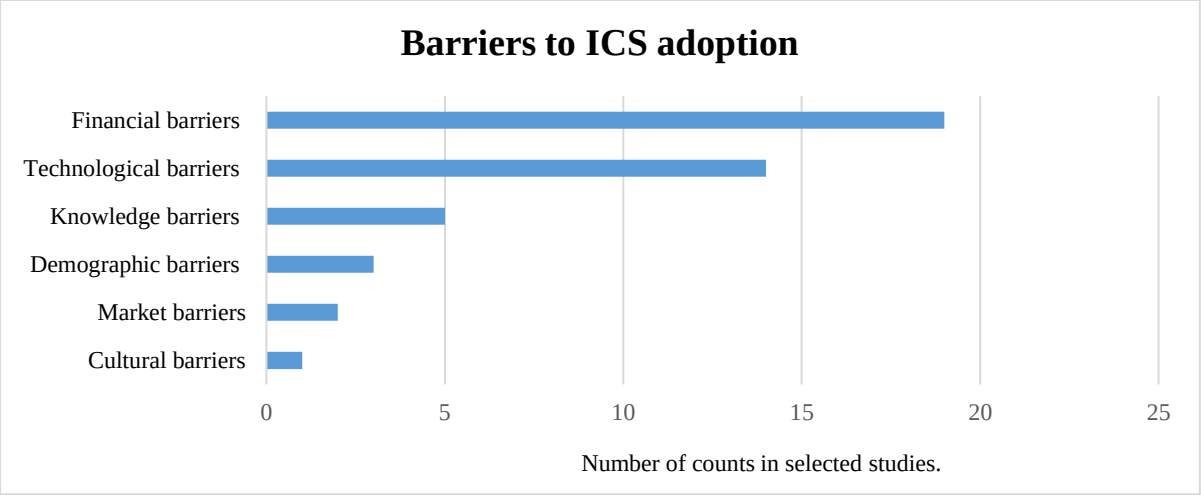


Figure 3. Total variable count in selected studies per category for the barriers to ICS adoption (n=24).

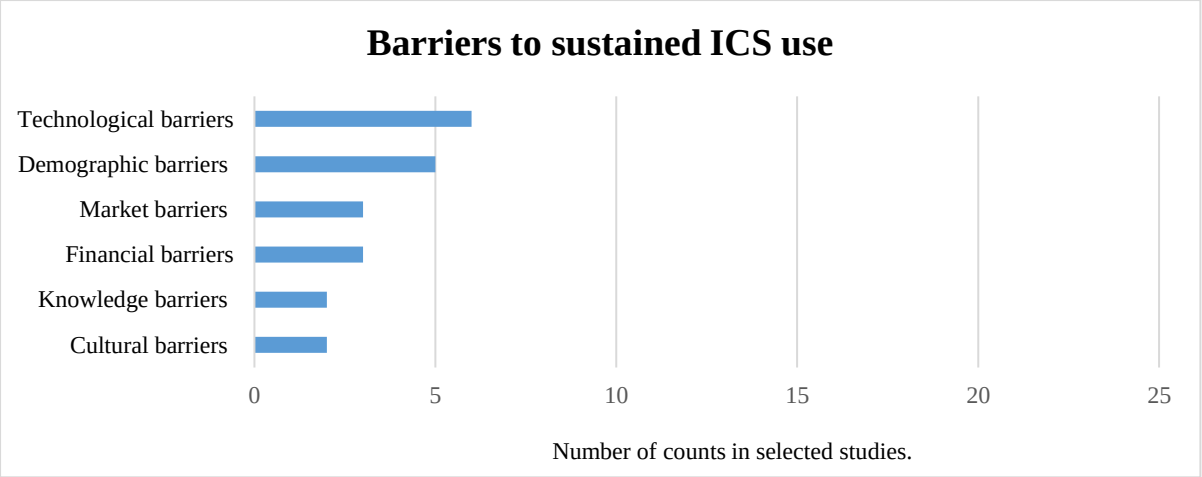


Figure 4. Total variable count in selected studies per category for the barriers to the sustained use of ICS (n=24).

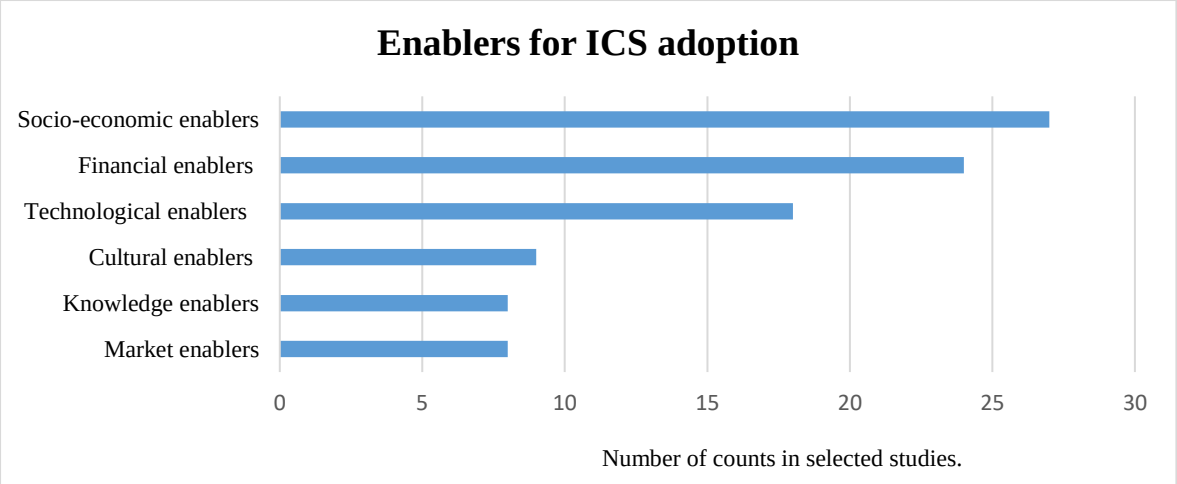


Figure 5. Total variable count in selected studies per category for the enabling factors for the adoption of ICS (n=24).

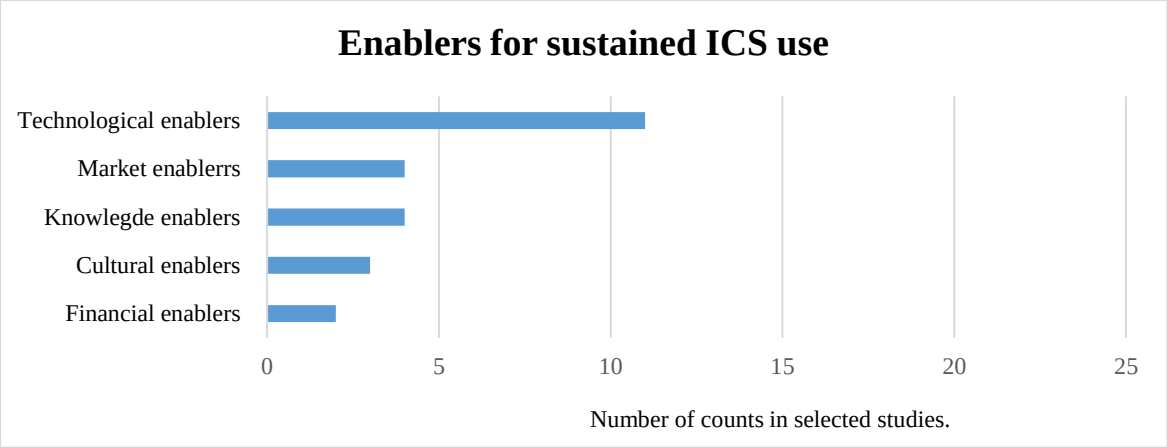


Figure 6. Total variable count in selected studies per category for the enabling factors for the sustained use of ICS (n=24).

Considering all categories and subsections, 12 individual variables were mentioned in more than 5 of the 24 selected studies as presented in Figure 7. High income, the price of the stove and the level of education of the head of the household were most often mentioned as either an enabling factor or barrier for the adoption and use of improved cookstoves. All three factors were included in over 40% percent of all studies selected as part of the literature meta-analysis. The positive or negative direction of the relationship, whether it is a barrier or enabling factor, depended on where on the continuum the particular factor fell e.g., if the price of the stove is high or low and was not always unidirectional, as is further detailed in section 4.1.2.

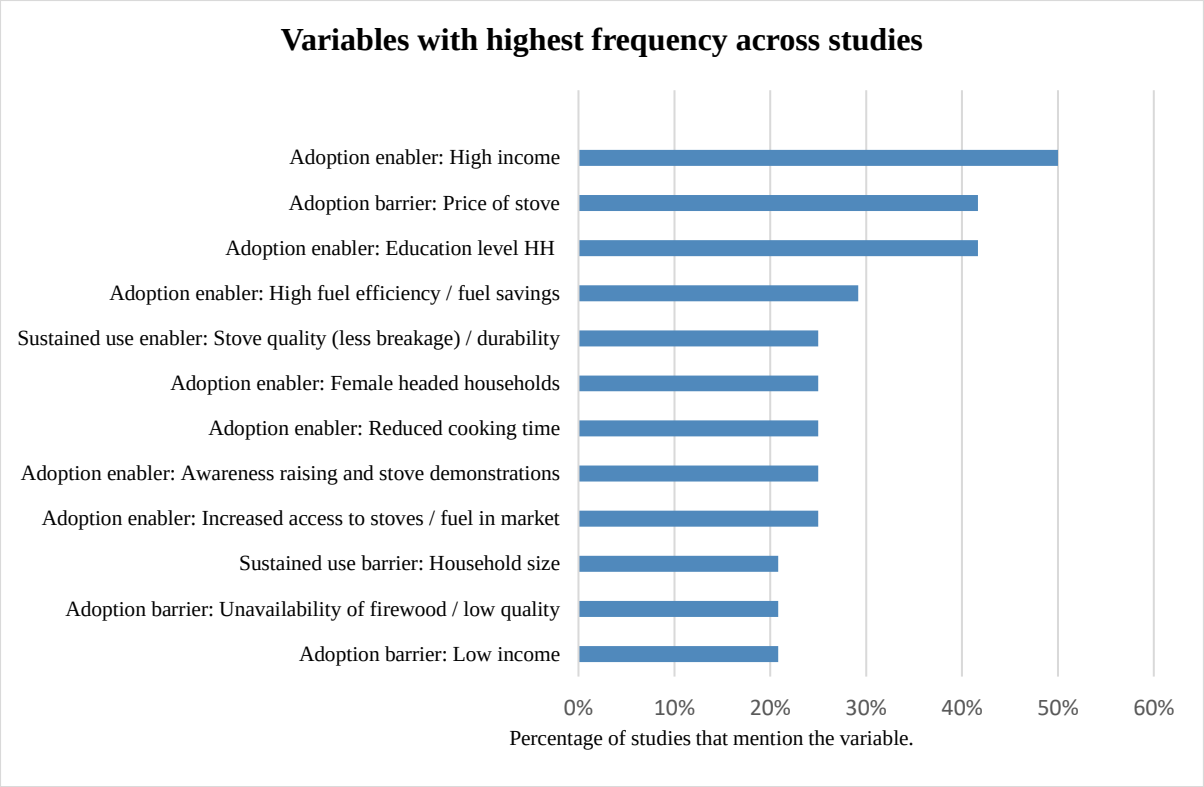


Figure 7. Frequencies of barriers and enabling factors for the adoption and sustained use of ICS reported in at least five papers included in the literature meta-analysis (n=24).

4.1.2 Direction and significance of ICS adoption and sustained use determinants

For each of the variables the direction of its relationship was evaluated, indicating a positive or negative influence on the adoption and sustained use of ICS as well as its significance with a p-value ≤ 0.1. The number of studies and the relationship to adoption and sustained use of improved cookstoves are quantified in stacked bar charts in Figure 8-11, adapted from the 2012 Lewis and Pattanayak meta-analysis (Lewis and Pattanayak, 2012).

The price of the stove was most often significant and negatively related to adoption of ICS when considering potential adoption barriers (Fig. 8). Here, an inverse relationship is seen where an increment in the stove price results in a negative outcome on the adoption rate of ICS at the household level. Only one positive insignificant relationship was found in a study where stoves were subsidized and price therefore had less impact at the household level (Pakravan and MacCarty, 2020). This variable is also linked to the effects we see for low income levels as it alters the affordability of the

stove relative to its price. Other more notable negative relationships to the adoption of ICS included low income, high fuel price, limited perceived benefits and a lack of fit with household cooking practices.

The availability of firewood showed both negative as well as positive significant relationships to ICS adoption and was dependent on the fuel choice that accompanied the stove. Here, an increase in adoption was seen for any increase in firewood collection time or when the ICS would switch away from fuelwood to an alternative fuel (Jagger and Jumbe, 2016). At the same time, the unavailability of firewood, or good quality firewood, acted as a barrier to the adoption of ICS when people had adapted to using other forms of biomass instead of firewood. This barrier was also prominent if the proposed ICS continued to utilize firewood or biomass instead of an ICS option which would provide a fuel change (Massawe et al., 2014; Van der Kroon et al., 2014).

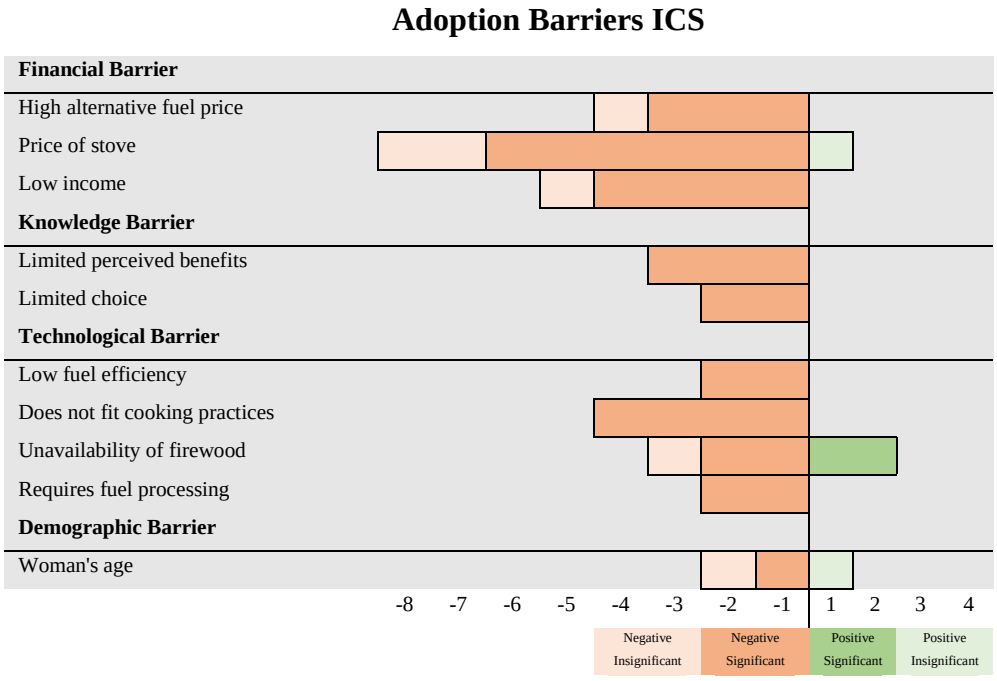


Figure 8. Number of positive or negative relationships recorded in the literature for ICS adoption barriers per factor (n=24).

Enabling factors to the adoption of ICS were the most researched determinants to ICS use, represented in 20 variables across all categories (Fig. 9). The majority of studies demonstrated a

strong focus on Financial factors as measures of followed by Technological, Socio-economic, Demographic and Knowledge related factors.

While there was an overall robust positive significant relationship between increased Financial and Socio-economic levels and ICS adoption, depending on the context, this also resulted in few negative significant outcomes. One such negative relationship was found in a study where increased household income led to a negative effect on household ICS adoption. This outcome was explained as potentially stemming from the households' increased access to more modern cooking fuels and solutions such as LPG or electricity diminishing the need for a biomass-based ICS (Muneer, 2003). Considering the definition adopted within this study, these results could still be interpreted as following a positive relationship where advanced cookstoves that utilize LPG, continue to fall under the ICS umbrella (Putti et al., 2015). Similar somewhat unexpected negative relations were found for increased socio-economic levels. Whilst in most instances increased education levels of the head of the household would demonstrate a positive relationship with ICS adoption, in few studies higher levels of education actually resulted in a negative relationship and households were less likely to adopt an ICS (Orr et al., 2015).

Technological factors scored high as a potential enabler to ICS adoption. Positive significant relationships were found for a number of technological aspects of the stove including its fuel efficiency, reduced cooking time and the perceived benefits. In addition, the importance of awareness creation and stove demonstrations proved to hold a significant positive effect on ICS adoption for rural households (Tigabu, 2017).

Lastly, the results also emphasized an important gender aspect where a higher age of the woman in the household, a woman's decision making power and being a female-headed household were found to have a significant positive relation with the adoption of ICS.

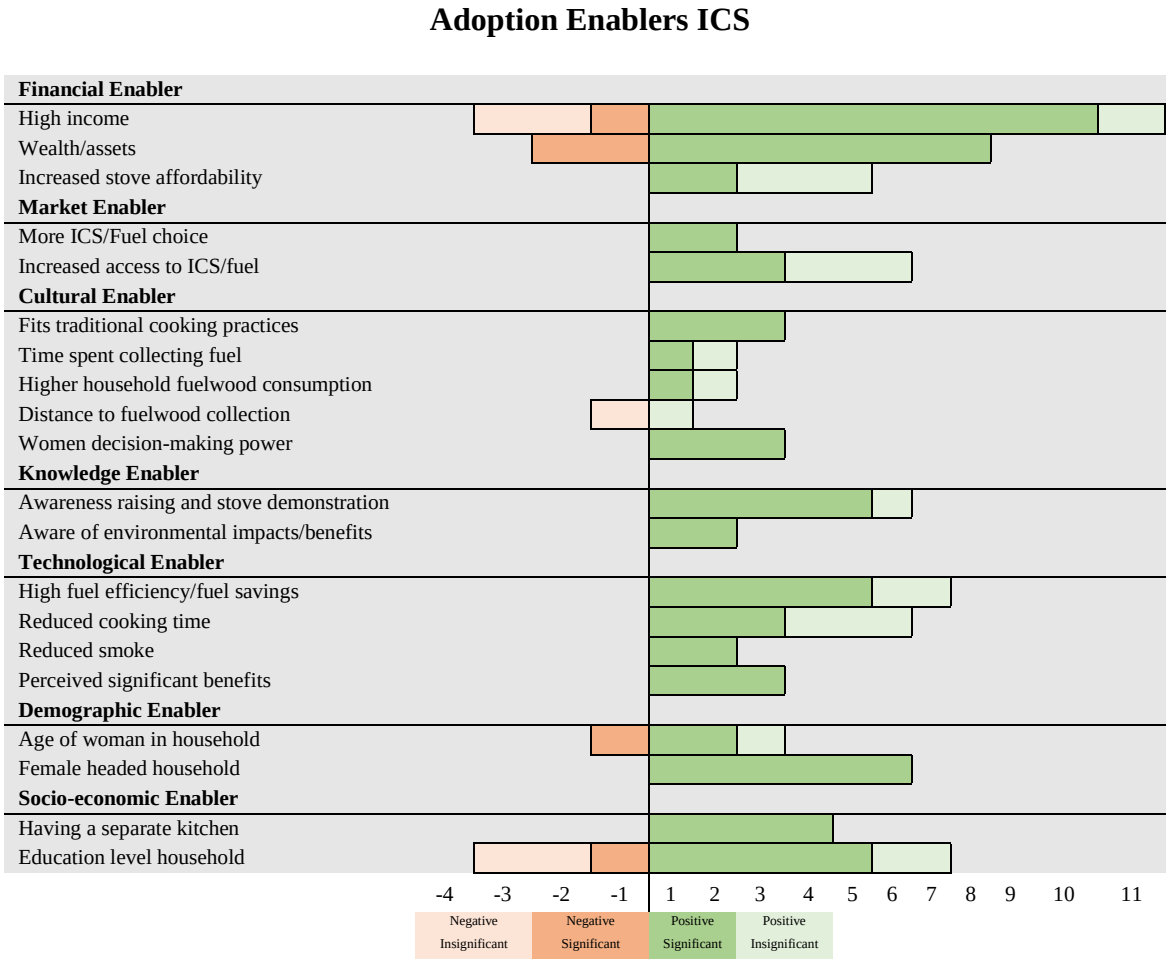


Figure 9. Number of positive or negative relationships recorded in the literature for ICS adoption enablers per factor (n=24).

There were few sustained use barriers recognized in the papers consulted as a majority of the studies focused on initial adoption. Longitudinal studies measuring sustained ICS use were lacking. The studies that did include sustained use and dis-adoption of ICS solutions included only the high operational cost of ICS, lack of access and/or availability to the fuel required for the ICS and household size as significant and negatively related to its sustained use (Fig. 10). In contrast, household size was found to be a significant positive influence for ICS sustained use in the case of a biogas powered ICS study in Uganda. Here it was speculated that biogas fuelled ICS are likely not the best fit for smaller households as it requires significant labour (Lwiza et al., 2017).

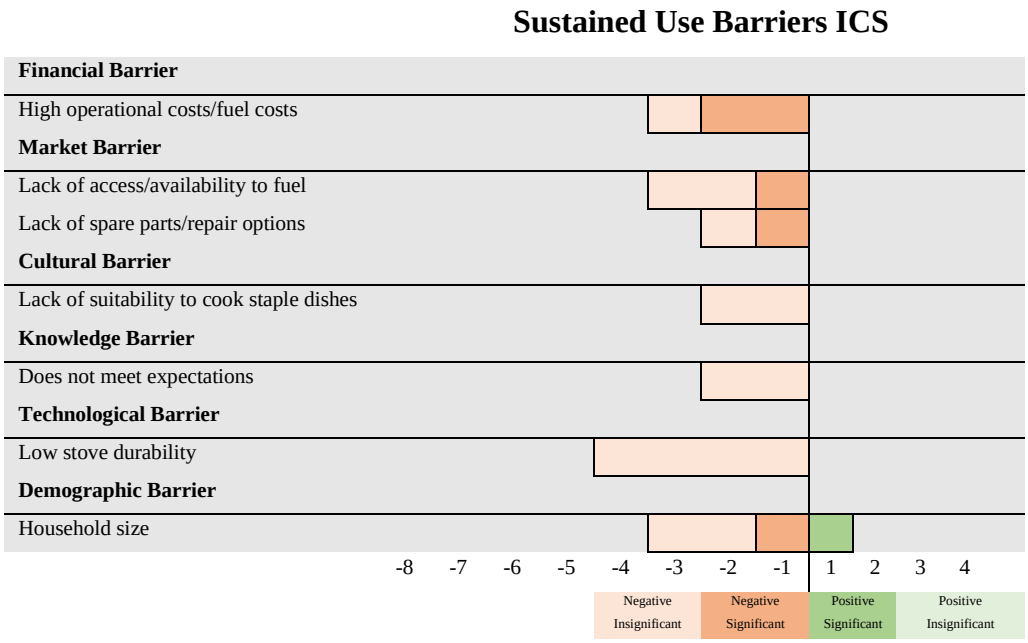


Figure 10. Number of positive or negative relationships recorded in the literature for ICS sustained use barriers per factor (n=24).

Research on the enabling factors for the sustained use of ICS was also relatively uncommon. A limited number of studies did include longitudinal monitoring and were able to identify few factors that can help prevent dis-adoption of ICS and contribute to its long-term use (Fig. 11). Stove quality and durability was most often recorded in the studies as facilitating long-term ICS use as this directly prevents discontinuation of the stove due to damage and break-down. The longer the life-span of the stove, the longer people were able to utilize the technology without having to purchase a new one which is often hindered by financial factors as seen as part of the ICS adoption barriers.

Although a small number of factors demonstrated a significant relationship, the affordability of ICS compatible fuel, access to repair and maintenance centres for the stove, the ability of the technology to prepare staple dishes, as well as continued awareness raising and follow-up with the households also demonstrated to be a significant and positive influence on the sustained use of ICS technologies (Lwiza et al., 2017; Tigabu, 2017).

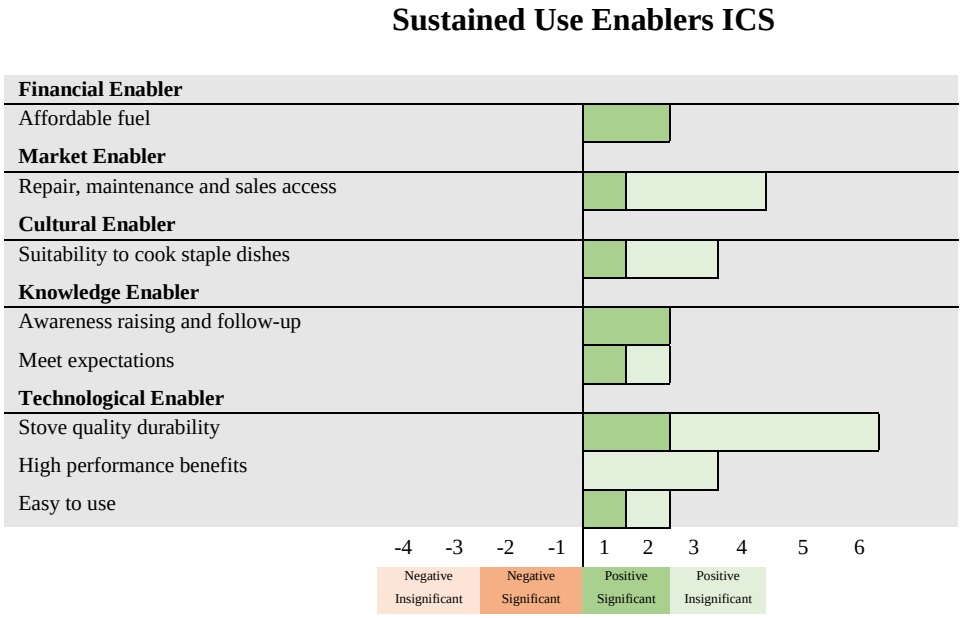


Figure 11. Number of positive or negative relationships recorded in the literature for ICS sustained use enablers per factor (n=24).

4.2 Key-informant interviews

All seventeen interviewed participants demonstrated a high level of knowledge on the concept of ICS development, implementation of ICS programmes and adoption. Four informants provided expert knowledge on the topic specifically related to Lesotho and thirteen informants were able to share their experience and knowledge regarding ICS adoption and sustained use determinants in similar contexts in the Sub-Saharan African region. Information and quotes provided regarding Lesotho specifically, has been captured in bold throughout the results section. The Informants often provided multiple responses that pertained to a certain category. These responses were therefore grouped under Financial, Technological, Market, Cultural, Knowledge, Socio-economic or Demographic categories.

There was strong consensus regarding a number of determinants although discrepancies were also observed amongst key-informants interviewed. Overall agreement was found that the adoption of ICS has been very slow and numerous issues were mentioned that caused this slow progress. There was a divide among experts in Lesotho if the uptake of stoves was slow as it was hard to identify given the limited number of ICS solutions introduced in the country. The reason for a relative slow uptake

might therefore not been as a result from household apprehension, but lack of access to ICS technologies as a whole.

A number of informants mentioned that cooking energy access as part of the energy discussion had received limited attention, but a slow transition was noticeable and cooking energy issues were slowly gaining recognition. Although some participants indicated the importance of affordability and adapting biomass stoves to become more suitable for rural households, other informants shared that if the product is good enough, price is less of an issue than it is made out to be. Besides misalignment on the most suitable payment and pricing methods of ICS, there were also noticeable differences between the type of fuels that should be supported and promoted among rural households, distribution methods, differences in the interpretation of rural households needs and means as well as the role of the government versus the household in the ICS and fuel decision-making process. In Lesotho, there was generally more support to continue the focus on fuel-efficient and clean biomass stoves as suggested by the informants. Despite these different viewpoints, clear trends were noticeable when analysing the data as can be seen in Figure 12.

Technology, Finance, Programme and Knowledge categories are considered to be the most influential factors persuading and hindering the adoption and use of ICS. While not highlighted in the literature meta-analysis, programmatic and policy approaches related to ICS were mentioned frequently as both a barrier as well as a necessary means to support the adoption and sustained use of improved cookstoves. For Lesotho specifically, Technology, Finance, Market and Knowledge barriers were highlighted as primary hindering factors to the uptake of ICS. Not only were there few ICS options available, the majority of households would not be able to afford the majority of technologies. Interestingly, some of the ICS interventions in Lesotho had addressed these financial issues by offering payment models instead of requiring households to pay all costs up-front. The barriers and enablers are discussed separately in the sections below.

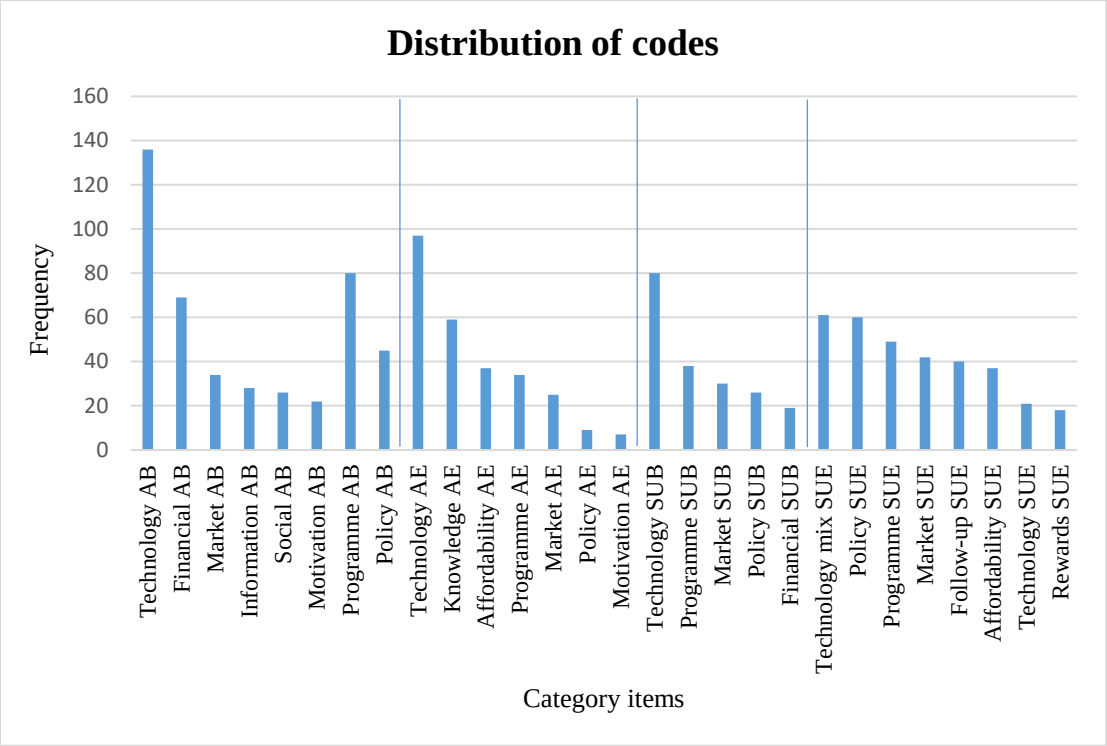


Figure 12. Frequency distribution of coded items extracted from the key-informant interview per category; AB (Adoption Barriers), AE (Adoption Enablers), SUB (Sustained Use Barriers) and SUE (Sustained use enablers) (n=17).

4.2.1 Adoption barriers

Similar to the literature meta-analysis results, technological issues as well as financial barriers were most often recorded as hindering factors to ICS adoption. Greatest emphasis was placed on the stoves' technological aspects (30.9%) followed by programmatic issues (18.2%) and financial factors (15,7%). The failure of ICS to meet local rural household needs, inability of ICS to replace all benefits of traditional stoves and incorrect targeting of stove and fuel interventions were the most frequent mentioned items to negatively influence adoption (Table 1).

There was general agreement among participants about the main culprits that hindered the adoption of ICS both regionally as well as among informants with knowledge of Lesotho. This focused on shortcomings in the stove affordability, lack of fit between the technology and the user, marginal benefits for households and issues surrounding programmatic approaches and lacking enabling

policies. The primary importance placed on technological aspects as main barriers to adoption uncovered a number of factors that could contribute to regional low adoption rates. A particular issue of concern reported was the unrealistic ideologic expectation that one stove will be able to replace and provide significant benefits to rural households who currently use a multifunctional traditional three-stone fire. It was mentioned that people normally cook multiple dishes which requires different levels of heat as well as the use of multiple pots in different sizes, all attributes and needs that can be challenging to accommodate in just one improved stove. In addition, the traditional three-stone fire is said to provide heating, lighting and functions as an insect repellent and often one stove design cannot substitute all these functions. Given the cold winters in the mountainous country of Lesotho, the loss of such additional benefits in the form of heating was emphasized as a barrier to ICS adoption.

Actual fuel savings in households were said to be often limited in reality compared to laboratory testing. This was suggested to be linked to the lack of training or the level of difficulty in correctly using the stove. There were also some noteworthy differences among experts when it came to the preferred type of ICS, fuel choice, targeting of households as well as the level of significance given to some of the other identified barriers to adoption. For example, a number of informants mentioned the importance of an ICS to fit cultural cooking practices and the challenges that occur when attempting to change the stove type and fuel source away from preferred traditional cooking methods. However, contrasting views were also shared:

"I think people overestimate cultural barriers. We know that LPG and electricity as a fuel for cooking works for every single dish in the world. There is not a single household that does not want to cook on gas or electricity. I acknowledge it's difficult to get people to switch 100% to one single cooking fuel or stove, but it's clear that electricity and LPG meet 99% of cooking needs so I don't buy this 'well but they like the taste of firewood for their Ugali'."

"Most people in the Lesotho mountain areas are still keeping the traditional way of living. In this type of context, it is difficult to convince a herder who is attached to traditional ways to adapt to modern ways maybe by using a fuel efficient stove. These traditional ways still dominate people in

the rural context. Closer to the lowlands people and urban areas people have had more access to modern cooking practices and prefer new ways of cooking. They understand the value of saving fuel as well as the impacts of deforestation and climate change."

Other conflicting opinions centred around the lack of enabling policies as a key barrier to ICS adoption. Some deemed this a requirement but others, albeit fewer informants, considered this to be less of a concern. Lastly, the importance of the fuel when it comes to the adoption of ICS was often highlighted as an imperative part of the equation for successful ICS uptake. The lack of focus on the ICS compatible fuel source was regarded as a considerable barrier to household adoption by those who mentioned this issue:

"Besides the stove technology, the fuel is much more important. People ignore the elephant in the room because it is the fuel that runs to stoves. If you only look at the ICS, it does not work. You need to understand the fuel supply chain, you need to know where the firewood will continue to come from, how to make it sustainable and that people have access to it."

Table 1. Most frequent coded items and description emerging from key-informant interview transcript analysis for the adoption barriers to ICS for rural households (n=17).

Adoption Barriers	**Explanations provided**	**#**
Financial		
Lack of affordability	"In Kenya they develop very efficient rocket stoves, but these metal stoves are 50-60 USD and upward which is expensive for many rural families. The trade-off between improved performance, affordability and usability is challenging." "Affordability is a big issue. What is an appropriate price that is affordable for households and would lead them to spend their limited funds on that? Especially when their alternatives, such as the three stone fire, are very inexpensive."	22
Additional costs compared to firewood collection	**"When people use firewood, they usually collect it for free. Whenever you introduce a new technology, you introduce this with a cost. So, you compete no cost with cost."**	19
Lack of financial benefits compared to investment required	"The benefits, such as time savings that they could achieve by reducing firewood collection or cooking, apparently do not add up to them, or it's not enough for them to spend money on a cookstove as it is not linked to a monetary value. That is really where the cracks lie for rural populations."	10
Technology		
Inability to replace all aspects of traditional cooking	"Firewood use on a three-stone open fire has additional uses apart from cooking. This includes space heating, which normally happens when people are cooking, or it functions as an insect repellent when adding green firewood and pepper on the stove. Switching to another fuel with an ICS would have people lose these benefits unless addressed"	27

	"Another problem. Many live in huts in Lesotho. In mid-winter it is critical to have fire inside as it is freezing outside."	
Fails to meet household cooking needs	"Some societies need stoves that produces a consistent low heat to simmer a dish for a long time. Some societies require high heat. The stove needs to match the staple dishes and when they cannot cook their staple dishes on the stove, it doesn't work." **"**The technology needs to address the main cooking events. If people have a large family and are cooking rice and beans, when you give a stove that can only cook sauces for three people, which is the case for most rocket stoves, people will not use it. Households do not cook just one thing and one cookstove is never enough."	39
Marginal benefits	"The savings we talk about are usually not significant enough for the household to be observed. When we say 10% or 20%, it is hard for them to see that saving".	22
Requires additional work	"It is pertinent to understand the incentive for people. To change the way people cook for thousands of years with a stove that is making their cooking preparation more difficult, they will not make that choice unless it is going to bring visible benefits in their lives." "Earlier designs had a small feeding chamber to enhance efficiency, not realizing that women could not use the stove without chopping firewood into tiny pieces. They did not figure out that there was a woman and the lack of an axe at the end of it. If women have to chop firewood to a specific size it is too much additional work for few benefits".	20
Programme		
Incorrect targeting	"We need to target a stove design at the most common or energy intensive cooking practices not just because it is the most efficient." "It is nice thought to give everybody an advanced stove and modern fuel, of course that is the ultimate goal. Right now, this is reaching people who might not be in the greatest need. We need to focus on rural households with the highest level of household air pollution and furthest from the grid. For many, advanced stoves and fuels are not going to be affordable."	26
Lack of local context and assessment	"There have been a lot of designs that were not liked by the communities. And that is because there's a lot of ICS design that was not done with communities."	20
Policy		
Lack of government support or interest	"In Lesotho there is a very dynamic political environment. When decisionmakers do not see any value in terms of supporting their political interests, it becomes a challenge for such an intervention to be supported and become successful."	15
Lack of enabling policy	"What's interesting to me is that governments around East Africa and some governments in Southern Africa are starting to ban charcoal. The problem is that it is not a complete policy. They are not backing it up with an alternative."	18

4.2.2 Sustained use barriers

An overview of the barriers to the continued and long-term use of ICS are provided in Table 2. These barriers for the sustained use of ICS focussed heavily on the technical aspects, such as the compatibility of the stove with the user and the household needs. Financial barriers were mentioned less frequently although continued access and affordability of the fuel is mentioned as an issue. If the ICS requires a more expensive fuel type, this can lead to people returning to less expensive fuels, such as firewood, if the costs cannot be managed or the benefits do not continue to outweigh these costs. Market related issues are secondary to technological barriers and predominantly concern the lack of access to stove repair and maintenance options. This is in particular the case for ICS projects in the development and humanitarian field. Here, the stoves are often provided for free or heavily

subsidized, but little consideration is given to the maintenance and repair of the product in case it breaks or gets damaged.

"Humanitarian agencies make a lot of mistakes by thinking that communities magically are fixing their own stoves or start producing their own stoves. This is not reality. You need to invest in a private sector for maintenance and after sales."

If the community lacks the skills to repair these themselves, and there is no private sector in the picture providing after sales, people can no longer use their stoves. No matter how successful the initial adoption was. The purchase of a new stove will then be hindered by the same initial financial barriers if a second stove is no longer provided for free or subsidized. Similar concerns were expressed regarding the sustainability of the fuel supply given that certain stoves can only use one type of fuel e.g., bio-mass pellets or ethanol. If the fuel-supply is disrupted, despite a households' intention, people are forced to return to traditional methods to continue to prepare meals for their families. A number of programmatic issues surfaced that link to market and technology challenges such as supply chain disruptions and lack of repair options. For Lesotho specifically, there was mention of the remoteness of many of the villages and the importance of durability and ICS technology supply chain reach to reach across valleys and mountains.

"*The remoteness is definitely a big challenge in Lesotho. That is again why the quality of the stove comes into play because if you have to replace the stove or maintain it every one or two years then it gets inexpensive very, very fast."*

Mainly, there is a broad consensus around the lack of long-term programmatic vision and planning for ICS interventions as well as monitoring and follow-up to learn if people are continuing to use the stove and if not, where the issue lies.

"Very often the intervention starts as a project and when the project ends there is no continued supply, or prices change, or subsidy ends. The design of the intervention is not very systemic, people have not thought of about all actors and functions within this market system and supply chain needs."

"After sales and monitoring is a key weakness in this industry. As a supplier of ICS to humanitarian organizations, there is hardly any follow-up or feedback. If you buy rice from a supermarket nobody comes to your home to see how you cook it and if you ate it. But now we do not know if there are problems and if the stoves are used."

Table 2. Most frequent coded items and description emerging from key-informant interview transcript analysis for the barriers to the sustained use of ICS for rural households (n=17).

Sustained Use Barriers	**Explanations provided**	**#**
Financial		
High operational costs	"If you change from firewood to a different fuel type, and if you collect firewood yourself and then have to purchase charcoal or kerosene or LPG you know it is a big ask. When you have to do that 365 days a year it quickly adds up and becomes quite a bit of money."	6
Technology		
No maintenance or repair options	"We had an ICS project without repair centres. After two years, of the 800 households some 200 were no longer using the stove. They told us this was because there were no options to repair broken stoves."	41
Lack of training	**"In Lesotho, we discovered that people were not understanding how to use the stoves and they ended up saying 'No this kind of technology is taking long'."**	12
Market		
No sustainable fuel supply	**"The challenge is how to maintain it, because there has to be a fuel supply chain."**	9
Programme		
Lack of long-term vision	" It is not just about short-term savings of bio-mass, you have to think about the medium and long term. It is a complex nonlinear and dynamic system. You have to look at long-term implications." "If you do not have a long-term vision the program is going to fail. In Burundi we had the technology, we had the adoption rates and people walked three kilometres to buy a stove. But there wasn't a clear distribution strategy and long-term vision."	13
Lack of monitoring and follow-up	"Monitoring makes a lot of difference. Immediately you can address people's questions. This is important as lots of things can happen that could lead to people stop using a stove."	11
Policy		
Lack of enabling policies	"There's absolutely no proper policy for the private sector, including social enterprises to have access to raw materials where they could import with no tariffs and taxes and duties. Nobody, nobody in the cook stoves market is profitable." "I think policy can really drive cooking energy changes but I think there's been not enough attention to making this a priority."	12

4.2.3 Adoption enablers

As enabling factors for the adoption of improved stoves, Technology (36.2%), Knowledge (22%), Affordability (13.8%) and Programme related factors (12.7%) were most often mentioned as being able to positively influence their uptake (Table 3). The ICS fit with local household needs was mentioned by 14 out of 17 informants as a vital element to allow for successful adoption. If the stove is unable to meet a households' needs, if e.g., they cannot cook with their own size and shape pots or pans, not have enough power for the most common prepared dishes, or is very inconvenient in use, people have little interest in the stove. The usability in this sense deemed to be more important than the actual savings obtained from the stove as these savings are at times hard to identify by households who are mainly dependent on wood fuel. The ICS should also provide immediate visible benefits, which are not only in the form of fuel savings, but could also be through reduced smoke, faster or easier cooking than the current traditional method used. Different aspects pertaining to the knowledge about ICS, the benefits and the use of the stove were also identified as key influencing factors to enable adoption. However, there were some critical differences among informants when it came to the importance and necessity of user training. While on one hand a number of experts said it was indispensable for the cook to receive user training as it allows them to maximize the benefits of the stove and get comfortable with a new style of cooking, others explained such level of training for this product should not be required. Even within the context of Lesotho, the perceived need for training varied greatly. Where on one hand, due to the remoteness of the villages, this was deemed essential and on the other hand experts considered it a failed product if extensive training would be necessary.

"If you need to train people how to use it, it means that you have failed. You don't need to make a course for people to use a washing machine because then there's something wrong with your product."

"Training, especially in rural places is very, very important. In rural places you need to have more intensive training to show them one how it is operated and how they can get the benefits. Only when they operate it in a proper way, they will get the benefits mentioned."

The importance of communications campaigns in terms of awareness creation and marketing, including market assessments to ensure the products meets the needs of the target audience, were discussed as central issues and necessary to create demand. Further unpacking this issue, another area of disagreement was uncovered. Where the majority of participants identified a market-based approach as an enabling factor to the adoption of ICS, some indicated that such a strategy would achieve the opposite outcome, especially for last mile households due to their low purchasing power.

"I'm slightly nervous about the trend as it is not at all clear to me that pure private sector delivery of cookstoves is the way to go. I've not seen evidence that people have the finances and income stability to really keep up with private sector payment needs in humanitarian interventions."

"Market based solutions are always the best. People will look for means or ways of getting whatever they think is important in their lives. What makes you think they will not see the importance of a stove and buy it."

Lastly, the debate about locally versus foreign produced cookstoves was also highlighted. Participants acknowledged that it is a challenge for people outside of Africa to understand Africa and its population's needs. It was observed that the need for local context and understanding is an important part of the equation to deliver a successful intervention. While in certain circumstances there was a preference for locally made products, as this can help establish trust, support the feedback loop between customer and manufacturer to address local needs, reduce additional transport costs and the environmental footprint of the stove, questions about the potential lack of quality were also mentioned. Some participants cited the investment in ramped up local production supported by the government and donors, the development of context specific solutions and the development of selection criteria for stoves as ways to address these challenges to enhance local production and help overcome certain adoption barriers. For Lesotho, local production and a variety of products and fuel sources that match income levels and cooking methods was the preferred approach. The remoteness of the villages was again reiterated as a reason for the need for local production.

Table 3. Most frequent coded items and description emerging from key-informant interview transcript analysis identifying enabling factors to the adoption of ICS among rural households (n=17).

Adoption Enablers	**Explanations provided**	#
Financial		
Availability of affordable stoves	"The main thing is that it has to be affordable. I have seen all those firewood stoves that are super nice, efficient and clean but that are 40 or 50 or 100 USD. People are not going to spend this kind of money."	15
Competitive with or cheaper than other fuel options	"When people have to buy the stove and fuel, versus they keep the same stove and maybe spend another hour looking for fuelwood, given the lack of price competitiveness, you are not going to see huge uptake."	11
Technology		
Fits local households needs and cooking practices	"If we did not spend four months studying local cooking practices, there was no way we could have designed a stove that was going to be adopted in Haiti. Having done this, this ICS is the best stove in the history of Haiti because we went through this painful process to try to understand what people want and need."	40
User friendly technology	**"When you talk about rural households, I say convenience is one of the major priorities compared to other things."**	19
User training	**"**If people do not get training to understand the functionality of the stove, they're not going to use it. In Uganda we saw our stoves not being used because they did not receive training."	16
Demonstratable immediate benefits	"The market has been flooded with devices that basically do not provide enough improvements compared to the methods that people already use. It is difficult to produce a stove that really gives evidence of clear improvements and benefits compared to the method that they normally use."	12
Appropriate local stove selection or local production	"One size does not fit all because every geographical location is different in terms of available resources, opportunities, challenges within the system and the government. So altogether it has to be contextualized and localized." **" In some regions you have cheaper options to provide electricity for cooking, but it might not be reliable. In other areas electricity will become too expensive. You need a number of solutions fitting the context, for example where income is low and electricity costs high an improved biomass stove and wonder bag would still be the best option".**	11
Knowledge		
Marketing and communications to create demand	"Private sector companies spend billions of dollars studying the market for an 8-year-old versus an 11-year-old for a certain product because if people do not buy their products, they're out of business like this. The problem in this industry is, that we are not accountable to anybody."	25
Expectation management	"There is no one solution or technology that's going to address all the needs of the households, and the expectations need to be realistic. Multiple solutions need to address the problem instead of just one which needs to be communicated to the household."	10
Market		
Market driven approach	Households can get attracted to a new technology and have expectations. When they start to use it and do not find what they were expecting, that can be a factor for them to be discouraged.'	13
Programme		
Improved feedback from lessons learned	"There is the issue of reputational risk, failures are not always properly documented and shared because of this dependence on donor funding. If it is not shared what went wrong it cannot be fixed."	10
Development of context specific solutions and selection criteria	**"The issue of adoption is not that much of a problem if we understand who the user is. This context specific understanding is what has been extremely missing in this industry."**	10

4.2.4 Sustained use enablers

There were relative fewer respondents who mentioned the enabling factors for the sustained use of ICS compared to adoption enablers. However, each enabler that was provided was mentioned frequently, providing a strong overall consensus. The most frequently mentioned sustained use

enablers are provided in Table 4. Most recurring enabling factor were related to Technology (18.6%) Policy opportunities (18.3%) and Programme approaches (14.9%). While Policy related factors were less often mentioned as a determinant to the adoption of ICS, effective and supporting policy was cited most frequently as a sustained use enabler. In particular, the importance of government decision in coordinating and supporting the fuel choice and establish supporting policies were deemed essential to achieve long-term ICS success.

Not surprisingly, the affordability of stoves and fuels were mentioned by a great number of respondents, and all respondents from Lesotho. Potential financial enablers to long-term ICS use included fuel subsidies to reduce its operational cost, and warranty provisions and financing mechanisms to replace damaged or broken stoves. The importance of monitoring, follow-up and feedback into the ICS intervention or product design were also frequently mentioned as currently lacking. These considerations were shared for the region, as well as within the Lesotho-specific context. Integrating monitoring and evaluation into programme design was considered vital to its the long-term success as it can allow timely interventions and changes to the stove design, financing mechanisms or targeting strategy where needed. A greater understanding of the optimal technology mix and support of stove and fuel stacking also came to the forefront in numerous interviews. Explaining the complementarity of certain ICS solutions and supporting this mix of different stoves to meet their household needs was mentioned to facilitate the long-term use of a mix of technologies, including ICS, together with traditional cooking methods.

"It is a problem that we are expecting that we can fully substitute their traditional stove with one tiny stove and that is why it is very much in order for people to be able to stack stoves when changing from low tier stoves to more improved stoves."

"Do not expect people to just jump from firewood to electricity without this stacking transition in between. Maybe they cook on a higher tier technology in the afternoon but a low tier technology in the evening because that will heat their house. We should appreciate it that they are able to manoeuvre their own life to be able to survive with whatever they have and make their lives

comfortable. We should not feel that we are failing and that these people are lagging behind. These people have every right to be combining technologies."

Emphasis was also placed on the need for improved context specific fuel and stove selection to meet specific local household needs, better fit the local economic and political landscape and ensure sustainability in the fuel(s) supply chain. While many respondents focused on moving towards 'cleaner' fuels such as LPG and electricity, considerations of biomass as a potential clean, renewable and locally available fuel was also expressed. Given that LPG is a fossil fuel with its own challenges, and electricity specifically in Sub-Saharan Africa is often derived from the burning of coal, the concept of addressing LPG or electricity as a 'cleaner' fuel was at times disputed. These fuels are stated to burn clean at the household level but the complete value chain does not always ensure these are truly clean solutions. The interest for cleaner biomass solutions was especially highlighted for families furthest removed from the grid, such as in the case of the majority of the rural population in Lesotho, and where realistically alternative fuel options could become challenging as supply chain issues were expected. Besides the need for clean burning biomass technologies, the necessity to pair cooking interventions and cooking fuel interventions with sustainable resource management was considered important. The lack of wood fuel in Lesotho was considered a great concern and sustainable natural resource management as part of biomass cooking interventions considered a necessity. Some respondents supported the shift in focus towards cleaner biomass fuels and stove solutions given its ability to tackle many supply chain and affordability issues. Combining these two approaches was said to address environmental concerns related to unsustainable firewood use.

"I think if we can burn biomass cleanly and efficiently then it is a great renewable fuel source that is local and inexpensive. If we can just get the technologies to be designed and used in a way that we are able to do that, then biomass continues to be a good resource for these families."

"At some point LPG might be seen as a bad alternative where biomass can be utilized in a clean and renewable way. It strikes me that the support in sustainable resource management for firewood are

relatively few and far in between. Humanitarian and development agencies have rarely truly connected the dots between the environment and sustainable wood fuel management."

Enabling factors to help overcome the lack of long-term affordability was said to require income generating activities alongside cooking interventions, subsidy of both stoves and fuels to reduce the costs at the household level and tax incentives and private sector support to help lower the cost of fuels and stoves. The latter would also provide private sector incentives and sustainability. These regional views were reiterated for Lesotho. Lastly, ensuring that repair and maintenance centres are established were expressed to be paramount to prevent people from dis-adopting the ICS after breakage occurs. Efficient and timely maintenance was stated to extent the durability of the stove, prolonging the time between stove purchases and reducing the overall costs of ICS cooking for households.

Table 4. Most frequent coded items and description emerging from key-informant interview transcript analysis identifying enabling factors for the sustained use of ICS among rural households (n=17).

Sustained Use Enablers	**Explanations provided**	**#**
Financial		
Income generation through ICS	**"You need to link this with livelihood opportunities, besides just the cooking aspect for them to be ready and able to transition to some other fuel type."**	10
Stove and fuel subsidy	"The other key issue is making sure that the government provides subsidies where free aid or market-based approaches cannot be sustained. It is not only about vulnerable people; fuel efficient stoves are required for all members in society whether you are rich or poor."	15
Technology		
Support stove/fuel stacking	"Evaluations and literature effectively judge the success of cooking interventions based on whether the stove is being used for 100% of cooking tasks. I do not think that it needs to be the case to be a successful stove for that family. I guess when it is becoming part of the overall more sustainable cooking solution for that household then that is a good thing."	20
Repair and maintenance access	"I think you will have a lasting presence in the community where spare parts are available. In Kenya they have a good model where they are training car repair shops to fix the stoves and provide them with a set of spare parts so they are leveraging existing resources in the community. I think that is interesting in a powerful model for the longevity of ICS use."	16
Experience value over time	"It comes down to whether people believe ICS make a genuinely positive difference over time. If we can speed up their cooking, save money, make food taste better. This will lead to people carrying on using ICS and not returning to traditional methods."	14
User training	"It is really important to get one-on-one training just to increase people's comfort level with the technology. Training is a huge aspect of successful long-term adoption"	12
Address loss of additional benefits from traditional cooking	"The whole household can be looked at as an energy system. Now, energy services are provided by the three-stone fire for lighting, heating, water heating. But if we had different devices for each of those that provide those services more optimally then we can start really displacing the open fire effectively."	12
Market sustainability		
Focus on sustainable supply chain	"Development organizations should not be part of the supply chain but create conditions so when they exit, the market and supply are sustained." "The challenge is how to maintain it, because there has to be a continued supply chain."	21

Programme		
Monitoring and programme design feedback	**"Long-term monitoring is needed to know how much it is used and how much they replace traditional technologies. Understand the lifespan e.g., how many years before 50% is not usable anymore? Then you know the real impacts of the fuel savings and sustained use."**	24
Improved community consultation and stove selection criteria	"There is a need to have an approach similar to water and sanitation where after decades they were able to trigger behaviour change by using the community and be cognizant of certain stigmas and using that to your advantage. A similar thing should be used for ICS, with the difference that this would focus on the households not just the community.	15
Context specific stove and fuel selection	"Speaking about rural households is already too broad, it really is dependent on the context. Even if we talk about Sub-Saharan Africa it is still a very big continent and I don't think a rule that applies to Uganda applies to Tanzania in the same way."	15
Policy		
Policy alignment	"We had the government tell us that their mandate says to invest in high technology and ICS is not enough. It is the decisionmakers that say they are not interested in supporting it." "There is a lot of attention in regards to the electric grid, which is still very challenging, but a lot of people have a good understanding of this. No one is looking at cooking on such level. It is all little programs everywhere, but no one has done it with a vision from A-Z."	15
Government support and decision on fuel	"I think that the energy of choice will have to be a government policy to decide on. When it is clear that firewood is not sustainable, it needs to be addressed and it should be either completely financed by the government or by development money. At least initially."	20
Tax incentives and private sector support	"If they focus on developing a fuel market and targeted subsidies or removal of taxes for this fuel, that can encourage the producers to commit to the fuel market and produce more ethanol and cheaper. So that you can get into the supply chain at a cheap enough price to have a sustainable, accessible and affordable supply."	17

4.3 Expert survey

The results section below features an overview of local cookstove and fuel choice, rural household adoption rates for different ICS solutions, cooking fuel and stove challenges experienced by these households and the relative importance of the most commonly mentioned barriers and enablers from section 4.1 and 4.2 and its applicability for rural households in Lesotho. A total of 30 respondents from Lesotho completed the survey and all results are directly applicable to the local context.

4.3.1 Local challenges

The majority of expert respondents indicated that rural households in the lowlands of Lesotho use firewood (56.7%) or other forms of bio-mass (16.7%) to prepare meals on either a traditional stove (33.3%) or three-stone open fire (40%). Very few answers were given for other cooking options such as electricity, kerosene or charcoal. Of more modern fuels, LPG was the most mentioned cooking fuel and stove technology (13.3%) and additional options were given indicating that households use a mix of fuels such as straw, animal dung, firewood and crop residue depending on the altitude and availability. Alternative cooking methodologies not included in the questionnaire were also provided and included an open shielded fire and bucket with holes using a three-legged pot. Households access

their primary cooking fuel mainly through free collection (in the case of biomass and firewood) or purchase via individual firewood sellers or at the market.

Respondents recognized a number of challenges for the main cooking methods and cooking fuel(s) used at the household level (Fig. 13). The most commonly mentioned challenges were, firstly, the lack of access to sufficient wood fuel to prepare meals, secondly, localized environmental degradation, and thirdly, health concerns due to emissions of polluting cooking techniques practiced. Answers provided outside the list of challenges included the time-consuming practice of firewood collection particularly for women, as well as the high environmental cost as shrubs and forests are not restored, making firewood use unsustainable.

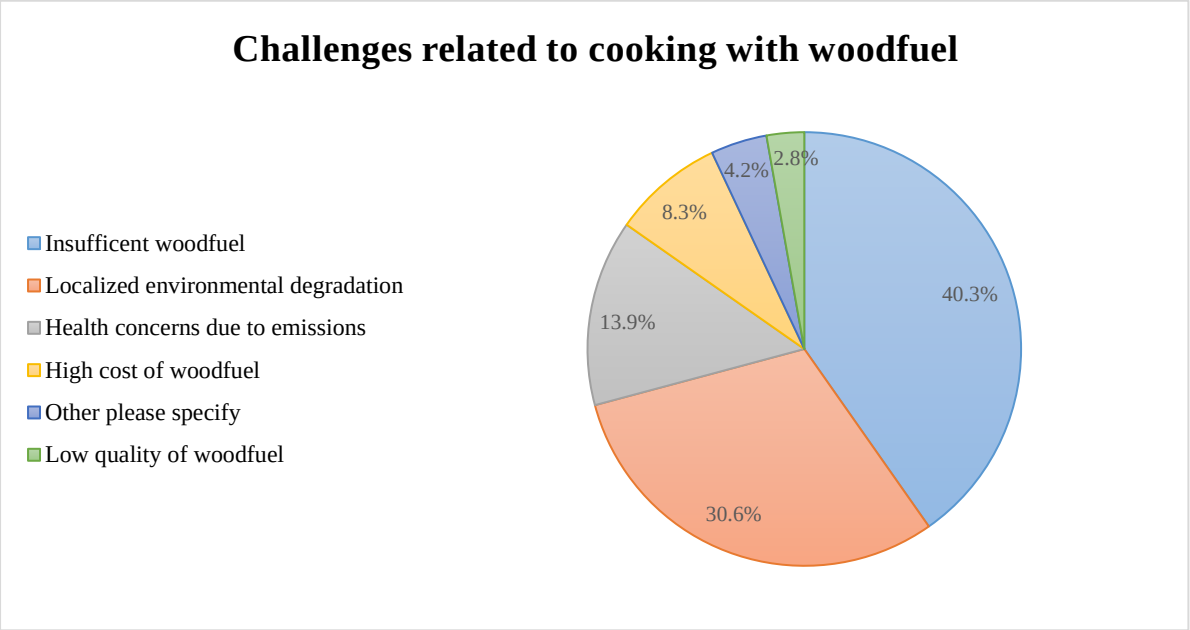


Figure 13. Most frequent mentioned challenges related to household wood fuel use in rural Lesotho (n=30).

According to the respondents, the adoption and sustained use of traditional biomass ICS, ethanol, LPG or gasifier stoves which are and generally considered ‘cleaner’ ICS, and electric cooking solutions ICS are relatively low in Lesotho (Fig. 14). On the Likert scale, which ranges from 1 to 5, the adoption and sustained use of traditional biomass ICS received a mode value of 2. The adoption and sustained use of this technology was therefore considered to be low and not successful by the majority of experts. For ‘cleaner’ ICS solutions, the mode score was 3, indicating that the adoption

and sustained use was considered neither low nor high. Comparatively, more experts indicated the adoption and sustained use of 'cleaner' ICS high (4) or very high (5) compared to traditional biomass-driven ICS solutions. This could indicate that higher quality or cleaner ICS are somewhat preferred by rural households.

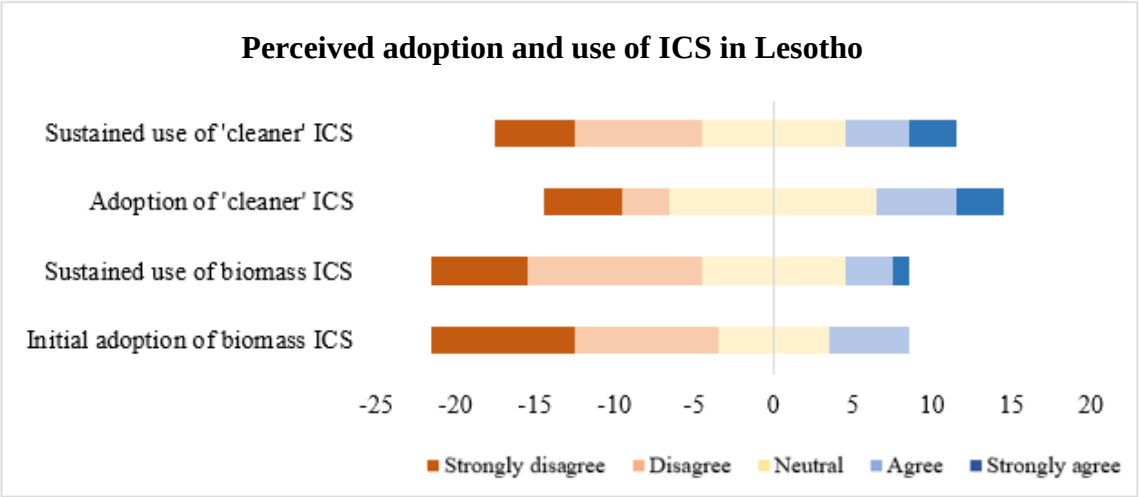


Figure 14. Response count for the perceived adoption rate and sustained use of ICS technologies (n=30).

4.3.2 Barriers to the adoption and sustained use of ICS

The survey results found that the main barriers to the adoption and sustained use of ICS, as perceived by the expert respondents, encompassed financial shortcomings as well as lack of access to repair and maintenance options. Statements related to these issues received the highest scores, indicating that respondents strongly agreed with these factors as potential barriers. The lack of sufficient benefits obtained from ICS or the low quality of stoves available to households received some of the lowest scores. Based on these results, the performance and quality of locally available stoves do not seem to be hindering factors for rural households in Lesotho. All survey results considering barriers for ICS adoption and sustained use are discussed separately in the sections below.

A total of 13 different barriers for the adoption of ICS in rural households were presented to the respondents and rated from strongly agree (1) to strongly disagree (5) (Fig. 15). The low quality of

stoves and limited benefits of the stove perceived by the household received the most negative, or strongly disagree (1) votes. Factors related to cost, including 'high initial purchasing costs', 'lack of access to financing mechanisms' and 'high fuel costs' received the most positive votes indicating that people agreed (4) or strongly agreed (5) that these factors were primary hindrances for rural households to adopt ICS technologies.

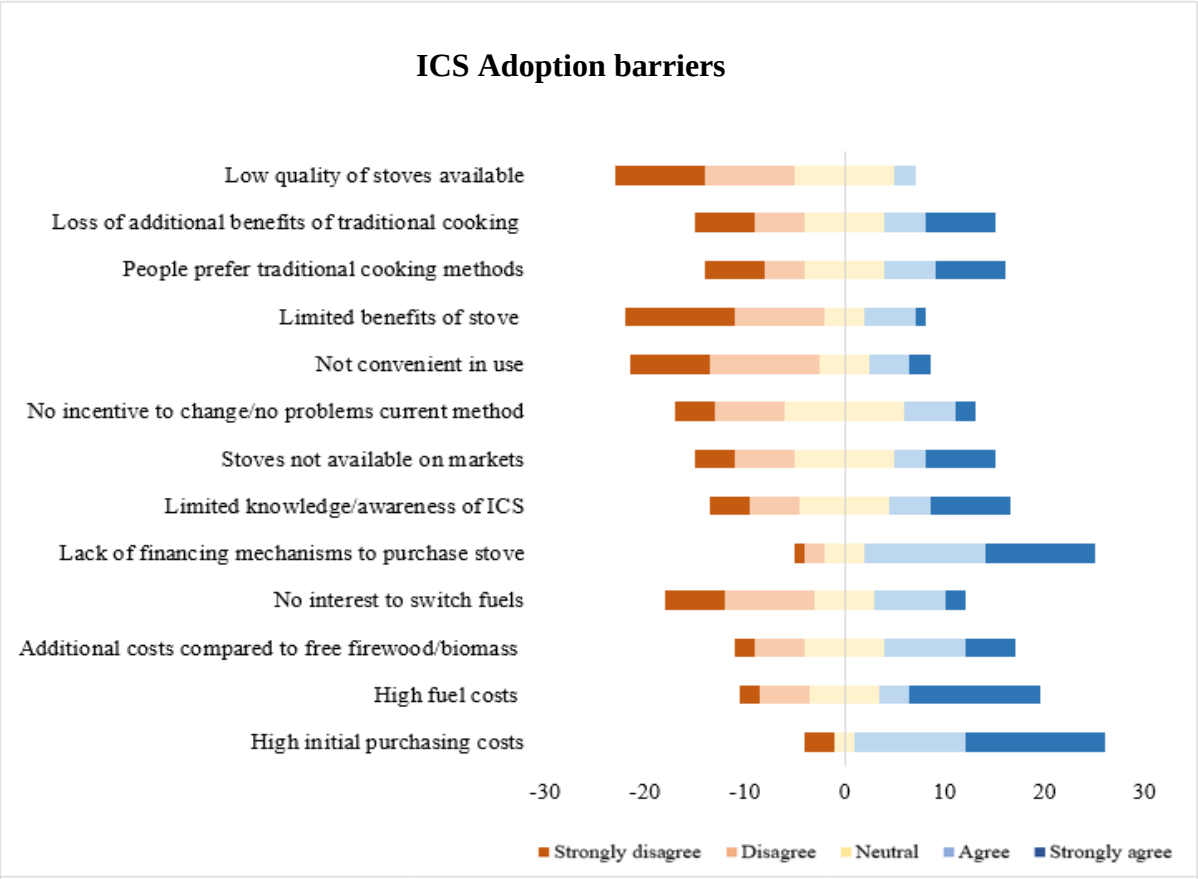


Figure 15. Response count for the perceived adoption barriers to ICS technologies (n=30).

A large number of variables received mixed responses where the experts both agreed and disagreed with the factor as a potential barrier. The median and mode of the expert survey response scores provided more clarity on the general consensus (Fig. 16). All three factors which received the most 'Strongly Agree' votes i.e., the high stove purchasing cost, high fuel costs and lack of financing mechanisms, also received the highest median score of 4 (Agree). The loss of additional benefits from the use of the traditional cooking methods, the preference for traditional cooking methods, the lack of availability of stoves on the market, the lack of incentive to change current cooking methods, limited

knowledge and awareness of ICS solutions and additional costs compared to using free biomass received more split results with median and mode values of 3 (Do not agree / Do not disagree).

A couple of factors were not seen as potential barriers in Lesotho as most respondents tended to either 'Strongly disagree' of 'Disagree' with the statement. The lowest most recurring value in the dataset was for 'Limited benefits of the stove' with a mode of 1 (Strongly disagree). The results for 'Not convenient in use' and 'No interest to switch fuels' had the second lowest mode with 2 (Disagree) being the most recurring answer. Low median scores of 2 were also found for 'Low quality of stoves available', 'Limited benefits of the stove' and 'Not convenient in use', signifying that these factors are of the least concern when it comes to ICS adoption in rural Lesotho according to the experts questioned.

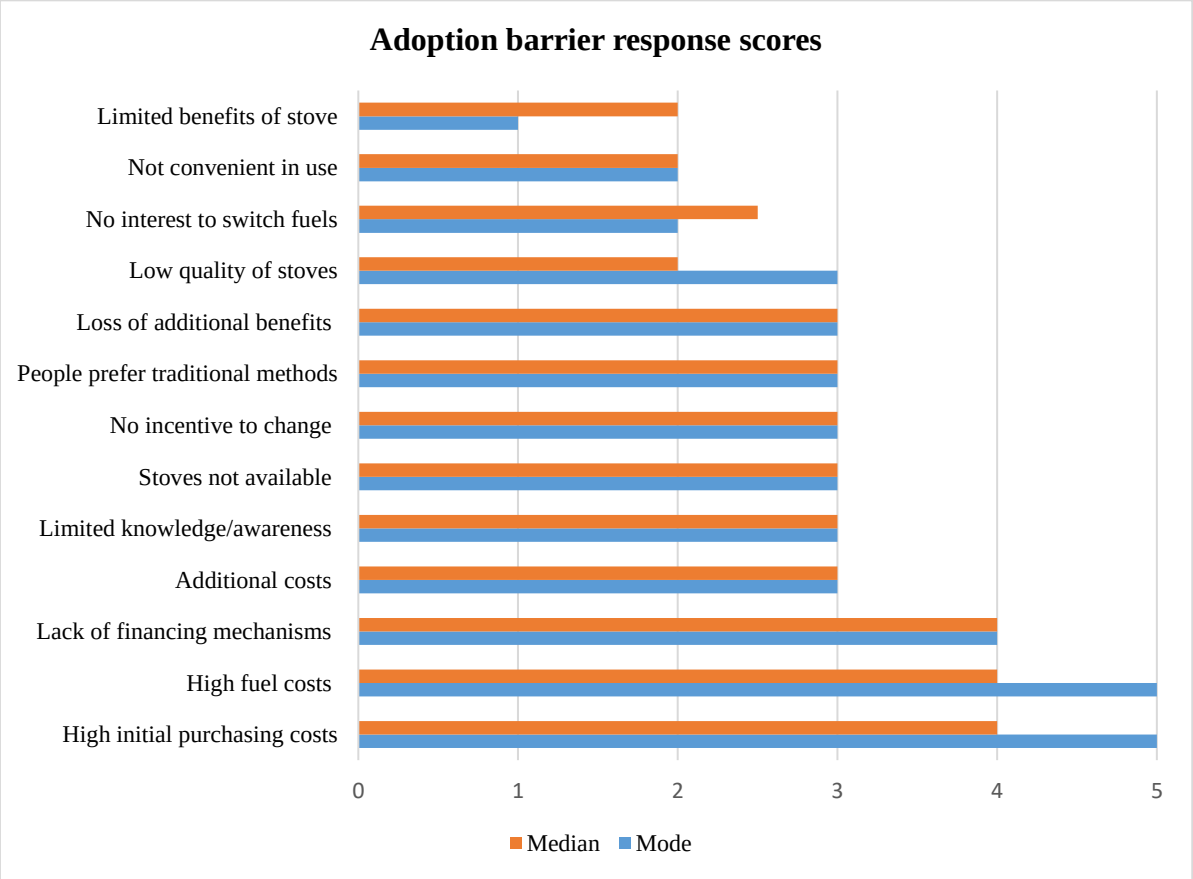


Figure 16. Median and mode of expert survey response scores for the perceived adoption barriers to ICS (n=30).

To measure potential barriers to the sustained use of ICS a total of 10 factors derived from the literature meta-analysis and key-informant interviews were presented to the expert survey respondents

(Fig. 17). The only overlap found between adoption barriers and sustained use barriers was the cost of fuel required for the ICS. 'High fuel costs in the case of a non-biomass ICS' and the 'Lack of training on ICS use' received the most 'Strongly agree' (5) responses. This was followed by 'No repair and maintenance options' and 'Does not fit cultural cooking practices' with most Agree (4) responses. Quite a few factors received relatively few 'Strongly disagree' (1) scores indicating that these factors were not seen as principal barriers to the sustained use of ICS by the experts.

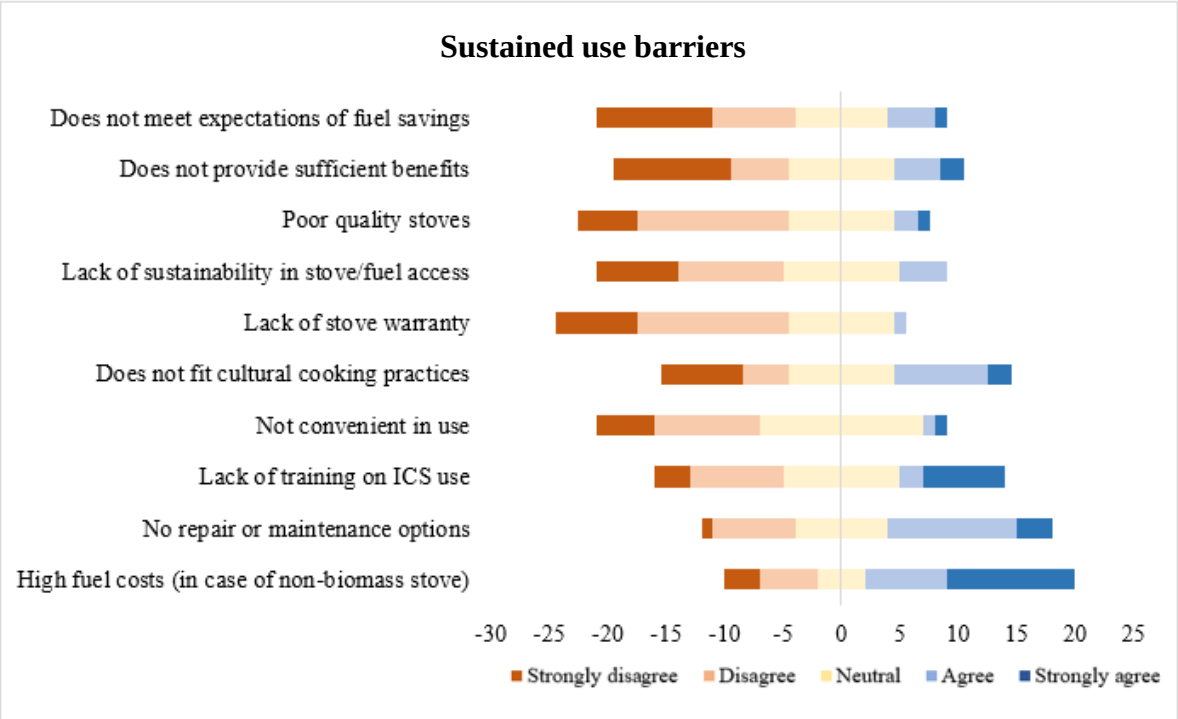


Figure 17. Response count for the perceived barriers to the sustained use of ICS technologies (n=30).

The median and mode scores in Figure 18 further unpack the responses for the potential sustained use barriers. High fuel costs with a mode value of 5 (Strongly agree) and 'No repair or maintenance options' with a mode of 4 (Agree) were the only two factors that respondents overall agreed with. The lowest scoring factor with a mode of 1 (Strongly disagree) and median of 2 (Disagree) was 'Does not meet expectations of fuel savings', followed by 'Does not provide sufficient benefits' with a mode value of 1 and median of 2.5.

Other factors that were not considered barriers by the expert respondents for the sustained use of ICS at the household level included the 'Lack of stove warranty' and 'Poor quality of stoves' marking a median and mode of 2 (Disagree). There was limited clarity on the potential influence of several factors presented in the survey, including the sustainability of stove and fuel access, the fit with local cooking practices, the lack of ICS convenience, and interestingly, the lack of training. Lack of training was mentioned frequently during the key-informant interviews as a barrier to long-term ICS use. Most survey respondents however allocated these factors a score of 3 where they neither agreed nor disagreed if limited or lack of training could be potential barrier for the sustained use ICS in rural households. Similarly, as seen in the response scores to adoption barriers, these more neutral responses received for identifying potential barriers to the sustained use of ICS could have resulted from lower confidence levels, or limited knowledge by respondents in scoring these factors.

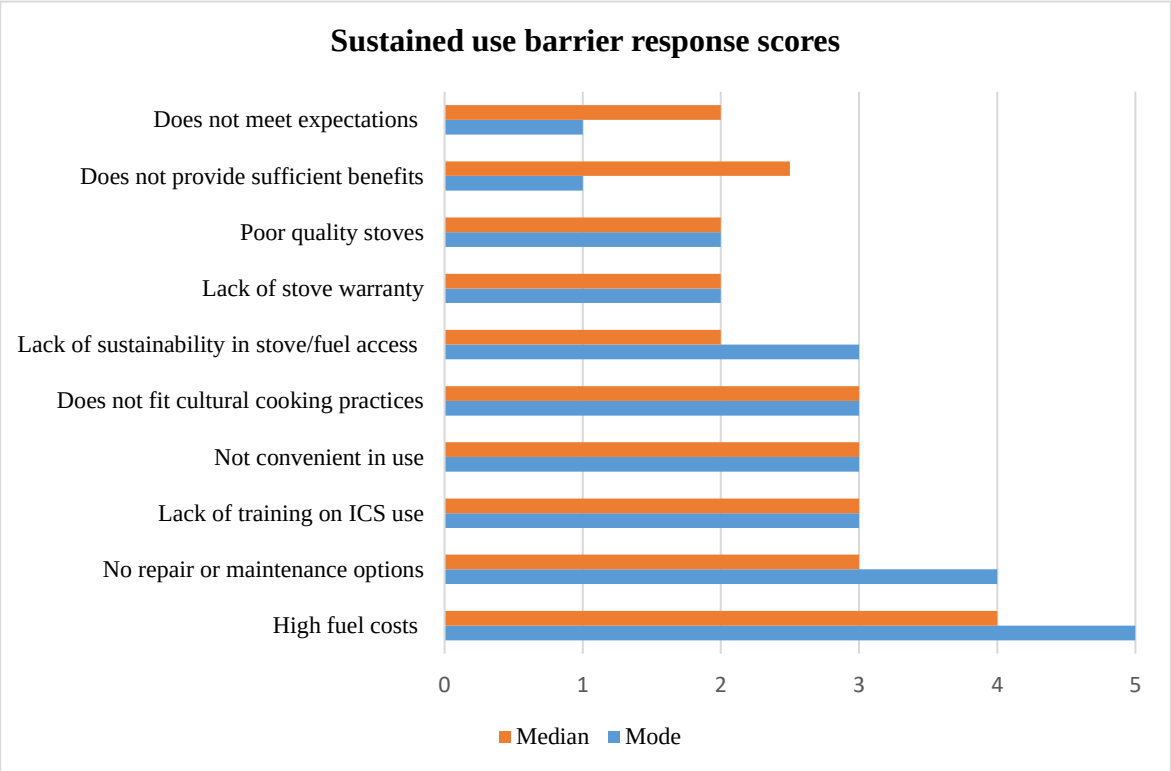


Figure 18. Median and mode of expert survey response scores for the perceived barriers to sustained ICS use (n=30).

In the comment section, experts echoed some of the identified barriers and expanded on a number of current issues that hinder the adoption and sustained use in rural Lesotho. One such barrier was the

absence of well-defined delivery and financing models and lack of education regarding the subject. The limited access to ICS stoves in the market was repeated to be a barrier in Lesotho and the reason increased market access is required to help ICS adoption. At the same time, others mentioned that rural households are aware of different types of ICS and these are available in the market. However, the key barrier was deemed to be the inability for poor households to sustain the cost of re-filling the fuel required for the stove.

4.3.3 Enablers to the adoption and sustained use of ICS

Strong agreement was found among respondents concerning enabling factors to help the adoption and sustained use of ICS. The majority of factors were aimed to overcome financial barriers, either related to the initial high costs of purchasing a stove, as well as the upkeep costs. Several technological aspects were also prominently featured in the results, particularly the need for ICS to be easy in its use, demonstrate immediate and substantial benefits and the ability to prepare local staple dishes. There were also a number of enablers related to the access and sustainability of ICS and compatible fuels on the market. Further, a number of programmatic factors such as provision of training, establishment of repair and maintenance systems and monitoring, follow-up and feedback to help improve the stove design or the implementation model were mentioned. The results for enabling factors for adoption and sustained use of ICS are discussed separately in the section below.

A total of 14 potential enabling factors for the adoption of ICS in rural households were presented in the survey (Fig. 19). Most respondents agreed or strongly agreed with the majority of adoption enablers presented as potentially positively influencing the uptake of ICS among rural households. The highest scores were allocated to factors relating to the household fit of the stove, household cooking practices and technological aspects of the ICS itself. These technological aspects included the need for high quality stoves, the ability of stoves to prepare the majority of local staple dishes and the ease and convenience of the stove when used. There was a high level of agreement amongst respondents regarding which factors could be considered enabling factors for the adoption of ICS for

rural households in Lesotho. This was further demonstrated by the high median and mode scores for the majority of variables (Fig. 20).

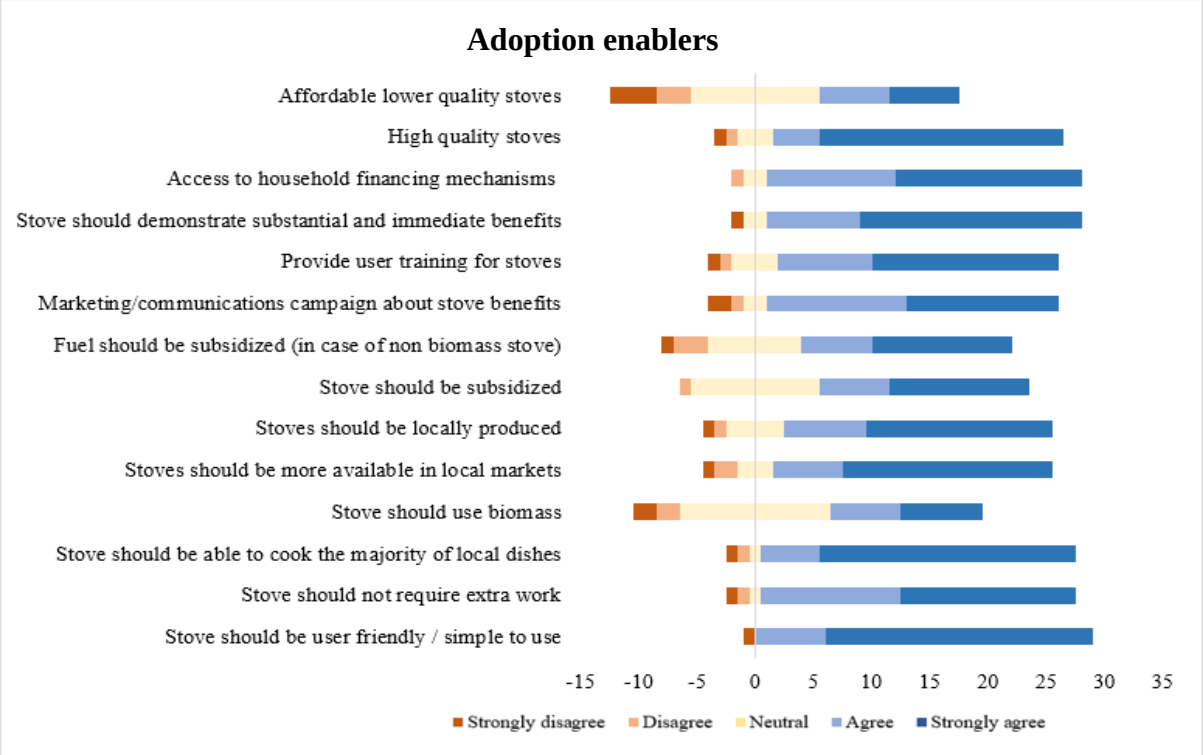


Figure 19. Response count for enabling factors for the adoption of ICS technologies (n=30).

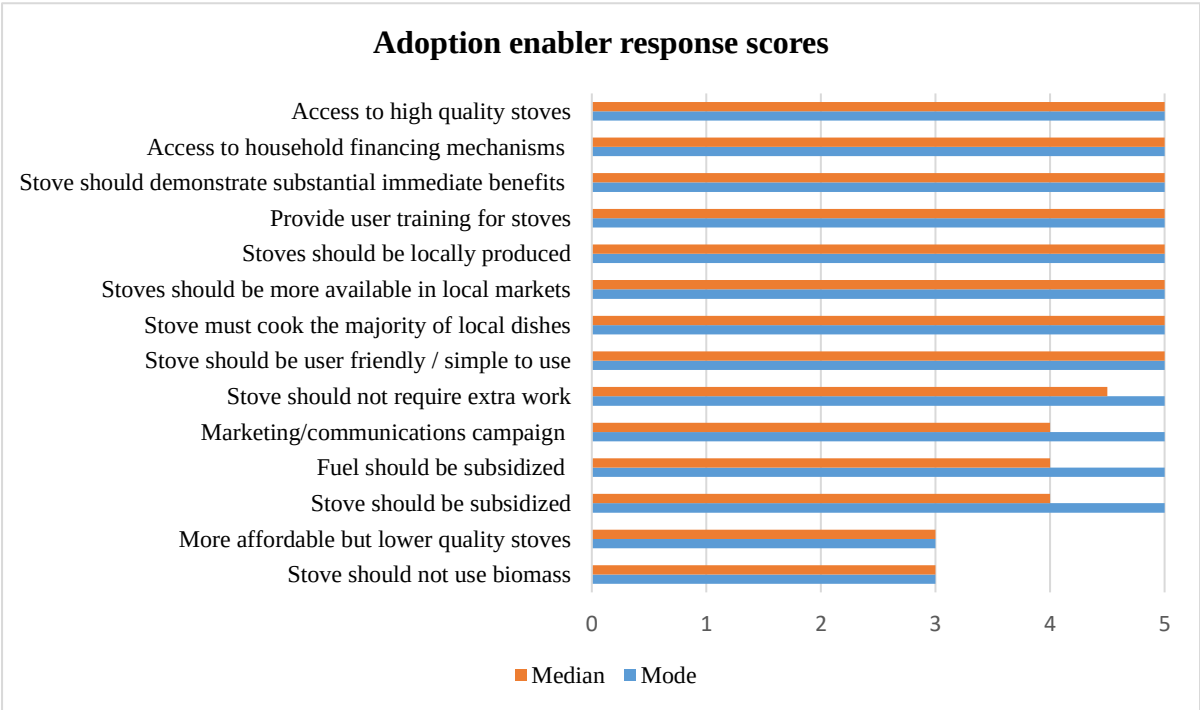


Figure 20. Median and mode of expert survey response scores for potential ICS adoption enablers (n=30).

A total of nine potential enabling factors for the sustained use of ICS solutions in rural households were presented in the survey. Respondents agreed or strongly agreed with all factors and few respondents mentioned to disagree or strongly disagree with any of the statements (Fig. 21).

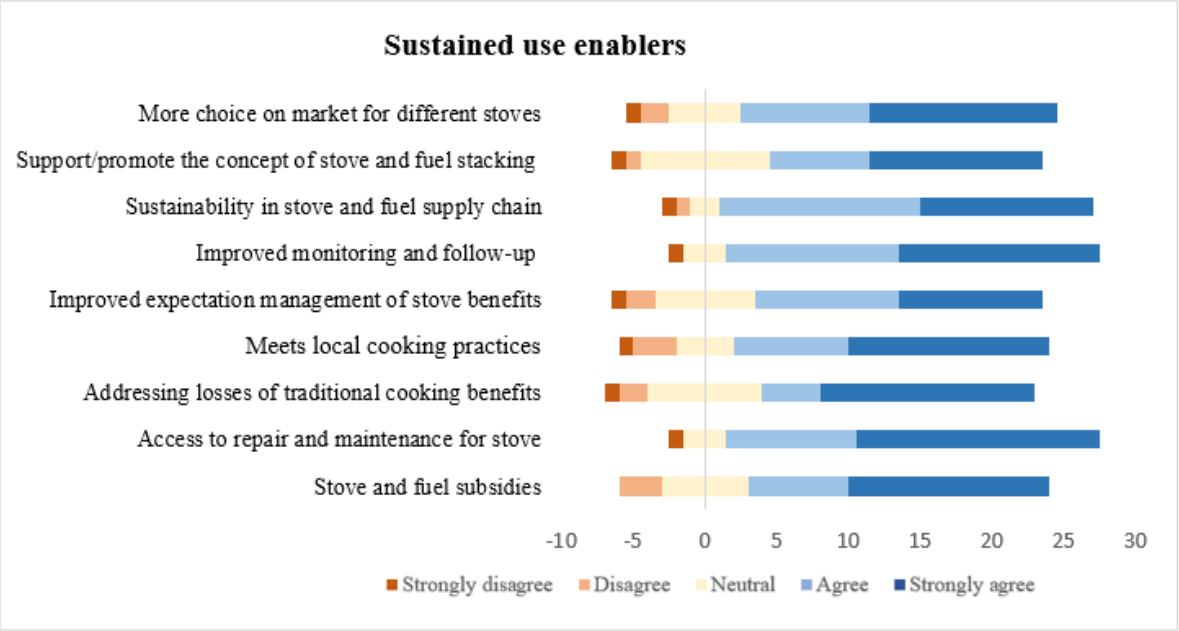


Figure 21. Response count for the perceived enabling factors for the sustained use of ICS technologies (n=30).

The enabling factor 'Access to repair and maintenance' received the majority of 'Strongly Agree' (5) responses and had a median and mode of 5 (Fig. 22). The second most important enabling factor considered by experts was 'Addressing losses of traditional cooking benefits' with a mode of 5 and a median score of 4.5. Only 'Improved expectation management' and 'Sustainability in stove and fuel supply chain' had a score of 4 (Agree) as the most frequent answer provided, were all other factors received a mode score of 5. Some of these factors were reiterated in the comment section of the survey underlining the necessity for marketing and awareness creation and sensitization campaigns for ICS solutions among local communities, including through demonstrations which can help explain the use and benefits.

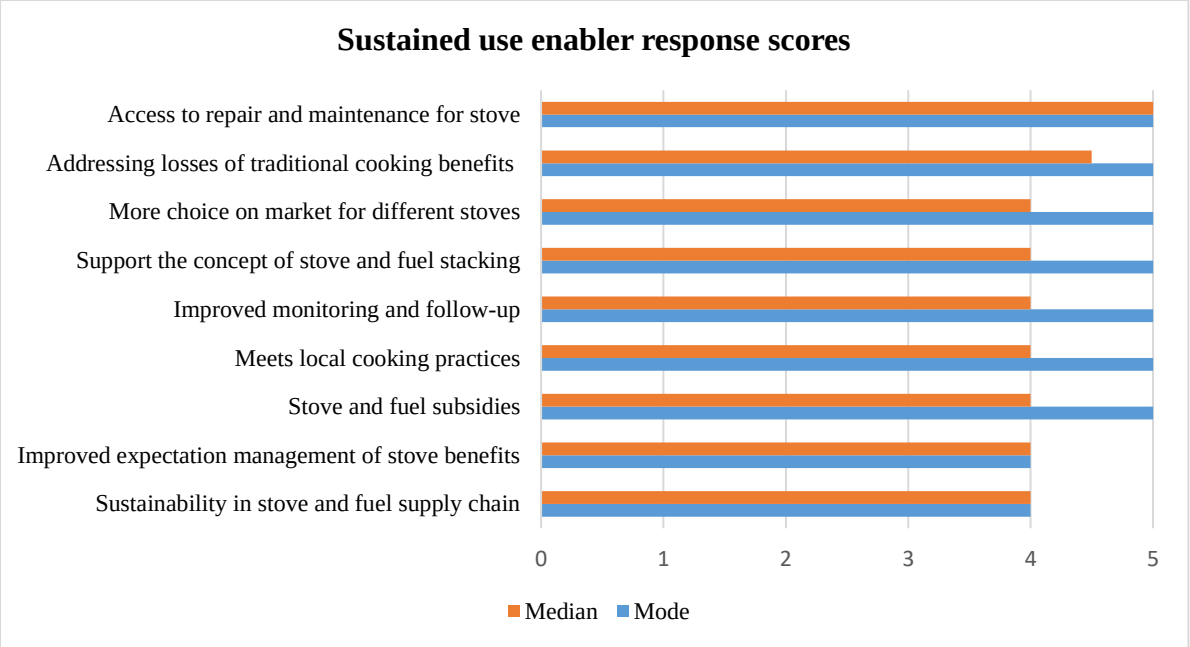


Figure 22. Median and mode of expert survey response scores for the potential enablers for sustained ICS use (n=30).

Additional comments provided by the experts mentioned access to finance, instalment payment options, affordable maintenance and repair opportunities, and subsidy to reduce the cost of fuels to allow poor rural households in Lesotho to realistically continue to use ICS. Government validation or endorsement was also highlighted as a potential enabler to help establish trust around ICS use. In addition, the need for clarity and transparency regarding the stove types available and benefits that the consumer can expect was highlighted as lack of correct and trustworthy information has led to confusion and spoiled the market.

Chapter 5 DISCUSSION

This study set out to examine the barriers and enablers for the adoption and long-term use of ICS among rural households in Lesotho to support the transition away from traditional and unsustainable wood fuel use. Data were collected to first assess the primary determinants for ICS uptake and sustained use in Sub-Saharan Africa more broadly, through a detailed analysis of the literature and key-informant interviews. The main trends that were observed from this data collection exercise were further assessed to test the local relevance and relative importance of these factors for rural households in the lowlands of Lesotho.

To compare the unique challenges faced by rural communities in Lesotho within the Sub-Saharan African context, the local wood fuel landscape and associated challenges are first discussed in section 5.1 to answer research questions 2.1, 2.2 and 3.2:

- Research question 2.1: In what manner and for which purposes is biomass or wood fuel currently used in rural households in Lesotho?
- Research question 2.2: What are the current challenges experienced by rural households in Lesotho with their biomass and firewood cooking fuel use and cooking methods?
- Research question 3.2: Which ICS models have been introduced in Lesotho and have failed or succeeded to achieve adoption and sustained use?

Then, an overview of the primary determinants of the adoption and sustained use across methodologies in section 5.2 answers research questions 1.1 and 1.2:

- Research question 1.1: Which enabling factors and barriers are identified in the literature as main determinants for the adoption and sustained use of ICS in rural households in Sub-Saharan Africa?
- Research question 1.2: Which policy, programmatic and regulatory barriers and enabling factors have been identified in support of the adoption and continued use of improved cookstoves for rural households in Sub-Saharan Africa?

The subsequent sections under 5.3 are structured to explore the barriers and enablers for the adoption and sustained use of ICS in Sub-Saharan Africa and Lesotho respectively. Local findings are compared with regional determinants and existing literature to reveal potential differentiating factors and implications to provide further detail to research question 1.1 and 1.2 as well as answers research questions 3.1 and 4.1:

- Research question 3.1: Which prevailing barriers and enabling factors are identified that prevent or support the uptake and long-term use of ICS in rural households in Lesotho?
- Research question 4.1: Which ICS policies, ICS dissemination models, financial schemes and regulations are in place that support or hinder the adoption and long-term use of improved and clean cooking solutions at household level in rural Lesotho?

The discussion further incorporates the perceived effectiveness of existing policies and ICS programmes in Lesotho based on the identified adoption barriers and makes recommendations to inform and guide future ICS interventions, technologies and policies to answer research question 4.2:

- Research question 4.2: How well do these existing policies, ICS programmes, private sector models and regulations help overcome existing barriers and align with the needs of households to drive the adoption and continued use of ICS?

5.1 Wood fuel use and challenges in Lesotho

The issues surrounding wood fuel use in terms of lack of access, time-poverty, food insecurity, household-air pollution, and environmental degradation have been well documented over the past couple of decades (Von Schirnding et al., 2002; Torres-Duque et al., 2008; Kissinger et al., 2012; Jan and Pervez, 2015; Pope et al., 2015; Caniato et al., 2017; IEA, 2019). Despite these well-observed challenges, and a growing body of research, many developing nations and their communities continue to struggle with high levels of wood fuel dependency and accompanying difficulties. This concern was strongly reiterated by the key-informants for Sub-Saharan Africa as a result of the region's low electrification rates, lack of sustainability and affordability of electricity and alternative fuel sources

for many rural households on top of low levels of ICS adoption. As increased efforts towards expansion of the grid in the region are intended to reduce this wood fuel dependency, key-informants also brought nuance to this vision for remote rural communities in Sub-Saharan Africa and Lesotho.

The high costs of the required infrastructure and supply chain challenges are expected to delay reaching the most remote households. The costs associated with electric cooking or modern cooking fuels were also seen as a financial constraint reemphasizing that increased electricity or alternative fuel access does not equal a transition away from traditional wood fuel use. Similar obstacles were found in the study of Madubansi and Shackleton (2007) in South Africa, a country further ahead in terms of rural electrification than Lesotho. Here it was demonstrated that households did not fully switch to electric cooking when connected to the grid. This was in part due to issues of affordability given that cooking takes up the bulk of most rural household energy needs. Considering Lesotho's low rural electrification rates as observed in the World Bank indicators (2017a) and high levels of rural poverty (World Bank, 2019) it was therefore not surprising that this study found that the majority of rural households in Lesotho are still mostly reliant on traditional wood fuel (56.7%) and other forms of biomass (16.7%) for cooking and heating their homes. The survey conducted amongst ICS experts, manufacturers, implementers and policy-makers in Lesotho showed a general consensus on the current cooking practices of rural households in the lowlands of Lesotho and the challenges associated with these traditions.

This high wood fuel dependency in Lesotho has been documented in the studies of Mwangi (2008) and Qalabane and Chakela (2014) as a contributor to local environmental degradation. It also seems to place a high strain on rural household's energy access as the expert study found insufficient wood fuel (40.3%) to be the most pressing wood fuel use related concern, followed by local environmental degradation (30.6%) as seen in other regions. The country's predominant grassland landscape already naturally limits the amount of wood available compared to other countries in the region consisting of savannas, woodlands, rain forests, bushlands and thickets. When pairing these results with the regional climate change projections, population growth, high levels of over-grazing, and the challenges experienced by the Rural Electrification Unit to extend the grid, sustainable rural

household energy access in Lesotho might become even more challenging (LMS, 2017a; Mpholo et al., 2018; World Bank, 2018; World Bank Climate Change Knowledge portal, 2020).

In response, the NDC of Lesotho aims to increase the use of ICS (LMS, 2017b). This study showed that the adoption rate of such technologies is perceived to be low and the majority of rural households continue to cook on three-stone open fires (40%) or traditional stoves (33.3%). While this could be a result of the limited current scope of ICS interventions in the country, other ICS barriers determined in the experiences of the global south may also be applicable in the context of Lesotho. Despite the few ICS interventions in the country, a number of barriers were identified to the adoption and sustained use of these stoves, including technology, market and knowledge constraints that could explain the limited success of the majority of these interventions. Models that were deemed more successful offered high quality products with long-term durability, reduced loss of additional benefits such as heating, and added new benefits including electricity generation. The high cost of these particular stoves did not seem to deter the consumer. Given the financial barriers mentioned in Lesotho, it is likely that these stoves would not meet the needs of all rural households and a mix of solutions is likely needed to reach the majority of the rural population.

Achieving the targets and commitments set forth in the NDC might become an uphill task if no efforts are made to examine and factor in the challenges of ICS adoption before embarking upon new interventions by various stakeholders involved. One important aspect of consideration is the fuel of choice for the clean and improved stoves that are defined in policy and strategy documents proposing ICS solutions. The study findings indicate that changes in wood fuel availability, as is expected in Lesotho, can both positively or negatively influence ICS adoption, based on the fuel choice of the ICS. Most commonly, if firewood becomes increasingly scarce, a move away from biomass is more likely to increase the success of ICS adoption unless supply chain challenges are tackled (Massawe et al., 2014; Van der Kroon et al., 2014; Jagger and Jumbe, 2016). Further research among rural households is necessary to accurately inform stove and fuel decisions as part of these government commitments.

Despite the importance of context specificity in attempting to address these energy-access concerns and enhance the uptake of ICS solutions, such as presented in the studies of Lewis and Pattanayak (2012), Kersten et al (2017) and Pailman et al (2018), very few studies focussed on the wood fuel challenge in Lesotho, and none considered context-specific factors that determined local ICS uptake. There has been limited agreement in the sector how to best address energy-access issues particularly for cooking, including which stove and fuel is best suited for different audiences and circumstance (Ekouevi, 2013; Palit and Bhattacharyya, 2014; Vigolo et al., 2018). This study both agrees with these results and further refines the determinants for ICS adoption and sustained use for Sub-Saharan Africa and Lesotho.

5.2 Overview of primary determinants to ICS adoption and use across methodologies

The key findings for each of the data collection methodologies presented in Chapter 4 have been synthesized and ranked in Table 5 in support of the discussion. It became evident that while various studies have analysed the possible deterrents to, and catalysts for the successful adoption of improved and clean cooking solutions by assessing the influence of different variables, of these studies, few have focused on the complete range of potential determinants (Ruiz-Mercado et al., 2011; Burwen and Levine, 2012; Putti et al., 2015; Luthra et al., 2015a; Khandelwal et al., 2017; Kapfudzaruwa et al., 2017; Caniato et al., 2017; Vigolo et al., 2018). The findings of this study revealed ICS adoption and sustained use to be much more complex than often considered in the majority of ICS literature. For example, the review of Rehfuess et all (2014) identified 31 factors across 57 studies, the literature meta-analysis in this study encompassed a total of 51 factors influencing ICS uptake and use across 24 studies. More so, the key-informant interviews captured 231 different factors, highlighting many disparities in existing ICS adoption studies.

The relative importance of the identified barriers and enablers where also not always consistent with existing literature and across the data-collection methods. For example, the literature-analysis placed more importance on financial barriers and enablers whilst key-informants positioned technology to be the most influential in the adoption and sustained use of ICS. The key-informant interviews and expert surveys also identified the importance of policy and programmatic aspects when it comes to

ICS adoption and its long-term use, categories which were largely missing in the literature included in the meta-analysis. At the same time, while a large number of determinants identified by the meta-analysis and key-informant interviews were supported in Lesotho, certain factors were deemed comparatively less or more important in the local context. In particular, it was found that financial constraints, different technological aspects and market limitations were more prominent in Lesotho than in the Sub-Saharan Africa context. These outcomes underline the contextual differences when it comes to ICS adoption and sustained use. The following sections take a closer look at these context-specific barriers and enabling factors for Lesotho and if, and how, they diverge from regionally observed trends.

Table 5. Overview of key barriers and enablers for ICS in Sub-Saharan Africa and Lesotho derived from meta-analysis, key-informant interviews and survey results.

Literature meta-analysis (SSA)	Key-informant interviews (SSA-Lesotho)	Expert survey (Lesotho)
Adoption barriers		
1. Financial: - Stove price - Low income - Fuel price	**1. Technology:** - No fit with local cooking practices - Limited benefits - Fails to replace all aspects of traditional stove	**1. Financial:** - High stove purchasing costs - High fuel costs - Lack of financing mechanisms
2. Technology - No fit with local cooking practices - No firewood available - Low fuel-efficiency - Requires wood processing	**2. Programme:** -Incorrect targeting -Lack of context assessment	N/A
3. Knowledge: - Limited perceived benefits	**3. Financial:** - Lack of stove affordability - Additional fuel costs	N/A
4. Demographic - Woman's age	**4. Policy** - Lack of government support or interest - Lack of enabling policies	N/A
Sustained use barriers		
1. Financial: - Operational costs	**1. Technology** - No access to maintenance / repair - Lack of user training	**1. Financial:** - High fuel costs
2. Market: - Lack of access to fuel	**2. Programme:** -Lack of long-term vision -Lack of monitoring / follow-up	**2. Technology** - No access to maintenance / repair
3. Technology - Low stove durability	**3. Policy** - Lack of enabling policies	N/A
Adoption enablers		
1. Financial / Socio-economic: - High income / wealth - Affordable stoves	**1. Technology** - Fit with local cooking practices / needs - User friendly - Clear benefits - Locally produced	**1. Technology** - High quality stoves - User training - Immediate benefits - Fit with local cooking practices - Easy to use
2. Technology - High fuel-efficiency - Reduced cooking time - Requires no wood processing	**2. Knowledge:** - Marketing and communications campaigns - User training	**2. Financial:** - Financing mechanisms - Stove and fuel subsidy
3. Demographic - Female-headed household	**3. Financial:** - Lower priced stoves	**3. Market:** - Locally produced - Increased availability in market
4. Knowledge: - Awareness raising	**4. Programme:** - Feedback from lessons learned - Context-specific stove and fuel selection	**4. Knowledge:** - Marketing and communications
Sustained use enablers		
1. Technology: - Stove quality and durability - Easy to use - Can cook staple dishes - Access to repair and maintenance	**1. Technology** - Supporting stove / fuel stacking - Address loss of additional benefits - User training - Access to repair and maintenance	**1. Technology:** - Access to repair and maintenance - Address loss of additional benefits - Support stove / fuel stacking - Meet local cooking practices
2. Knowledge: - Awareness raising - Meets expectations	**2. Policy / financial:** - Government support and decisions on fuel use -Tax incentives and private sector support - Policy alignment - Stove and fuel subsidy	**2. Market** - More choice on market - Sustainability in stove / fuel supply
3. Financial: - Affordable fuel	**3. Programme:** - Monitoring and inclusion of feedback - Improved community consultations - Context-specific stove and fuel selection	**3. Programme / knowledge:** - Improved monitoring / follow-up - Expectation management of ICS benefits
N/A	**4. Market:** - Sustainability in stove and ICS supply-chain	**4. Financial / Policy:** - Stove and fuel subsidy

5.3 ICS Adoption determinants

Adoption barriers and enablers are better understood than sustained use determinants. This premise is based on the exhaustive list of challenges and potential solutions described by key-informants as well as the number of studies conducted that cover this subject identified through the meta-analysis. Sustained use determinants received comparatively little attention in the interviews and literature research. Both data collection methods found similar trends regarding the prioritization of financial and technological factors as primary adoption determinants often highlighted in ICS adoption research (Urmee and Gyamfi, 2014; Vigolo et al., 2018). Despite this overlap in results, the data also signalled a significant gap in the level of detail provided to these factors. A number of categories that were prominent in the key-informant interviews were absent in the literature analysed. As such, the key-informant interviews uncovered a number of factors that had not yet been well-studied and provides more nuance to the more well-known variables. For example, the importance placed on programmatic determinants as well as knowledge as a primary enabling factor was not found in the meta-analysis.

Enabling factors were, surprisingly, considerably less often mentioned than potential barriers and there was more agreement among informants about the barriers that were driving low adoption rates, and disagreement on which enabling factors could provide solutions to overcome these obstacles. This could indicate that although adoption barriers are firmly understood there is lack of knowledge or conflicting information on how to address these issues. These findings could give some practical guidance on new areas of focus when it comes to ICS interventions and address part of the limitations in ICS research mentioned in the paper of Lewis and Pattanayak (2012). The main adoption determinants for Sub-Saharan Africa and Lesotho from the study are discussed in more detail below.

5.3.1 Financial determinants of ICS adoption

Financial and socio-economic constraints are a very well-researched barrier to ICS adoption (Lewis and Pattanayak, 2012; Rehfuess et al., 2014; Luthra et al., 2015a; Vigolo et al., 2018). In line with these findings, the results of the meta-analysis further define these barriers into low household income, high stove prices and additional fuel costs compared to free firewood as the main barriers to

adoption of ICS in Sub-Saharan Africa. Similar trends were found globally in the systematic review of Lewis and Pattanayak (2012) highlighting both the fuel price and income as key determinants to ICS adoption. The focus on financial constraints as a key barrier adoption is unsurprising as these technologies are predominantly targeted at poor households in developing countries who seldom purchase their fuel or cooking instruments (Akbar and World Bank., 2011). The results of this study indicate that the majority of rural households in Lesotho freely collect firewood or other forms of biomass and cook on a three-stone fire or traditional stove. This could help the explain why financial barriers are the only factors mentioned by experts that hinder the adoption of ICS in Lesotho. Surprisingly, technological barriers were considered the primary adoption barriers for Sub-Saharan Africa according to key-informants. The focus on financial barriers solely could be in response to the upfront investment costs for ICS and the high levels of poverty in the region. These costs can become a considerable hurdle for poor families, a phenomenon demonstrated in several other country-specific studies such as in Burkina Faso (Bensch et al., 2015), Peru (Williams et al., 2020) and Uganda (Levine and Cotterman, 2012). The identified need for increased access to financing mechanisms as well as stove and fuel subsidies to reduce the costs for rural households in Lesotho is in line with these findings. As such, it is very likely that without addressing financial barriers in Lesotho rural households will struggle with ICS adoption, but removing financial limitations alone are not the key to adoption success.

These financial factors are often part of a sub-set of determinants and cannot be seen as stand-alone barriers to ICS adoption. When financial barriers are taken away, ICS interventions still fail to see high levels of adoption. For example in the case of Rwanda, free distribution of ICS did not result in high adoption rates (Gebre Egziabher and Marara, 2016). This is a recurrent a pattern in humanitarian ICS programmes (Himel et al., 2019). The conclusion from the expert survey that the sole barriers to ICS adoption in Lesotho are hinging on financial constraints might therefore be incomplete or perhaps even over-simplistic as financial schemes for ICS in other poor settings have not been able to overcome adoption challenges (Palit and Bhattacharyya, 2014). This becomes more evident as the enabling factors mentioned in the survey encompass a wider range of categories. Here, technological aspects, including the ease-of-use and fit with local household needs as well as the perceived added

value through demonstrable benefits are the most frequently mentioned enablers. These findings seem to imply that while financial barriers are certainly an obstacle that requires appropriate measures to facilitate adoption, these economic constrains should be seen as part of a trade-off between affordability, performance and usability. The importance of such considerations are reflected in technology acceptance literature where other variables are often considered equally or more important than the technology cost alone (Davis, 1985; Porter and Donthu, 2006). Both perceived-usefulness and perceived ease-of-use are notable determinants of the widely accepted Technology Acceptance Model (TAM) by Davis (1985). As could be expected, the introduction of lower quality but affordable stoves were therefore not seen as a solution to overcome financial adoption barriers.

More in-depth research is required to understand the broader range of ICS adoption barriers for rural households. Nevertheless, based on locally identified enabling factors and regional trends it seems evident that solely addressing the financial hurdles surrounding ICS and its fuel costs in Lesotho might increase the access to, and uptake of, this technology only if other important barriers from the household perspective are addressed as well. The opportunity cost of ICS efficiency and usability seems to be one of the more challenging aspects of the equation although the evidence suggests that the careful balance of these trade-offs could even be more important than the more well-researched financial barriers.

5.3.2 Technological determinants for ICS adoption

Technological constraints to the adoption of ICS were emphasized in both the meta-analysis and key-informant interviews, underscoring the challenge of this mainly laboratory-developed technology and its real-world compatibility. Key-informants even considered such technological aspects to be both the primary barrier as well as key enabling factor to ICS adoption. The expert survey respondents only recognized technological factors as enablers to ICS adoption and did not mention these to be barriers. This was an unexpected result based on the outcomes of the meta-analysis and key-informant interviews. The results indicate that most determinants fall on a continuum where the lack of certain aspects are deemed to be a barrier and improving these aspects could be considered an enabler. The fact that experts in Lesotho considered technological aspects solely to be an enabler, rather than both a

potential barrier and enabler as found in literature review and key-informant interviews, could be attributed to limitations of survey scope or methodology used. The neutral scores given by expert respondent in Lesotho for the potential technological barriers to ICS adoption could also be a result of low respondent confidence levels or lack of knowledge on the topic. In this case, the lack of identified technological barriers could be the result of a response bias as people are more likely to select a neutral option when presented the choice instead of their opinion. Given the importance placed on technology as a key barrier to ICS adoption in the region by key-informants, the lack of clarity in expert responses regarding technological barriers in Lesotho would benefit from further research.

ICS solutions are often designed with the highest levels of efficiency in mind, and field testing of stoves predominantly focus on performance, leaving room for error when it comes the ease-of-use or addressing households needs (Jetter et al., 2012; Lombardi et al., 2017; Pakravan and MacCarty, 2020). As a result, the stove can become too complex, require too much work or just not suitable for the context-specific cooking practices regardless of potential fuel efficiencies. In contrast, the meta-analysis found low fuel-savings to be one of the barriers to ICS adoption in Sub-Saharan Africa as this contributes to limited perceived benefits. Similar outcomes have been presented in a number of studies including in Tanzania and Uganda (Adkins et al., 2010). Here it was reported that even while the ICS user was cognizant of the fuel savings due to its high efficiency, the adoption of the stove was dependent on a combination of factors, including usability. This illustrates that high fuel savings are not so much less important than stove usability, as high fuel savings are imperative for any ICS to achieve impact, but it emphasizes the need to address numerous technological aspects that consider household convenience and compatibility. The fact that lack of convenience in ICS use was mentioned as a primary barrier to adoption in Lesotho is therefore not unexpected and should warrant the focus of ICS technology designers.

Introducing any solutions aimed at improved cooking that requires additional work can exacerbate the already heavy work burden carried by women in Sub-Saharan Africa. In many developing countries, including in Lesotho, the majority of cooking-related tasks, and with this the responsibility of using the ICS, falls on the women in the household (Qalabane and Chakela, 2014; Putti et al., 2015). At the

same time, women in this region already carry a disproportionate heavy workload, a well-studied phenomenon as per the World Bank report on gender and time-poverty in Sub-Saharan Africa (Wodon and Blackden, 2006). It is not surprising that the key-informants most often mention additional wood preparation requirements for ICS use and limited comparative benefits as barriers to ICS adoption, well surpassing its financial limitations. Women often value other ICS characteristics over fuel efficiency (Subramaniam, 2000; Urmee and Gyamfi, 2014). Key-informants mentioned technological barriers twice as often as potential financial constraints, again establishing the importance of looking beyond cost as a barrier to ICS adoption.

Durable high quality stoves, high fuel savings, easy use and the ability of ICS to prepare local dishes were recognized as essential enabling factors for ICS adoption in the region, and in particular in Lesotho. This could indicate that locally available stoves are of high quality and efficiency but come at a premium price that remains beyond the means of the majority of rural households. The notion that both key-informants and experts mentioned the benefit of locally produced stoves to increase ICS adoption rates could further be explained by the perceived failure of ICS to align with local rural household needs. This could also imply that the majority of stoves are currently sourced or manufactured abroad and do not come with warranties, repair or replacements. If these stoves are produced locally, perhaps it would resolve part of the market sustainability challenges. However, although locally produced stoves might be better in addressing local needs, they have been heavily criticized due to the often low quality of the product. Field tests have however demonstrated that the potential wood fuel savings from locally well-built biomass stoves can actually exceed fuel savings from more expensive and commercial stoves (Adkins et al., 2010; Putti et al., 2015). If the intended impact of an ICS is to reduce environmental degradation or GHG, the total carbon footprint of imported stoves also warrant further understanding. The discussion on locally produced versus internationally procured stoves should therefore not only depend on local capacity and cost, but the ability of either stove to produce a quality and locally appropriate stove as well as the extent to which it meets the ICS intervention objectives.

5.3.3 Knowledge determinants of ICS adoption

The impact of knowledge on ICS technology and its potential benefits was considered both a barrier (in Sub-Saharan African context) and enabler (in both Lesotho and Sub-Saharan Africa) of ICS adoption. Limited knowledge of ICS technologies was not seen as a hindering factor in Lesotho, but in contrast, increased user training and marketing and communication campaigns to raise awareness on the benefits of ICS were considered locally enabling factors. The lack of perceived interest of rural households to switch stoves was also considered a barrier by the majority of experts and could be an implication of limited awareness and knowledge of ICS technologies. Increasing communication efforts to emphasize the benefits of ICS could be necessary but challenging. Research on effective marketing and communication surrounding ICS interventions have provided mixed outcomes regarding which messaging is most effective in enhancing ICS adoption and use. A study in Malawi by Jagger and Jumber (2016) found a significant positive relation between a households' knowledge on the environmental impacts of traditional wood fuel use and the adoption of ICS in one region, but not in another. A focus on local environmental benefits in ICS communications and marketing to drive adoption is likely dependent on other external factors such as the level of wood fuel scarcity. The results from the meta-analysis show that in some cases the lack of wood fuel can drive ICS adoption, particularly if this means a switch away from biomass, and in other cases it actually hinders adoption. Health benefits of ICS and other health related technologies are often not considered an enabling factor given that health-related messaging has proven to be largely ineffective (Bishop et al., 2014; Shankar et al., 2014).

To drive ICS adoption, marketing campaigns should focus on what is locally considered one of the most important benefits of the technology (Shankar et al., 2014). Per experts' perception, the ease-of-use, ability to cook local dishes and immediate benefits such as fuel and time savings are considered high priority in Lesotho. These findings align with the study by Pailman et al. (2018) conducted in South Africa, Mozambique, Malawi and Zambia which found fuel-savings to be one of the key perceived benefits in ICS use. They also found significant differences among perceived ICS benefits, further driving home the point of the importance of local context considerations. The need for

increased knowledge on the messaging of marketing and communication campaigns therefore needs to be assessed within the context of Lesotho. The current state of heavy environmental degradation in Lesotho and the challenges experienced by households to obtain sufficient wood fuel to meet their household energy needs could also pique interest for ICS adoption. However, the effect of such messaging did not lie within the scope of this study and would warrant further research.

Understanding how to operate the stove, and the consistent and correct use of ICS, is an important facet to obtain the fuel-savings to benefit the household and support the mitigation of localized environmental degradation. Although it was expressed that stoves should be simple in use, it is likely that a number of ICS still require training for the user to maximize the stove's efficiency potential. Such user trainings have proven to be effective for a number of different ICS technologies including in Uganda for biomass stoves (Namagembe et al., 2015) and Sudan and India for LPG stoves (Bates, 2009). Failing to do so can lead to reduced efficiency or even dangerous situations. For example, in Indonesia's massive energy-initiative to convert households to LPG use, initial accidents where blamed on lack of sufficient user training (Budya and Yasir Arofat, 2011; Puzzolo et al., 2016). The importance of getting it right the first time was pointed out in the key-informant interviews. It is likely more difficult to achieve adoption with an ICS product if the household's first experience was a poor one.

5.3.4 Household demographic determinants for ICS adoption

The meta-analysis presented a skewed focus on household demographics compared to other variables mentioned in the key-informant interviews. In most cases, the size of the household seemed to negatively correlate with ICS adoption. Research has demonstrated that fuel expenses for larger households negatively affects the uptake of some ICS solution (Pandey and Chaubal, 2011) and capacity limitations of ICS cannot always meet the needs of larger households (Gitau et al., 2019). This implies that it is not so much the household size that is the limitation but different targeting strategies and potentially fuel and stove selection that do not meet larger household needs are the key issue of concern here. Other factors that could contribute to this negative relationship between household size and ICS adoption are not yet well explored and could help further improve the uptake

among larger households. For example, where the unavailability of fuel wood can influence ICS adoption rates as seen in the study of Massawe (2014), larger households might not be as adversely affected by wood fuel shortages as they have more labour available to collect wood. The need for fuelwood pre-processing as a barrier identified in this study was also highlighted in studies in Ethiopia and Tanzania (Massawe et al., 2014; Adane et al., 2020). Such barriers could be a bigger inconvenience for larger households that require more fuel and would warrant more attention when it comes to targeting larger households.

Understanding household demographics and its impact on adoption can help improve targeting and communication strategies. The results of the meta-analysis highlighted the gender aspect of cooking energy technologies. The higher the age of the women in the household, increased women's decision-making power and being a female-headed household, increases the chances of adopting ICS technologies. As reiterated in the key-informant interviews, the task of cooking and wood fuel collection lies predominantly with women, and while they benefit most from ICS, purchasing decisions are mostly led by men. The slow adoption of more modern cooking technologies and fuels remain unchanged if these gender dimensions are not addressed in ICS interventions (Pachauri and Rao, 2013). These regional trends are also experienced in Lesotho, particularly in rural areas. Here, the family decision-making power lies predominantly with men and women are often not allowed to make independent decisions (LCN, 2015). Such factors should be incorporated in ICS programme approaches, financial mechanisms in support for ICS adoption and communications and marketing campaigns.

5.3.5 Programme and policy determinants for ICS adoption

Two other areas emerged that could be partially responsible for the low levels of adoption as seen in Sub-Saharan Africa (IEA, 2019, 2014; Putti et al., 2015) namely; the key-informants' account of programmatic and policy barriers and enablers. The influence of these factors highlights a gap in research on this topic as the focus has predominantly been on household demographics, financial and technical factors as supported by the meta-analysis results and the Lewis and Pattanayak (2012) study.

Firstly, from a programmatic perspective, incorrect targeting and lack of context assessment, in which the latter plays a significant role in informing the prior, were signalled to be imperative factors in hindering rural household ICS adoption. Similar failures have been demonstrated in a number of rural development programmes (Subramaniam, 2000). The results of this study made it evident that one stove or fuel solution often cannot satisfy all households in different geographic and demographic contexts. The debate on which type of energy source or cooking method is best for rural households could be clarified from such a context assessment. As expected, a primary adoption enabler emphasized in the key-informant interviews was the need for context specific solutions and selection criteria. Existing studies have often overlooked the heterogeneity of rural households' ICS preferences and contexts (Jeuland et al., 2015; Putti et al., 2015; Vigolo et al., 2018; Pailman et al., 2018). In the absence of informed market or targeting segmentation, rural households in this region could be mistakenly seen as a homogenous group with similar energy needs and financial constraints. On the contrary, the potential consumer base for ICS encompasses rural households with great variation in socio-economic status, fuel access, energy use and cooking techniques on top of different local climates and wood fuel related challenges (Putti et al., 2015).

Secondly, a lack of national geographic prioritization also contributes to piecemeal approaches by various stakeholders and can hinder concerted efforts to reduce the cost of ICS and fuels. Organizations such as the World Food Programme have in-house corporate tools to identify priority areas for interventions based on organization-specific objectives (WFP, 2017). These prioritizations are based on the mandate of WFP, or the respective organization, not the national government. As such, it is possible to find disparate efforts being made using disparate technologies across the country (Rehfuess et al., 2014).

Third, government policy can play an important role in increasing access to finance and affordable stove and fuel solutions for rural households. The current lack of government support in the form of subsidy and tax incentives as an adoption barrier for ICS is not unsurprising. India is an example of a successful energy transition from wood fuel to LPG largely due to government efforts and subsidies. However, these subsidies were mostly given to higher income households (Sharma et al., 2019). A

similar pattern is seen in Sub-Saharan Africa where the majority of regionally allocated subsidy funds are received by wealthier households (Rijal, 2007). Several studies have been devoted to the challenges surrounding energy subsidies. It seems not only difficult for governments to maintain, but can even become more challenging to phase-out and run the risk that people will return to their traditional cooking and fuel sources once the subsidy is removed. On the contrary, promising results have been reported for one-off subsidies such as in the paper of Dupas (2014). Here such an approach to subsidy for Malaria nets boosted adoption through household learning. In the key-informant interviews and survey, fuel and stove subsidy were identified as import enabling factors for Sub-Saharan Africa and Lesotho. In reality long-term subsidies might not address the financial barriers and energy needs for poor rural households. In least developed countries such as Lesotho, continued subsidy provision might not be realistic or effective and other financial incentives such as one-off subsidies, tax exemptions, rural household access to credit, ICS and fuel payment plans and funds for rural household energy could provide more feasible financial policy opportunities (Luthra et al., 2015b).

Lastly, lack of government support and enabling policies in Sub-Saharan Africa was the fourth most mentioned category by key-informants as a potential ICS adoption barrier. This category was completely missing within the literature meta-analysis, providing interesting avenues for future research. Governmental institutions and their regulatory abilities can bear a large influence on technology adoption e.g. through the regulatory measures and incentives they can provide (Hall and Khan, 2003). These outcomes highlight the need to further explore both programmatic and policy related factors to turnaround decades of failed attempts to address wood fuel challenges in Sub-Saharan Africa. Explanations provided for the lack of government interest and policy support were linked to the complexities surrounding cooking energy access and by the fact that cooking energy for rural households is not always recognized as a separate challenge from rural electrification (Owen et al., 2013). The share of government involvement required continues to be a complicated issue and might necessitate more concerted efforts from the ICS sector to drive government engagement and action.

Both state-driven and market-based approaches to cooking energy access and ICS have benefits and weaknesses which seem to require future attention in ICS research (Rehfuess et al., 2014). Regardless, my results show that some amount of government involvement is required to stipulate and deliver supporting policies, regulations and provide oversight. Currently, when the scale-up of ICS is included in environmental and energy policies in this region, they often fail to include specific policies, regulations and incentives that support these interventions and the uptake of stoves (Lambe et al., 2015; LMS, 2015; Putti et al., 2015; IEA, 2019). The results refine these findings as to why such issues are conceived to be barriers for ICS adoption. Low consistency in policies and regulations as highlighted in the key-informant interviews can contribute to fragmented or counter-effective interventions. For example, Tanzania's charcoal ban as described in the study of Mabele (2020) resulted in a price increase without effect on the amount of charcoal produced. At the same time, these policies undercut efforts from NGO's focussing on sustainable charcoal production which might have been able to address some of the environmental challenges the government was trying to mitigate (Putti et al., 2015; Mabele, 2020). Poorly conceived and incomplete policies can hinder future private sector investment and unnecessarily raise costs of ICS, increasing the already rampant financial barriers that households experience. Another limitation for the development of robust enabling policies is that oftentimes focal ministries in charge of drafting climate change commitments, environmental or energy policies and financial regulations are not aligned. Implementation of these policies fall regularly under different ministries altogether (Dougill et al., 2018; England et al., 2018).

In Lesotho, various policies and regulations mention ICS, although a unified strategy and clarity in implementation is lacking. The Nationally Determined Contributions of Lesotho to the global effort to reduce GHG (LMS, 2017b) mentions clean cooking solutions through electrification access as part of the country's GHG mitigation measures and aims to disseminate efficient cook-stoves and replace wood fuel with LPG. The National Climate Change Implementation Strategy as part of the National Climate Change Implementation Strategy (2017-2027) of Lesotho (LMS, 2017a, 2017c) includes ICS to develop and promote renewable sources of energy and increase energy efficiency. Here the focus lies on the provision of clean and sustainable energy sources, the adoption of biogas and the reduction of biomass consumption via energy efficient cook stoves. A lack of consistency in identifying

objectives and the prioritization of ICS solutions and fuel sources make it difficult for technology providers, manufacturers and development actors to limit the scope of solutions based on the road set of policies and hence work on different types of solutions with different partners simultaneously. The suitability of these selected ICS and fuel options did not receive further attention in the policy documentation in Lesotho while the results of this study stress how important it is that consideration is given to the local suitability of the stove and fuel choice. If not, over time, this could slow down the effort to shift from traditional wood fuel based cooking practices and perhaps partially explain why few ICS solutions are currently available in Lesotho.

5.4 ICS Sustained use determinants

The contribution of ICS to reduce traditional wood fuel use dependency and its related challenges can only be realized if these products are widely adopted and used continuously. Unfortunately, the study results showed that sustained use determinants have received considerably less attention compared to ICS adoption determinants even while the frequency and long-term use of ICS are equally, if not more, important to achieve the long-term impacts of these stoves (Ruiz-Mercado et al., 2011). This result provides further evidence for recent calls to increase research on the final stages of the ICS adoption process, namely the trial phase and long-term adoption, as per Roger's Diffusion of Innovations theory (Dickinson et al., 2019; Rogers, 2010).

The determinants of sustained ICS use were examined and compared against adoption determinants for Sub-Saharan Africa and Lesotho respectively. The results of the study show some well-defined differences between adoption determinants and the barriers and facilitating factors that enable households to continue to use their ICS. In the meta-analysis, financial barriers and enablers where considered the primary determinant for ICS adoption followed by technological factors. For the sustained use of ICS, there is a shift in which technological aspects are barriers to, and key drivers of sustained use. In addition, a number of new factors were identified that are perceived to contribute to the long-term use of ICS, shedding light on more and different programmatic and market factors in particular. Issues around market sustainability, after-sales follow-up, access to repair and maintenance, ICS expectation management, and the loss of additional benefits obtained through traditional wood fuel

and stove use were perceived as new priority areas. Regardless of this shift in focus, financial barriers are certainly still an important factor in the long-term use of ICS. In Lesotho specifically, high fuel costs when the stove does not use biomass is determined the main barrier for local rural households. Given the often limited funds available for ICS interventions, a notion highlighted in our key-informant interviews, the results of this study provide key-areas of importance for ICS interventions in Lesotho and similar contexts. It also distinguishes the different aspects that need to be addressed and considered before and after initial adoption has taken place. The details of these determinants and its contribution to the existing body of knowledge are discussed in detail in the following sections.

5.4.1 Financial determinants of sustained ICS use

The results indicate that financial barriers remain a dire concern for rural, poor households. Similar to how the initial purchasing costs of a stove are hindering ICS adoption, the operational costs of buying fuel for daily use is a limitation to the sustained use of ICS. Even if financial mechanisms can be put in place to overcome the barrier of the initial purchasing cost, fuel costs remain a great worry. It is evident that the limited attention provided to long-term use has resulted in a focus of ICS policies and financial mechanisms that mainly aim to overcome initial adoption barriers (Ruiz-Mercado et al., 2011).

Efforts to overcome cost barriers for the household thus requires looking beyond such constraints for the initial adoption alone and include attention to sustained use costs. In line with these results, it was not unexpected that the need for fuel subsidy was seen as an enabler in both Sub-Saharan Africa as well as in Lesotho. The need for subsidy has been proven particularly important for rural and remote households as poor infrastructure can further increase stove or fuel costs (Bates, 2009; Puzzolo et al., 2016). Similar conditions are faced by the majority of rural households in Lesotho and logistic challenges to distribute fuels and stoves in the rural countryside were highlighted by a number of key-informants (WFP, 2018; World Bank, 2019). As touched upon in the discussion on ICS adoption determinants, it seems unlikely that the Government of Lesotho will be able to invest in long-term fuel subsidies. Although limited research has been conducted on addressing financial barriers for sustained ICS use, the paper of Jeuland et al. (2018), shows that the provision of fuel subsidy for

purchased fuels often still is insufficient to make such a switch an attractive opportunity for the household. This means that beyond increasing the attention towards more effective financial efforts to overcome operational cost barriers, it is important to select stoves and fuels that are within the financial possibilities of the households targeted. To overcome cost barriers, it seems evident that a long-term vision is needed to understand, plan and inform households of these expenses and develop a stove and compatible fuel selection that is feasible in the long-term. These issues tie in with the barriers and enabling factors raised for ICS adoption. In particular this links with the need for increased context-specific assessment and the inclusion of financial mechanisms to make not only the stove but also the fuel more obtainable. As such, this is an illustration of the importance that critical parameters for both adoption and long-term use of ICS technologies should be considered conjointly.

In Lesotho, high fuel costs appear to be the primary barrier for households to continue to use ICS if it is not biomass-powered. The data shows that the majority of rural households in the lowlands of Lesotho collect their fuel for free. The financial barrier to purchase an alternative fuel source could be substantial given the low socio-economic status of the household (World Bank, 2019). At the same time, the question if ICS stoves for rural households should be bio-mass powered to overcome this issue was not answered uniformly. One explanation for this could be the diminishing available national woody biomass and wood fuel imports of the country (Government of Lesotho, 2017; LMS, 2015). This dilemma might provide an opportunity to reduce the need for wood fuel imports and mitigate wood fuel scarcity as a barrier to ICS adoption. The reality is that wood fuel will remain the primary source of energy in the foreseeable future for a majority of poor rural households, as is expected for Lesotho (IEA, 2014; LMS, 2015; FAO, 2017a).

Despite the often notorious reputation of wood fuel as an unsustainable energy resource in many parts of Sub-Saharan Africa and its potential contribution to deforestation, there is opportunity for biomass-driven ICS interventions to be combined with sustainable wood fuel management. Key-informants raised the issue of sustainable wood fuel management as an aspect often lacking in ICS interventions. Sustainable wood fuel management efforts require appropriate and informed policies and regulations as the failure of many of such approaches that resulted in logging activities instead of wood fuel

management have demonstrated (Dewees, 1989; Chamshama, 2011; Matsika, 2012). When addressed correctly, this approach could help overcome issues of high alternative fuel costs as well as ensure a sustainable fuel supply chain, another important factor recognized to enable the sustained use of ICS.

5.4.2 Technological determinants of sustained ICS use

Technological aspects for ICS become more prominent when trying to predict the sustained use among rural households in comparison to the initial adoption when financial concerns weigh heavier. This has some concrete implications for ICS design and stove selection targeted at Sub-Saharan African rural households as well similar households in Lesotho. Where people initially want to experience an ICS design that fits with traditional cooking practices and is easy to use, for the sustained use, it seems that the limitations of ICS become more apparent among households. An often overlooked aspects in ICS literature that was emphasized in the key-informant interviews, is that of the numerous additional benefits the three-stone open fire brings households. Neglecting to replace these additional uses and benefits of traditional wood fuel use and cooking practices such as heating, lighting or insect repellent, can make the primary and continued use of ICS less interesting and beneficial for households, and may even result in the dis-adoption of ICS. The potential failure as a result of not addressing the loss of these additional benefits has been documented in a study in India. Here the introduction of a smokeless ICS was able to significantly reduce household air pollution but failed to repel insects, and as a result was ultimately unsuccessful (Subramaniam, 2000). The ability for ICS to overcome and address these missing positive externalities of traditional wood fuel use was determined an important enabler, especially in Lesotho.

For colder regions, heating is often a major additional benefit of using the three-stone open fire or traditional stove (Putti et al., 2015). In the lowlands of Lesotho the mean temperature can drop to -3° in its coldest months (LMS, 2021). The improved thermal efficiency of the ICS results in lower levels of heat loss that contribute to warming the house, requiring alternative heating solutions (Katakar and Kongre, 2017). When these positive externalities are not factored into ICS designs, the scope of ICS utility for a household in Lesotho therefore reduces substantially in comparison to a three-stone fire. Daioglou et al., (2012) demonstrate that while cooking is the main function of energy use in rural

households in developing countries, other functions including (water) heating and cooling, are becoming more important when households increase their income. This shift in energy use is due to increased access to other appliances and spending power that provide households the opportunity to meet secondary energy needs in addition to cooking. For space heating in particular, this increase in demand is still predominantly met using biomass. These findings do not only highlight the need to address this loss of benefits, but require further research on the relative importance of each of these benefits within different contexts, climatic conditions and socio-economic groups. If not factored in sufficiently, any gains from ICS wood fuel savings could be replaced by increases in biomass use for space heating, or other benefits normally derived from traditional wood fuel use.

When the goal is to replace the three-stone fire or traditional wood fuel, most ICS technologies focus on just one dimension i.e. the cooking aspect. Nevertheless, this study establishes that the general perception is that one stove cannot replace all cooking needs and additional uses of the three-stone open fire or traditional stove. This concept is reiterated by Shankar et al. (2020) who explores the necessity and phenomenon of stove and fuel stacking. Her study argues the need for stove and fuel stacking from a household perspective due to the costs, unsustainability in the fuel supply chain and mismatch between certain ICS technologies and household energy needs. Switching of fuel and stove use based on seasonal income fluctuations and fuel availability has already been established as contributing to multiple stove usage (Treiber et al., 2015; Pailman et al., 2018). The importance placed on the additional benefits obtained from traditional wood fuel use by households e.g. insect repelling properties in summer and heating in winter, could require a similar approach. An important consideration in this regard is to adjust what constitutes as the successful adoption of ICS. The focus might need to shift towards integrating ICS technologies in the day-to-day life of households to ‘clean up’ their energy use, instead of aiming for a full transition to one ICS or fuel source.

Another major aspect of sustained ICS use links stove technology with programmatic, financial and market decisions, namely, the access to stove maintenance and repair. Across all data collection methods this was seen as one of the most important factors influencing the long-term use of ICS. The lack of access to repair and maintenance options in many ICS interventions was mentioned frequently.

On the other hand, in the meta-analysis, stove quality and durability came to the forefront as a sustained use enabler. These findings imply a level of correlation as increased stove quality and durability might be needed as a result of the lack of repair and maintenance options. When a stove breaks down quickly or has a short life-span, this can result in additional costs for the household that were not accounted for. In Uganda, the lack of repair options and access to spare parts was one of the main causes to dis-adoption of biogas stoves (Lwiza et al., 2017). In turn, it has been established that lack of maintenance can actually reduce the efficiency of an ICS and with this the benefits perceived by the households as well as the life-span (Bensch and Peters, 2015). Although high quality stoves might be able to overcome the need for repair, access to these options are still seen as one of the most important factors that determine the long-term use of ICS in Lesotho.

5.4.3 Market determinants of sustained ICS use

The study found the sustainability of the fuel supply chain and the importance of fuel availability to be a largely neglected area of ICS interventions. Continued access to fuel is an integral part of a household's ability to use improved stoves. Key-informants mentioned that the focus is instead often placed on the ICS technology whilst it is the fuel that powers the stove. Even if all other concerns are addressed and people are willing and able to cook with a new fuel, supply-chain disruptions can prevent people from doing so. This can lead to either a temporary discontinuation of use, or halt the use of the fuel altogether (Quinn et al., 2018). In addition, a recent study conducted among rural households in India demonstrated how a robust fuel-supply chain can increase the demand for ICS (Pattanayak et al., 2019). This further supports our findings that fuel supply-chain sustainability is likely an important enabling factor for ICS sustained use and adoption in Lesotho and similar rural households in the wider Sub-Saharan African region. When ICS interventions are targeted towards remote and rural populations, this aspect requires special attention and links back to other challenges raised as part of ICS programmatic choices. The experience with grid connection and electric cooking demonstrated that unstable energy was one part of the explanation why households did not fully switch to electricity for cooking (Madubansi and Shackleton, 2006). It is therefore likely to expect

that supply-chain disruptions for other forms of fuel such as LPG or ethanol will follow a similar pattern. Programme design should incorporate such risks in their stove and fuel selection.

Even without supply-chain disruptions, poor rural households are hardly ever able to make a complete switch to more costly modern fuels and instead add this new fuel source to their energy-mix (Madubansi and Shackleton, 2006; Shankar et al., 2020). This brings us to the second market enabler expressed for Lesotho; the need for increased choice of stoves and fuels on the market. On one hand this does not seem uncommon as traditional marketing research informs that increased product choice allows people to make trade-offs among different product attributes that fits their needs (Chernev, 2011). This aligns with the study findings of the importance of stove and fuel fit with household cooking practices. On the other hand, too much choice can increase choice difficulty and can prevent people from purchasing a product all-together (Berger et al., 2007; Chernev, 2011). Given the current limited options that rural households in Lesotho have to move away from traditional firewood or biomass use, it is unlikely such choice fatigue would set in.

When the goal is to increase the long-term uptake of ICS and cleaner fuels compared to traditional wood fuel use, there should be a fall-back option when people temporarily cannot access such fuels, or when there are supply-chain disruptions. Anticipating this by enabling households to have access to more than one fuel or stove allows them to be flexible in their fuel choice based on their current circumstances. It also ensures that whichever fuel is chosen, it still contributes to reducing the harmful side-effects of traditional wood-fuel use in the region and mitigates household food insecurity by reducing risk of not being able to cook their food (Caniato et al., 2017). Following this approach would require improved efforts when it comes to marketing and information dissemination on the benefits and draw-backs of different fuel and stove solutions, improved financing mechanisms and investments in private sector and supply-chains.

5.4.4 Programme and policy determinants of sustained ICS use

The lack of enabling policies that support ICS in Lesotho and Sub-Saharan Africa were well-documented in our findings. One such gap relates directly to the explored market determinants for ICS adoption and sustained use. Policies not only give direction to government efforts in a certain

area, they also encourage or discourage various stakeholders from their involvement as established in the paper of Brew-Hammond (2010). The current policies of Lesotho regarding ICS and reducing wood fuel needs are ambitious, despite their limitations in uniformity regarding ICS objectives and implementation approaches (LMS, 2017a, 2017b, 2017c). As such, the need for increased market participation in this sector to achieve these goals could be hindered by the lack of enabling policy, financing investments and incentives for the private sector (Martinot et al., 2002). The need to better understand how the public sector can achieve and design enabling policies to increase private sector interest gives new direction for future research as these more detailed workings were beyond the scope of this study.

As the majority of determinants for ICS adoption and sustained use have proven to be complex, there were also promising findings that presented more easily to overcome challenges. One such area was the current lack of monitoring and follow-up after the introduction of ICS technologies or launch of ICS interventions. This outcome ties in with existing research on longitudinal monitoring and the need to understand any constraints or challenges that take place during all phases of the adoption process (Rogers, 2010). Taking into account the more recent advancements in performance-measurement technologies, addressing this current gap in ICS programme approaches has become much easier and deserves ICS implementers' attention (Putti et al., 2015). These technologies cannot only inform if the ICS provides the fuel-savings as promised, but they also have the ability to confirm if people are actually using a stove and how often. The introduction of these measures can also further contribute to a number of other determinants for ICS use and adoption, including improving the fit with local household needs and cooking practices. It can also deliver new opportunities to understand if user training was sufficient by assessing ICS fuel-efficiencies, which are often not met as a result of incorrect use (Puzzolo et al., 2016).

Lastly, the results show a broad consensus regarding the lack of long-term vision for ICS programmes. If the focus is too narrow and the goal revolves around short-term adoption, it begs the question if these programmes can actually deliver the results sought i.e. to decrease GHG emissions and reduce the pressure on biomass resources through fuel substitution and the introduction of ICS

(LMS, 2015; LMS, 2017b). As this study found notable differences among the determinants for ICS adoption versus the sustained use, this requires a long-term phased approach that addresses these changes over time.

Chapter 6 CONCLUSION

The widespread use of wood fuel to fulfil household energy needs faces an abundance of challenges for the wellbeing of people and their environments. Rural communities in Sub-Saharan Africa are especially reliant on traditional wood fuel and inefficient cooking methods for their energy needs. High levels of poverty and limited access to electricity or other modern or clean fuel sources exacerbate these problems, driving wood fuel dependence. With prognoses that traditional wood fuel use will only increase in this region despite gains in rural electrification, solutions that can help mitigate traditional wood fuel-related challenges or allow a transition towards cleaner and sustainable fuel sources become critical. For decades, the introduction of improved cookstoves was considered one such promising solution. Unfortunately, the implementation of this technology has been largely unsuccessful with limited uptake. Increasingly research is needed to understand what is driving this and bridge the gap between theory and practice.

In the context of Lesotho, a country with one of the lowest woody biomass resources in the region, high levels of traditional wood fuel dependence are contributing to localized environmental degradation and rural household energy poverty. The majority of Lesotho's rural households' energy consumption is taken up by cooking, while the uptake of improved cookstoves in this region has been very low. Although the country's energy policy and Nationally Determined Contribution rely partially on the success of this technology, there has been a glaring lack of research on both the topic of ICS adoption and its sustained use in Lesotho. This study addresses existing gaps in ICS literature to improve the success of ICS interventions and mitigate the challenges surrounding high levels of traditional wood fuel dependency in Sub-Saharan Africa and particularly Lesotho. This research contributes to the existing body of work by 1) analysing and identifying a broad range of Sub-Saharan-specific ICS adoption barriers as well as enablers for rural households, 2) exploring and classifying determinants to the sustained use of ICS within the same framework, and 3) applying these findings to the context of Lesotho.

First, I conclude that the research on ICS in Sub-Saharan Africa has mainly concentrated on a limited set of determinants for ICS adoption with a specific focus on socio-economic, demographic and financial factors. Much less attention has been given to factors that influence the sustained use of the technology. Without long-term ICS use, the potential impact of ICS as a mitigation measure to harmful traditional wood fuel use cannot be attained. The data in this study unveiled a more in-depth and comprehensive understanding of the different factors that influence initial adoption versus those that enable the long-term use of ICS technologies. The study concludes that if the focus remains solely on ICS adoption, the potential of ICS technologies cannot be obtained. While it remains important to understand and address determinants that allow and entice households to adopt ICS technologies and reduce their wood fuel use, the long-term primary use of ICS is what creates and sustains long-term wood fuel reductions. Financial, technology, market and policy factors are considered main determinants across both initial adoption and sustained ICS use, however, they are translated and require attention in different ways. Where initial purchasing costs is a key barrier to initial adoption, fuel costs are a greater concern for its sustained use. Similar differences are found when it concerns technological barriers as access to repair and maintenance becomes crucial to allow long-term use but an appropriate fit between cooking practice and matching technological is of far greater importance for its initial uptake. This research further refined and categorized the relative importance of these determining factors for Sub-Saharan Africa, and Lesotho specifically.

Second, more attention should be given to the user experience and its technological implications. Although it was evident that financial barriers remain a dire concern when it comes to ICS uptake and the transition away from traditional wood fuel use in Sub-Saharan Africa, this study finds that focussing solely on these issues is unlikely to drastically improve the outcomes. Instead, a number of often inter-connected technological, programmatic, knowledge, market and policy factors were recognized as key-determinants for ICS adoption and its sustained use. Where financial factors are often considered the primary barrier to adoption and sustained ICS use, our findings indicate that the technological aspects of ICS are more important enabling factors. Technological advancement and performance of ICS needs to be better balanced with the user context. Marginal benefits do not pique

the interest of the user if significant additional work is required or the technology is more of a daily inconvenience than improving their lives. Fuel savings alone often do not provide a monetary value to rural households who collect fuel for free, hence the perceived value of ICS needs to be met through convenience. The reluctance of households to switch away from traditional cooking methods is often attributed to cultural preferences, however such conclusions are not well-supported in our findings. More likely, poor benefits, additional costs and inconvenient technologies that do not meet rural household needs and cooking practices are more likely to drive such reluctance.

Third, the results indicate that less focus should be placed on the ideologic idea that one technology or fuel can replace all aspects of traditional wood fuel use and cooking. In Lesotho specifically, the loss of additional benefits obtained through traditional wood fuel use, such as heating, requires the attention of ICS implementors and manufacturers. Improved cookstove technology addresses just one aspect of traditional wood fuel use. This implies that even if all cooking aspects can be replaced through ICS, the reliance on traditional wood fuel use for other household energy needs remain. This understanding also ties in with the need to support stove and fuel stacking to realistically address the multi-faceted nature of how traditional wood fuel is used. As a consequence, this requires different programmatic, market and policy approaches within the ICS sector.

Fourth, my findings demonstrate the importance of policy and programme related determinants when it comes to ICS adoption and its sustained use, an area which has received fairly limited scientific attention to date. Increased emphasis should be placed on the (unintentional) hinderances of ineffective programmatic and policy work as well as the opportunities within these areas. The barriers to adoption and potential enablers are not only found at the household level but at times are created through incorrect and uninformed targeting, lack of long-term planning, limited or no government support and the absence of enabling policies and regulatory measures. This can result in market-, sustainability and supply-chain challenges, additional financial constraints, incoherent and counter effective regulations and implementation strategies, and an overall mismatch in fuel and stove choice and its consumer audience. In particular, increased long-term planning and vision, improved national strategy and enabling policies, monitoring and private sector support are considered key enabling

factors. Fuel and stove subsidies were frequently identified as potential enablers to overcome greater financial barriers. However, prior research demonstrated both success as well as potential damaging and ineffective results when subsidizing fuels and would warrant further research in the context of Lesotho. An improved contextual understanding is therefore of paramount importance and needs to be the basis for ICS and rural household energy policy formulation and programmatic approaches.

Lastly, the overarching determinants of ICS adoption and sustained use can differ depending on context and location specific influences. Where global or regional identified barriers or enabling factors can provide guidance to ICS manufacturers and implementors to their design and approach, location specific context is needed to interpret these determinants and its relative importance. The importance placed on different barriers and enablers in Lesotho at times varied from those seen in Sub-Saharan Africa. The discussion concerning locally made versus imported ICS remains an area of dispute among key-informants and within literature. As such, it did not emerge as a clear determinant for Sub-Saharan Africa. Nevertheless, my results indicated a preference in Lesotho for locally produced technologies to address a number of issues regarding the product-consumer fit. High quality stoves, the need for increased choice in fuels and stove in the market and addressing the loss of additional benefits obtained from traditional wood fuel use were considered more important in Lesotho compared to regional trends. In contrast, the local barriers for adoption and sustained use seemed to be much less understood and varied compared to findings for Sub-Saharan Africa. This illustrates the importance of a context-specific approach towards ICS and the need for a better understanding of the heterogeneity among rural households in this region, and likely within the country itself. As such, it is recommended to find a more holistic, long-term, context-specific and integrated approach to ICS interventions with a different interpretation of the abilities of ICS and its success.

It is hoped that this research can contribute to a better understanding of the key determinants to ICS adoption and its sustained use, the context-specificity of these factors and the importance of considering such critical parameters for both adoption and long-term use of ICS technologies

together. Without addressing these major roadblocks, tackling the widespread energy poverty and localized environmental degradation in Lesotho will be a mammoth task.

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Annex I Participant information and consent forms

1A Participant information sheet key-informant interviews

Animal, Plant and Environmental Sciences
University of the Witwatersrand
1 Jan Smuts Ave, Braamfontein
Johannesburg, South Africa

Dear (name of proposed candidate),

My name is Daphné Carliez and I am a Master student in Environmental Sciences at the university of Witwatersrand in Johannesburg, South Africa. As part of my studies, I am currently working on a research project that examines the determinants to the adoption and long-term use of improved or clean cookstoves in rural households in Lesotho under the supervision of Professor Wayne Twine. The aim of this research project is to help improve the design of improved cookstove (ICS) and alternative fuel programmes in Lesotho and contribute to the scientific body of knowledge on ICS adoption and long-term use.

As part of this project, and given your expertise in this area, I would like to invite you to take part in an interview. This one-time interview will involve answering some ten questions about the perceived barriers and enabling factors to the adoption and long-term use of improved cookstoves in rural households based on your personal experience. The complete interview will take around 30 minutes of your time. With your permission, I would also like to record the interview.

Your name will not be recorded outside of this consent form and any information that you provide will be confidential and not disclosed to other people. This study will be written up as a research report and the information collected will be used anonymously with no mention of specific persons or organizations if you prefer so. Your participation is voluntary, and you can choose not to answer any or all of the questions if you wish. If you agree to participate, I would like to ask you to provide your signature, or provide consent for me to sign on your behalf, on the consent form to agree with being included in the study anonymously. If you have any persons in mind who are experts in this subject matter and believe to be valuable for this research, I would be grateful if you could share their details with me so that I can reach out to them, or please feel free to forward this invitation letter.

If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. If you wish to receive a summary of the final report, I will be happy to send it to you. If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrec-medical.researchoffice@wits.ac.za

Yours sincerely,
Daphné Carliez
2395575@students.wits.ac.za

Supervisor:
Professor Wayne Twine
Wayne.Twine@wits.ac.za
[redacted]

1B Consent form key-informant interviews

Title of project:

"Determinants of improved cookstove adoption and sustained use to substitute or reduce traditional wood fuel use in rural Lesotho"

Name of researcher:
Daphné Carliez

Purpose and conditions of research
This interview is part of the research project that examines the determinants to the adoption and long-term use of improved or clean cookstoves in rural households in Lesotho. The research is conducted by Daphne Carliez, fulltime MSc student of Environmental Sciences at the University of Witwatersrand in Johannesburg, South Africa under the supervision of Professor Wayne Twine. The aim of this research project is to help improve the design of improved cookstove (ICS) and alternative fuel programmes in Lesotho and contribute to the scientific body of knowledge on ICS adoption and long-term use.

Your name will not be recorded outside of this consent form and any information that you provide will be confidential and not disclosed to other people. This study will be written up as a research report and the data collected during the survey will be used anonymously with no mention of specific persons or organizations if you prefer so.

Your participation is voluntary, and you can choose not to answer any or all of the questions if you wish. If you agree to participate, I would like to ask you to provide your consent to be included in the study anonymously.

I, ……..., agree to participate in this research project. The research has been explained to me and I understand what my participation will involve. Please circle the relevant options below.

I agree that my participation will remain anonymous	YES	NO
I agree that the researcher may use anonymous quotes and information provided by myself in her research report	YES	NO
I agree that the interview may be audio recorded	YES	NO

…… (signature)
…… (name of participant)
…… (date)

1C Participant information sheet online expert survey

Animal, Plant and Environmental Sciences
University of the Witwatersrand
1 Jan Smuts Ave, Braamfontein
Johannesburg, South Africa

Dear (name of proposed candidate),

My name is Daphné Carliez and I am a Master student in Environmental Sciences at the university of Witwatersrand in Johannesburg, South Africa. As part of my studies, I am currently working on a research project that examines the determinants to the adoption and long-term use of improved or clean cookstoves in rural households in Lesotho under the supervision of Professor Wayne Twine. The aim of this research project is to help improve the design of improved cookstove (ICS) and alternative fuel programmes in Lesotho and contribute to the scientific body of knowledge on ICS adoption and long-term use.
As part of this project, and given your expertise in this area, I would like to invite you to take part in an online survey. This one-time survey will involve answering some ten questions about the perceived barriers and enabling factors to the adoption and long-term use of improved cookstoves in rural households based on your personal experience. The full survey will take around 5-7 minutes to complete.

Your name will not be recorded and any information that you provide will be confidential and not disclosed to other people. This study will be written up as a research report and the data collected during the survey will be used anonymously with no mention of specific persons or organizations if you prefer so. Your participation is voluntary, and you can choose not to answer any or all of the questions if you wish. If you agree to participate, I would like to ask you to provide your consent to be included in the study anonymously. This can be done on the first page of the survey form.

Please find the link to the survey here: https://s.surveyplanet.com/itpo8jqrX
If you have any persons in mind who are experts in this subject matter and believe to be valuable for this research, I would be grateful if you could share their details with me so that I can reach out to them, or please feel free to forward this invitation letter.

If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. If you wish to receive a summary of the final report, I will be happy to send it to you. If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrec-medical.researchoffice@wits.ac.za

Yours sincerely,

Daphné Carliez
2395575@students.wits.ac.za

Supervisor:
Professor Wayne Twine
Wayne.Twine@wits.ac.za

[redacted]

1D Consent online expert survey

This survey consists of 10 questions which will take 5-7 minutes to complete. The survey is part of the research project that examines the determinants to the adoption and long-term use of improved or clean cookstoves in rural households in Lesotho. The research is conducted by Daphne Carliez, MSc student of Environmental Sciences at the University of Witwatersrand in Johannesburg, South Africa under the supervision of Professor Wayne Twine. The aim of this study is to help improve the design of improved cookstove (ICS) and alternative fuel programmes in Lesotho and contribute to the scientific body of knowledge on ICS adoption and long-term use.

Your name will not be recorded and any information that you provide will be confidential and not disclosed to other people. This study will be written up as a research report and the data collected during the survey will be used anonymously with no mention of specific persons or organizations. Your participation is voluntary, and you can choose not to answer any or all of the questions if you wish. If you agree to participate, I would like to ask your consent for your responses to be included in the research.

Page 1

BEGIN

I understand that there is no benefit to me by participating and no penalty to me for declining to participate in this survey. By taking this survey I acknowledge that my answers can be used anonymously for the purpose of the research project.*

- ☐ YES
- ☐ NO

* If selected NO the survey ended and people were thanked for their time. If selected YES, the survey started.

Annex II Interview guide

Purpose of key-informant interview: This data collection tool is intended to inform the research on the limitations and barriers, as well as opportunities and drivers of the uptake and use of improved cookstove interventions, and understand the situational context in rural households in developing countries through interviews with global and local ICS experts and policy and programme-makers. The interviewee is asked to sign the participant information document prior to the start of the interview via e-mail. If preferred by the respondent, the document can be signed on his/her behalf via oral confirmation. This can be done after introductions are provided and once the interviewee is informed on the expectations and his rights. For this, the following statement is to be read or shared.

Introduction and explanatory statement: "My name is Daphné Carliez and I am a student at the university of Witwatersrand in Johannesburg South Africa. I am currently working on a study that examines the determinants to the adoption and long-term use of improved or clean cookstoves in rural households in Lesotho. Given your expertise in this area I would like to ask you some questions about how the perceived barriers and enabling factors that hinder or support the adoption as well as the long-term use of fuel-efficient stoves based on your personal experiences and knowledge in this area. Your name will not be recorded and any information that you provide will be confidential and not be disclosed to other people. The outcomes of the study are aimed to help improve the design of cookstove and alternative fuel programmes in Lesotho and contribute to the scientific body of knowledge on ICS adoption and long-term use. Based on the interviews and expert surveys, the combined results total results will be included in the final report and available online but with no mention of specific persons or organizations if you prefer so. Your participation is voluntary, and you can choose not to answer any or all of the questions if you wish. If you agree to participate I would like to ask you to provide your signature, or provide consent for me to sign on your behalf, on the participant information document which states what I just said and that you agree with being included in the study anonymously.

Guiding interview questions

PARTICIPANT (name or number): _____

DATE, LOCATION: _____

OCCUPATION / ORGANIZATION: _____

YEARS OF ICS EXPERIENCE: _____

1. **What is your experience with the adoption and sustained use of ICS in rural households in developing countries, has this been relatively a fast or slow process?**

   If answered that is has been slow **" Why do you think the adoption and long-term use of ICS in rural households in developing countries have been so slow and often unsuccessful?"**
   (As a sub-question include if they deem ICS to be a viable solution to address environmental health and energy poverty challenges for wood fuel dependent rural households and why)

2. **What are the main challenges to overcome to increase the adoption of improved cookstoves in rural households in developing countries?**
   (Potentially categorize these under technical, economic, cultural, information, social, market, policy and programmatic barriers and as a sub question ask about these specific categories if not mentioned in the initial answer)

3. **Which enabling factors can you identify for the adoption of improved cookstoves for rural households in developing countries?**
   (As a sub-question ask for any anecdotal evidence of success of the aforementioned suggestions)

4. **Do you see differences in barriers and enabling factors that drive the adoption of ICS versus its long-term use?**
   (As a sub-question ask for any anecdotal evidence of these differences from their experience and how to bridge these different needs if any)

5. **Which policy and programme changes are needed to improve the adoption and long-term use of improved cookstoves for rural households in developing countries?**
   (As a sub-question ask for any anecdotal evidence of successful policies and programme interventions hat have been able to create a more enabling environment for ICS)

6. **Are there specific challenges for rural households that are currently not discussed, or included in any research or ICS programmes?**

Other topics to include in the interview sub-questions depending on the key informant:

Wood fuel and cooking challenges experienced by households that ICS should work on addressing / Markets / Needs & Demands / Household demographics influence on ICS adoption / Skills / ICS training / Infrastructure/ transportation / Marketing ICS / Successful ICS technologies / Social networks/ coordination for ICS dissemination / Wood fuel based livelihoods / ICS livelihood opportunities

Annex III Online expert survey

Q 1. What is the main used cooking method among rural households in the lowlands of Lesotho to prepare meals? (Please select the most predominantly used method)

- ☐ Three stone open fire (biomass/firewood)
- ☐ Traditional cookstove (biomass/firewood)
- ☐ Charcoal stove
- ☐ Improved cookstove (biomass/firewood)
- ☐ LPG stove
- ☐ Electric cookstove
- ☐ I do not know
- ☐ Other, please specify

Q2. What is the primary source of energy for cooking and heating among rural households in the lowlands of Lesotho? (select the most common source of fuel)

- ☐ Firewood
- ☐ Other forms of biomass (grass, agricultural waste)
- ☐ Biomass briquettes
- ☐ Animal dung
- ☐ Charcoal
- ☐ LPG
- ☐ Electricity
- ☐ Kerosene
- ☐ I do not know
- ☐ Other, please specify

Q3. How do the majority of households in the rural lowlands obtain their fuel? [Select all that apply]

- ☐ Purchase at market
- ☐ Purchase from individual firewood sellers
- ☐ Connection via the grid (electricity)
- ☐ Collect for free
- ☐ Barter fuel for other items
- ☐ Provided for free by government
- ☐ Provided for free by Humanitarian organization
- ☐ I do not know
- ☐ Other, please specify

Q4. What do you perceive as the biggest wood fuel challenges in the rural lowlands of Lesotho, for those dependent on firewood? [Select all that apply]

- ☐ Insufficient wood fuel
- ☐ Localized environmental degradation
- ☐ Low quality of wood fuel
- ☐ Health concerns due to emissions
- ☐ High cost of wood fuel
- ☐ I do not know
- ☐ Other, please specify

Q5. What is the rate of adoption and use of improved cookstoves or clean cookstoves in rural households in the lowlands of Lesotho? (please select one)

	1 Very low	2 Low	3 Medium	4 High	5 Very high
Initial adoption of improved biomass stoves	○	○	○	○	○
Sustained use of improved biomass stoves	○	○	○	○	○
Initial adoption of 'cleaner' ICS (e.g., ethanol, LPG)	○	○	○	○	○
Sustained use of 'cleaner' ICS (e.g., ethanol, LPG)	○	○	○	○	○

Q7. Which of the following statements are key barriers that hinder the adoption of improved cookstoves (ICS) in rural households in the lowlands of Lesotho? Please rate each statement from 'strongly disagree' to 'strongly agree'.

	1 Strongly disagree	2	3	4	5 Strongly agree
High initial purchasing costs	○	○	○	○	○
High fuel costs (in case of non-biomass stove)	○	○	○	○	○
Additional costs if it includes a fuel switch away from firewood/biomass that can be collected for free	○	○	○	○	○
No interest to switch fuels	○	○	○	○	○
Lack of financing mechanisms to purchase stove	○	○	○	○	○
Limited knowledge/awareness of ICS	○	○	○	○	○
Stoves not available on markets	○	○	○	○	○
No incentive to change (no problems with current cooking methods)	○	○	○	○	○
Not convenient in use	○	○	○	○	○
Limited benefits of stove (little savings, does not make it worth the investment)	○	○	○	○	○

People prefer traditional cooking methods	○	○	○	○	○
Loss of additional benefits of traditional cooking (heating, lighting, insect deterrent)	○	○	○	○	○
Low quality of stoves available	○	○	○	○	○

Q8. Which of the following factor are key barriers that hinder the sustained use of ICS in rural households after initial adoption? Please rate each statement from 'strongly disagree' to 'strongly agree'.*

	1 Strongly disagree	2	3	4	5 Strongly agree
High fuel costs (in case of non-biomass stove)	○	○	○	○	○
No repair or maintenance options	○	○	○	○	○
Lack of training on ICS use	○	○	○	○	○
Not convenient in use	○	○	○	○	○
Does not fit cultural cooking practices	○	○	○	○	○
Lack of stove warranty	○	○	○	○	○
Lack of sustainability in stove/fuel access in markets	○	○	○	○	○
Poor quality stoves	○	○	○	○	○
Does not provide sufficient benefits	○	○	○	○	○
Does not meet expectations of fuel savings	○	○	○	○	○

Q9. Which are enabling factors that can help the sustained use of ICS for rural households in Lesotho? (Please check the box ranging from strongly disagree to strongly agree)

	1 Strongly disagree	2	3	4	5 Strongly agree
Stove and fuel subsidies	○	○	○	○	○
Access to repair and maintenance for stoves	○	○	○	○	○
Addressing losses of traditional cooking benefits simultaneously (such as loss of heating, lightning)	○	○	○	○	○
Improved context specific stove and fuel selection (meets local cooking practices)	○	○	○	○	○
Improved expectation management of stove benefits	○	○	○	○	○
Improved monitoring and follow-up to be able to change stove design based on customer feedback	○	○	○	○	○
Sustainability in stove and fuel supply chain (continued market access)	○	○	○	○	○

Support the concept of stove and fuel stacking (clarifying that one stove/fuel might not meet all HH needs but improve parts of cooking and reduce fuel needs)	○	○	○	○	○
More choice on market for different stoves	○	○	○	○	○

Q10. Please share any barriers or enabling factors for the initial adoption or sustained use of improved cookstoves for rural households in the lowlands of Lesotho that you would like to add.

Q11. Thank you kindly for participating in this survey. Your contributions are very valuable for this research. Please feel free to reach out to me with any questions via [redacted] or leave any comments or additional information you would like to share below.

Appendix A

Overview of the sixty-four studies eligible for full-text review as part of the literature meta-analysis after initial screening. Based on the full review twenty-four studies qualified to be included in the final analysis which can be found in Appendix B.

Paper	Year	Author(s)	Meets criteria Y=1 N=0	Considers the adoption and/or use of ICSs	Includes at minimum three determinants	Uses household as the unit of measure	Is conducted in SSA	Uses statistical analysis
"Clean" Cooking Energy in Uganda–technologies, impacts, and key barriers and enablers to market acceleration	2017	Price	0	1	1	1	1	0
A multi-stakeholder perception analysis about the adoption, impacts and priority areas in the Kenyan clean cooking sector	2019	Karanje et al.	0	1	1	0	1	0
A strategy to increase adoption of locally produced, ceramic cookstoves in rural Kenyan households	2012	Silk et al.	1	1	1	1	1	1
Access to modern energy: a review of barriers, drivers and impacts	2017	Bonan et al	0	1	1	1	0	0
Adoption and impacts of clean bioenergy cookstoves in Kenya	2019	Karanja and Gasparatos	0	1	1	1	1	0
Adoption and kitchen performance test of improved cook stove in the Bale Eco-Region of Ethiopia	2018	Gizachew and Tolera	1	1	1	1	1	1
Adoption of biomass improved cookstoves in a patriarchal society: an example from Sudan	2003	Muneer and Mohamed	1	1	1	1	1	1
Adoption of cleaner cookstoves: Barriers and way forward	2014	Palit and Debajit	0	1	1	0	0	0
Adoption of improved biomass stoves and stove/fuel stacking in the REACCTING intervention study in Northern Ghana	2019	Dickinson et al.	1	1	1	1	1	1
Adoption of integrated Food-Energy systems: improved cookstoves and pigeon pea in Southern Malawi	2015	Orr et al.	1	1	1	1	1	1
Adoptions of improved biomass cookstoves by households: an example from Homabay County	2014	Okuthe and Akotzi	0	1	1	1	1	0
Barriers and facilitators to adoption and use of fuel pellets and improved cookstoves in urban Rwanda	2018	Seguin, Flax and Jagger	0	1	1	1	1	0
Barriers and Facilitators to the Adoption and Sustained Use of Cleaner Fuels in Southwest Cameroon: Situating 'Lay' Knowledge within Evidence-Based Policy and Practice	2019	Stanistreet et al.	0	1	1	1	1	0
Barriers and opportunities of biogas dissemination in Sub-Saharan Africa and lessons learned from Rwanda, Tanzania, China, India, and Nepal	2015	Rupf	0	1	1	1	1	0
Behavioural Attitudes and Preferences in Cooking Practices with Traditional Open-Fire Stoves in Peru, Nepal, and Kenya: Implications for Improved Cookstove Interventions	2014	Rhodes	0	1	1	1	0	0
Beyond buying: The application of service design methodology to understand adoption of clean cookstoves in Kenya and Zambia	2018	Jurisoo, Lambe and Osborn	0	1	1	1	1	0
Clean cooking for all? A critical review of behavior, stakeholder engagement, and adoption for the global diffusion of improved cookstoves	2020	Lindgren	0	1	1	1	1	0

Clean fuel-saving technology adoption in urban Ethiopia	2013	Beyene and Koch	1	1	1	1	1	1
Clean fuels for resource-poor settings: a systematic review of barriers and enablers to adoption and sustained use	2016	Puzzolo et al.	0	1	1	1	1	0
Consumers' perception on adoption of improved cookstoves: a case of Kilimanjaro region, Tanzania	2014	Masawe, Bengezi and Kweka	1	1	1	1	1	1
Determinants of adoption of improved biomass stove in rural households of Muhazi sector in Rwamagana district	2016	Kanangire et al.	1	1	1	1	1	1
Design for Clean Technology Adoption: Integration of Usage Context, User Behavior, and Technology Performance in Design	2020	Pakravan and MacCarty	1	1	1	1	1	1
Determining the Enablers and Barriers for the Adoption of Clean Cookstoves in the Middle Belt of Ghana-A Qualitative Study	2019	Agbokey et al.	0	1	1	1	1	0
Dis-adoption of Household Biogas technologies in Central Uganda	2017	Lwiza et al.	1	1	1	1	1	1
Does peer use influence adoption of efficient cookstoves? Evidence from a randomized controlled trial in Uganda	2015	Beltramo et al.	1	1	1	1	1	1
Drivers and barriers to clean cooking: A systematic literature review from a consumer behavior perspective	2018	Vigolo, Salakku and Testa	0					
Driving forces for households' adoption of improved cooking stoves in rural Tanzania	2018	Kulindwa, Lokina and Ahlgren	1	1	1	1	1	1
Enablers and barriers to large-scale uptake of improved solid fuel stoves: a systematic review	2013	Rehfuess et al.	0	1	1	1	1	0
Evaluating the relative strength of product-specific factors in fuel switching and stove choice decisions in Ethiopia. A discrete choice model of household preferences for clean cooking alternatives	2012	Takama et al.	1	1	1	1	1	1
Facilitators and barriers to improved cookstove adoption: a community-based cross-sectional study in Northwest Ethiopia	2020	Adane et al.	1	1	1	1	1	1
Factors associated with sustained use of improved solid fuel cookstoves: A case study from Kenya	2017	Tigabu	1	1	1	1	1	1
Factors influencing household uptake of improved solid fuel stoves in low-and middle-income countries: A qualitative systematic review	2014	Stanistreet et al.	0	1	1	1	0	0
Factors influencing the acquisition and correct and consistent use of the top-lit updraft cookstove in Uganda	2015	Namagembe et al.	0	1	1	1	1	0
Factors influencing the adoption of biochar-producing gasifier cookstoves by households in rural Kenya	2018	Gitau et al.	1	1	1	1	1	1
Fuel savings, cooking time and user satisfaction with improved biomass cookstoves: Evidence from controlled cooking tests in Ethiopia	2018	Gebreegziabher	0	1	0	1	1	1
Fuel switching: evidence from eight countries	2004	Heltberg	1	1	1	1	1	1
Gender differences in preferences, intra-household externalities, and low demand for improved cookstoves	2013	Mobarak	0	1	1	0	0	0
Household cooking fuel choice and adoption of improved cookstoves in developing countries: a review	2014	Malla and Timilsina	0	1	1	1	0	0
Identifying behavioural drivers of cookstove use: a household study in Kibera, Nairobi	2015	Lambe	0	1	1	1	1	0
Implementation and scale-up of a biomass pellet and improved cookstove enterprise in Rwanda	2018	Jagger and Das	0	1	1	1	1	0

Improved cookstoves in Africa: Explaining adoption patterns	2017	Kapfudzaru wa et al.	0	1	1	1	1	0
Market barriers to clean cooking fuels in sub-Saharan Africa: a review of literature	2008	Schlag and Zuzarte	0	1	1	1	1	0
Market mapping for improved cookstoves: barriers and opportunities in East Africa	2020	Stevens et al.	0	1	1	1	1	0
Maximizing the benefits of improved cookstoves: moving from acquisition to correct and consistent use	2014	Shankar et al.	0	1	1	0	0	0
Measuring and increasing adoption rates of cookstoves in a humanitarian crisis	2016	Wilson et al.	1	1	1	1	1	1
Patterns of stove use in the context of fuel–device stacking: rationale and implications	2015	Ruiz-mercado and Masera	0	1	1	1	0	0
Poverty, gender, and empowerment in sustained adoption of cleaner cooking systems: Making the case for refined measurement	2016	Kumar and Mehta	0	1	1	0	0	0
Reducing energy poverty through increasing choice of fuels and stoves in Kenya: Complementing the multiple fuel model	2015	Treiber et al.	0	1	0	1	1	1
Review of barriers to the dissemination of decentralized renewable energy systems	2016	Yaqoot et al	0	1	1	1	0	0
Scaling Up Clean Cooking Solutions: The Context, Status, Barriers and Key Drivers	2013	Ekouevi	0	1	1	1	0	1
Stoves or sugar? Willingness to adopt improved cookstoves in Malawi	2016	Jagger and Jumbe	1	1	1	1	1	1
Sustained uptake of clean cooking practices in poor communities: role of social networks	2019	Kumar and Igdalsky	0	1	1	1	0	0
Technological innovation and dispersion: Environmental benefits and the adoption of improved biomass cookstoves in Tigrai, northern Ethiopia	2017	Gebreegziab her	1	1	1	1	1	1
The impact of the household decision environment on fuel choice behavior	2014	Van der Kroon et al.	1	1	1	1	1	1
The intensive margin of technology adoption–Experimental evidence on improved cooking stoves in rural Senegal	2015	Bensch and Peters	1	1	1	1	1	1
The role of social relations in the adoption of improved cookstoves	2017	Vulturius and Wanjiru	0	1	1	1	1	0
User perceptions about the adoption and use of ethanol fuel and cookstoves in Maputo, Mozambique	2018	Modombi et al.	0	1	1	1	1	1
Using formative research to design a behavior change strategy to increase the use of improved cookstoves in peri-urban Kampala, Uganda	2013	Martin et al.	1	1	1	1	1	1
What boosts cookstove uptake?	2016	Matin and Roe	0	1	1	0	0	0
What impedes efficient adoption of products? Evidence from randomized sales offers for fuel-efficient cookstoves in Uganda	2018	Levine et al.	0	1	0	1	1	1
What makes people cook with improved cookstoves	1994	Barnes et al.	0	1	1	0	1	0
What's cooking? Unverified assumptions, overlooking of local needs and pro-solution biases in the solar cooking literature	2017	Iessa et al.	0	1	1	0	0	0
Who adopts improved fuels and cookstoves? A systematic review	2012	Lewis and Pattanayak	0	1	1	1	1	0
Why do households forego high returns from technology adoption? Evidence from improved cooking stoves in Burkina Faso	2015	Bensch et al.	1	1	1	1	1	1

Appendix B

Full review twenty-four studies qualified to be included in the final analysis. Variables mentioned only once have been excluded from the final results and overview to present an overview of the most common factors influencing the adoption and sustained use of ICS and its compatible fuels.

					1. Check all boxes of barriers identified for ICS adoption														
Paper	**Year**	**Author(s)**	**Statistical analysis**	**Country of study**	1.1 Financial barrier: High alternative fuel price	1.2 Financial barriers: Price of stove	1.3 Financial barrier: Low income	1.4 Knowledge barrier: Limited perceived benefits	1.5 Market barrier: Limited choice	1.6 Cultural Barrier: Reluctance to switch fuel	1.7 Technological barrier: Low fuel efficiency	1.8 Technological barrier: Fixed cooking pot holder	1.9 Technological barrier: Not user friendly	1.10 Technological barrier: Longer cooking time	1.11 Technological barrier: Not flexible for multiple uses	1.12 Technological barrier: Unavailability of (good) firewood	1.13 Technological barrier: Requires fuel processing	1.14 Demographic barrier: Head of household is male	1.15 Demographic barrier: Women's age
A strategy to increase adoption of locally produced, ceramic cookstoves in rural Kenyan households	2012	Silk et al.	Statistical analysis (Chi-square test)	Kenya			NS												NS
Adoption and kitchen performance test of improved cook stove in the Bale Eco-Region of Ethiopia	2018	Gizachew and Tolera	Binary logistic regression.	Ethiopia															
Adoption of biomass improved cookstoves in a patriarchal society: an example from Sudan	2003	Muneer and Mohamed	Regression analysis	Sudan				NS											
Adoption of improved biomass stoves and stove/fuel stacking in the REACCTING intervention study in Northern Ghana	2019	Dickinson et al.	Multinomial logit regression analysis	Ghana															
Adoption of integrated food-energy systems: improved cookstoves and pigeon pea in Southern Malawi	2015	Orr et al.	Multinomial logistic regression and t-test	Malawi			NS				NS								
Clean fuel-saving technology adoption in urban Ethiopia	2013	Beyene and Koch	Survival analysis and regression analysis	Ethiopia		NS	NS											NS	PI
Consumers' perception on adoption of improved cookstoves: a case of Kilimanjaro region, Tanzania	2014	Masawe, Bengezi and Kweka	Descriptive analysis, chi-square test, Kramer's V	Tanzania		NS		NS				NS	NS	NS	NS	NS	NS		
Determinants of adoption of improved biomass stove in rural households of Muhazi sector in Rwamagana district	2016	Kanangire et al.	Descriptive statistics, correlation and regression analysis	Rwanda		NI	NI	NS											
Design for Clean Technology Adoption: Integration of Usage Context, User Behaviour, and Technology Performance in Design	2020	Pakravan and MacCarty	Regression analysis	Uganda		PI (was subsidized so less important)			NS	PS									
Dis-adoption of Household Biogas technologies in Central Uganda	2017	Lwiza et al.	Anova	Uganda	NS											PS for other cleaner fuels			
Does peer use influence adoption of efficient cookstoves? Evidence from a randomized controlled trial in Uganda	2015	Beltramo et al.	Regression analysis	Uganda															
Driving forces for households' adoption of improved cooking stoves in rural Tanzania	2018	Kulindwa, Lokina and Ahlgren	multinomial logit and mixed logit	Tanzania	NS	NS			NS		NS								NS
Evaluating the relative strength of product-specific factors in fuel switching and stove choice decisions in Ethiopia. A discrete choice model of household preferences for clean cooking alternatives	2021	Takama et al.	Discrete choice and standard logit model	Ethiopia		NS													
Facilitators and barriers to improved cookstove adoption: a community-based cross-sectional study in Northwest Ethiopia	2020	Adane et al.	Logistic regression	Ethiopia													NS		
Factors associated with sustained use of improved solid fuel cookstoves: A case study from Kenya	2017	Tigabu	Regression analysis and ordered logit regression	Kenya															
Factors influencing the adoption of biochar-producing gasifier cookstoves by households in rural Kenya	2018	Gitau et al.	ANOVA and chi-square test	Kenya															
Measuring and increasing adoption rates of cookstoves in a humanitarian crisis	2016	Wilson et al.	Correlation coefficient and paired t test	Sudan															
Reducing energy poverty through increasing choice of fuels and stoves in Kenya: Complementing the multiple fuel model	2015	Treiber et al.	ANOVA and Tukey's Honest Significant Difference	Kenya		NI										NI			
Stoves or sugar? Willingness to adopt improved cookstoves in Malawi	2016	Jagger and Jumbe	Multilevel models and regression analysis	Malawi												PS			
Technological innovation and dispersion: Environmental benefits and the adoption of improved biomass cookstoves in Tigray, northern Ethiopia	2017	Gebreegziabher	Regression analysis	Ethiopia															
The impact of the household decision environment on fuel choice behaviour	2014	Van der Kroon et al.	Mixed Logic model and Pearson correlation	Kenya	NS	NS	NS									NS			
The intensive margin of technology adoption–Experimental evidence on improved cooking stoves in rural Senegal	2015	Bensch and Peters	Regression analysis	Senegal															
User perceptions about the adoption and use of ethanol fuel and cookstoves in Maputo, Mozambique	2018	Modombi et al.	ANOVA, Post-hoc test and descriptive statistics	Mozambique	NI	NI													
Why do households forego high returns from technology adoption? Evidence from improved cooking stoves in Burkina Faso	2015	Bensch et al.	Regression analysis and multinominal logit	Burkina Faso		NS													

Paper	Year	Author(s)	Statistical analysis	Country of study	2. Check all boxes for barriers to the sustained use of ICS						
					2.1 Financial barrier: High operational costs / fuel	2.2 Cultural barrier: Lack of suitability to cook staple dishes	2.3 Knowledge barrier: Does not meet expectations	2.4 Technological barrier: Lack of spare parts / repair options	2.5 Technological barrier: Low stove durability	2.6 Demographic barrier: Household size	2.7 Market barrier: lack of access to purchase fuel
A strategy to increase adoption of locally produced, ceramic cookstoves in rural Kenyan households	2012	Silk et al.	Statistical analysis (Chi-square test)	Kenya							
Adoption and kitchen performance test of improved cook stove in the Bale Eco-Region of Ethiopia	2018	Gizachew and Tolera	Binary logistic regression.	Ethiopia							
Adoption of biomass improved cookstoves in a patriarchal society: an example from Sudan	2003	Muneer and Mohamed	Regression analysis	Sudan							
Adoption of improved biomass stoves and stove/fuel stacking in the REACCTING intervention study in Northern Ghana	2019	Dickinson et al.	Multinomial logit regression analysis	Ghana		NI		NI	NI		
Adoption of integrated food-energy systems: improved cookstoves and pigeon pea in Southern Malawi	2015	Orr et al.	Multinomial logistic regression and t-test	Malawi							
Clean fuel-saving technology adoption in urban Ethiopia	2013	Beyene and Koch	Survival analysis and regression analysis	Ethiopia							
Consumers' perception on adoption of improved cookstoves: a case of Kilimanjaro region, Tanzania	2014	Masawe, Bengezi and Kweka	Descriptive analysis, chi-square test, Kramer's V	Tanzania							
Determinants of adoption of improved biomass stove in rural households of Muhazi sector in Rwamagana district	2016	Kanangire et al.	Descriptive statistics, correlation and regression analysis	Rwanda							
Design for Clean Technology Adoption: Integration of Usage Context, User Behaviour, and Technology Performance in Design	2020	Pakravan and MacCarty	Regression analysis	Uganda							NS
Dis-adoption of Household Biogas technologies in Central Uganda	2017	Lwiza et al.	Anova	Uganda	NS			NS	NI	PS	
Does peer use influence adoption of efficient cookstoves? Evidence from a randomized controlled trial in Uganda	2015	Beltramo et al.	Regression analysis	Uganda							
Driving forces for households' adoption of improved cooking stoves in rural Tanzania	2018	Kulindwa, Lokina and Ahlgren	multinomial logit and mixed logit	Tanzania						NS	
Evaluating the relative strength of product-specific factors in fuel switching and stove choice decisions in Ethiopia. A discrete choice model of household preferences for clean cooking alternatives	2021	Takama et al.	Discrete choice and standard logit model	Ethiopia	NS						
Facilitators and barriers to improved cookstove adoption: a community-based cross-sectional study in Northwest Ethiopia	2020	Adane et al.	Logistic regression	Ethiopia						NI	
Factors associated with sustained use of improved solid fuel cookstoves: A case study from Kenya	2017	Tigabu	Regression analysis and ordered logit regression	Kenya							
Factors influencing the adoption of biochar-producing gasifier cookstoves by households in rural Kenya	2018	Gitau et al.	ANOVA and chi-square test	Kenya						NI	
Measuring and increasing adoption rates of cookstoves in a humanitarian crisis	2016	Wilson et al.	Correlation coefficient and paired t test	Sudan							
Reducing energy poverty through increasing choice of fuels and stoves in Kenya: Complementing the multiple fuel model	2015	Treiber et al.	ANOVA and Tukey's Honest Significant Difference	Kenya		NI					NI
Stoves or sugar? Willingness to adopt improved cookstoves in Malawi	2016	Jagger and Jumbe	Multilevel models and regression analysis	Malawi			PI				
Technological innovation and dispersion: Environmental benefits and the adoption of improved biomass cookstoves in Tigray, northern Ethiopia	2017	Gebreegziabher	Regression analysis	Ethiopia							
The impact of the household decision environment on fuel choice behaviour	2014	Van der Kroon et al.	Mixed Logic model and Pearson correlation	Kenya							
The intensive margin of technology adoption–Experimental evidence on improved cooking stoves in rural Senegal	2015	Bensch and Peters	Regression analysis	Senegal					NI		
User perceptions about the adoption and use of ethanol fuel and cookstoves in Maputo, Mozambique	2018	Modombi et al.	ANOVA, Post-hoc test and descriptive statistics	Mozambique	NI		NI		NI		NI
Why do households forego high returns from technology adoption? Evidence from improved cooking stoves in Burkina Faso	2015	Bensch et al.	Regression analysis and multinominal logit	Burkina Faso						NS for LPG and PS for biomass	

Paper	Year	Author(s)	Statistical analysis	Country of study	3. Check all the boxes that identify enabling factors to household adoption									
					3.1 Financial enabler: High income *	3.2 Financial enabler: Wealth /assets *	3.3 Financial enabler: Already purchase fuel	3.4 Financial enabler: increased stove affordability (subsidy / finance mechanisms)	3.5 Market enabler: Offer more choice in ICS / fuel	3.6 Market enabler: Increased access to stoves / fuel in market	3.7: Knowledge enabler: Awareness raising and stove demonstrations	3.8 Knowledge enabler: Aware of environmental impacts / benefits of reduced fuel use	3.9 Cultural enabler: Fits traditional cooking practices / convenience	3.10 Cultural enabler: Time spent collecting fuel
A strategy to increase adoption of locally produced, ceramic cookstoves in rural Kenyan households	2012	Silk et al.	Statistical analysis (Chi-square test)	Kenya		PS		**PI**			PS			
Adoption and kitchen performance test of improved cook stove in the Bale Eco-Region of Ethiopia	2018	Gizachew and Tolera	Binary logistic regression.	Ethiopia										
Adoption of biomass improved cookstoves in a patriarchal society: an example from Sudan	2003	Muneer and Mohamed	Regression analysis	Sudan	NS	NS (cause they need it more)				PI	PS			
Adoption of improved biomass stoves and stove/fuel stacking in the REACCTING intervention study in Northern Ghana	2019	Dickinson et al.	Multinomial logit regression analysis	Ghana	NI (likely cause biomass would not be of interest)	NS								
Adoption of integrated food-energy systems: improved cookstoves and pigeon pea in Southern Malawi	2015	Orr et al.	Multinomial logistic regression and t-test	Malawi	PS									
Clean fuel-saving technology adoption in urban Ethiopia	2013	Beyene and Koch	Survival analysis and regression analysis	Ethiopia	PS			**PI**						
Consumers' perception on adoption of improved cookstoves: a case of Kilimanjaro region, Tanzania	2014	Masawe, Bengezi and Kweka	Descriptive analysis, chi-square test, Kramer's V	Tanzania										
Determinants of adoption of improved biomass stove in rural households of Muhazi sector in Rwamagana district	2016	Kanangire et al.	Descriptive statistics, correlation and regression analysis	Rwanda	PS	PS					PS		PS	
Design for Clean Technology Adoption: Integration of Usage Context, User Behaviour, and Technology Performance in Design	2020	Pakravan and MacCarty	Regression analysis	Uganda					**PS**	PS		PS	PS	
Dis-adoption of Household Biogas technologies in Central Uganda	2017	Lwiza et al.	Anova	Uganda										
Does peer use influence adoption of efficient cookstoves? Evidence from a randomized controlled trial in Uganda	2015	Beltramo et al.	Regression analysis	Uganda	PS	PS								
Driving forces for households' adoption of improved cooking stoves in rural Tanzania	2018	Kulindwa, Lokina and Ahlgren	multinomial logit and mixed logit	Tanzania	PS			**PS**	**PS**					
Evaluating the relative strength of product-specific factors in fuel switching and stove choice decisions in Ethiopia. A discrete choice model of household preferences for clean cooking alternatives	2021	Takama et al.	Discrete choice and standard logit model	Ethiopia	PS	PS								
Facilitators and barriers to improved cookstove adoption: a community-based cross-sectional study in Northwest Ethiopia	2020	Adane et al.	Logistic regression	Ethiopia	PS	PS	**PS**	**PS**		PS	PS		PS	
Factors associated with sustained use of improved solid fuel cookstoves: A case study from Kenya	2017	Tigabu	Regression analysis and ordered logit regression	Kenya	NI						PS			
Factors influencing the adoption of biochar-producing gasifier cookstoves by households in rural Kenya	2018	Gitau et al.	ANOVA and chi-square test	Kenya	PS	PS								
Measuring and increasing adoption rates of cookstoves in a humanitarian crisis	2016	Wilson et al.	Correlation coefficient and paired t test	Sudan										
Reducing energy poverty through increasing choice of fuels and stoves in Kenya: Complementing the multiple fuel model	2015	Treiber et al.	ANOVA and Tukey's Honest Significant Difference	Kenya						PI				
Stoves or sugar? Willingness to adopt improved cookstoves in Malawi	2016	Jagger and Jumbe	Multilevel models and regression analysis	Malawi	PI	PS				PI	PI	PS		PS
Technological innovation and dispersion: Environmental benefits and the adoption of improved biomass cookstoves in Tigray, northern Ethiopia	2017	Gebreegziabher	Regression analysis	Ethiopia	PS									PI
The impact of the household decision environment on fuel choice behaviour	2014	Van der Kroon et al.	Mixed Logic model and Pearson correlation	Kenya						PS				
The intensive margin of technology adoption–Experimental evidence on improved cooking stoves in rural Senegal	2015	Bensch and Peters	Regression analysis	Senegal										
User perceptions about the adoption and use of ethanol fuel and cookstoves in Maputo, Mozambique	2018	Modombi et al.	ANOVA, Post-hoc test and descriptive statistics	Mozambique	PS									
Why do households forego high returns from technology adoption? Evidence from improved cooking stoves in Burkina Faso	2015	Bensch et al.	Regression analysis and multinominal logit	Burkina Faso		PS		**PI**						

Paper	Year	Author(s)	Statistical analysis	Country of study	3. Check all the boxes that identify enabling factors to household adoption										
					3.11 Cultural enabler: Higher fuel wood consumption	3.12 Cultural enabler: Distance to firewood collection	3.13 Technological enabler: High fuel efficiency / fuel savings	3.14 Technological enabler: Reduced cooking time	3.15 Technological enabler: Reduced smoke	3.16 Technological enabler: Perceived significant benefits of stove	3.17 Socio-economic enabler: Having a separate kitchen(	3.18 Socio-economic enabler: Female headed households	3.19 Socio-economic enabler: Age of woman in HH	3.20 Socio-economic enabler: Women decision-making power	3.21 Socio-economic enabler: Education level HH
A strategy to increase adoption of locally produced, ceramic cookstoves in rural Kenyan households	2012	Silk et al.	Statistical analysis (Chi-square test)	Kenya							PS		PS		
Adoption and kitchen performance test of improved cook stove in the Bale Eco-Region of Ethiopia	2018	Gizachew and Tolera	Binary logistic regression.	Ethiopia							PS	PS			PS
Adoption of biomass improved cookstoves in a patriarchal society: an example from Sudan	2003	Muneer and Mohamed	Regression analysis	Sudan						PS			NS		PS
Adoption of improved biomass stoves and stove/fuel stacking in the REACCTING intervention study in Northern Ghana	2019	Dickinson et al.	Multinomial logit regression analysis	Ghana											
Adoption of integrated food-energy systems: improved cookstoves and pigeon pea in Southern Malawi	2015	Orr et al.	Multinomial logistic regression and t-test	Malawi	PI	NI	PI	PI				PS		PS	NS
Clean fuel-saving technology adoption in urban Ethiopia	2013	Beyene and Koch	Survival analysis and regression analysis	Ethiopia							PS				PS
Consumers' perception on adoption of improved cookstoves: a case of Kilimanjaro region, Tanzania	2014	Masawe, Bengezi and Kweka	Descriptive analysis, chi-square test, Kramer's V	Tanzania			PS	PS	PS						
Determinants of adoption of improved biomass stove in rural households of Muhazi sector in Rwamagana district	2016	Kanangire et al.	Descriptive statistics, correlation and regression analysis	Rwanda						PS		PS			PS
Design for Clean Technology Adoption: Integration of Usage Context, User Behaviour, and Technology Performance in Design	2020	Pakravan and MacCarty	Regression analysis	Uganda			PS							PS	
Dis-adoption of Household Biogas technologies in Central Uganda	2017	Lwiza et al.	Anova	Uganda											
Does peer use influence adoption of efficient cookstoves? Evidence from a randomized controlled trial in Uganda	2015	Beltramo et al.	Regression analysis	Uganda											
Driving forces for households' adoption of improved cooking stoves in rural Tanzania	2018	Kulindwa, Lokina and Ahlgren	multinomial logit and mixed logit	Tanzania			PS					PS	PS		NI
Evaluating the relative strength of product-specific factors in fuel switching and stove choice decisions in Ethiopia. A discrete choice model of household preferences for clean cooking alternatives	2021	Takama et al.	Discrete choice and standard logit model	Ethiopia											
Facilitators and barriers to improved cookstove adoption: a community-based cross-sectional study in Northwest Ethiopia	2020	Adane et al.	Logistic regression	Ethiopia	PS		PS	PI		PS	PS	PS			PS
Factors associated with sustained use of improved solid fuel cookstoves: A case study from Kenya	2017	Tigabu	Regression analysis and ordered logit regression	Kenya											NI
Factors influencing the adoption of biochar-producing gasifier cookstoves by households in rural Kenya	2018	Gitau et al.	ANOVA and chi-square test	Kenya											PI
Measuring and increasing adoption rates of cookstoves in a humanitarian crisis	2016	Wilson et al.	Correlation coefficient and paired t test	Sudan											
Reducing energy poverty through increasing choice of fuels and stoves in Kenya: Complementing the multiple fuel model	2015	Treiber et al.	ANOVA and Tukey's Honest Significant Difference	Kenya			PI								
Stoves or sugar? Willingness to adopt improved cookstoves in Malawi	2016	Jagger and Jumbe	Multilevel models and regression analysis	Malawi		PI						PS	PI		PI
Technological innovation and dispersion: Environmental benefits and the adoption of improved biomass cookstoves in Tigray, northern Ethiopia	2017	Gebreegziabher	Regression analysis	Ethiopia			PS	PS							
The impact of the household decision environment on fuel choice behaviour	2014	Van der Kroon et al.	Mixed Logic model and Pearson correlation	Kenya				PS	PS						
The intensive margin of technology adoption–Experimental evidence on improved cooking stoves in rural Senegal	2015	Bensch and Peters	Regression analysis	Senegal											
User perceptions about the adoption and use of ethanol fuel and cookstoves in Maputo, Mozambique	2018	Modombi et al.	ANOVA, Post-hoc test and descriptive statistics	Mozambique				PI							
Why do households forego high returns from technology adoption? Evidence from improved cooking stoves in Burkina Faso	2015	Bensch et al.	Regression analysis and multinominal logit	Burkina Faso										PS	

Paper	Year	Author(s)	Statistical analysis	Country of study	4. Check all boxes for enabling factors for sustained use of ICS							
					4.1 Financial enabler: Affordable fuel	4.2 Cultural enabler: Suitability to cook staple dishes	4.3: Knowledge enabler: Awareness raising and follow-up	4.4 Knowledge enabler: Meets expectations	4.5 Technological enabler: Stove quality / durability	4.6 Technological enabler: High performance/ benefits	4.7 Technological enabler: Easy to use / no fuel reloading	4.7 Market enabler: Repair, maintenance and sales access
A strategy to increase adoption of locally produced, ceramic cookstoves in rural Kenyan households	2012	Silk et al.	Statistical analysis (Chi-square test)	Kenya								
Adoption and kitchen performance test of improved cook stove in the Bale Eco-Region of Ethiopia	2018	Gizachew and Tolera	Binary logistic regression.	Ethiopia								
Adoption of biomass improved cookstoves in a patriarchal society: an example from Sudan	2003	Muneer and Mohamed	Regression analysis	Sudan								
Adoption of improved biomass stoves and stove/fuel stacking in the REACCTING intervention study in Northern Ghana	2019	Dickinson et al.	Multinomial logit regression analysis	Ghana		PI			PI			PI
Adoption of integrated food-energy systems: improved cookstoves and pigeon pea in Southern Malawi	2015	Orr et al.	Multinomial logistic regression and t-test	Malawi								
Clean fuel-saving technology adoption in urban Ethiopia	2013	Beyene and Koch	Survival analysis and regression analysis	Ethiopia								
Consumers' perception on adoption of improved cookstoves: a case of Kilimanjaro region, Tanzania	2014	Masawe, Bengezi and Kweka	Descriptive analysis, chi-square test, Kramer's V	Tanzania								
Determinants of adoption of improved biomass stove in rural households of Muhazi sector in Rwamagana district	2016	Kanangire et al.	Descriptive statistics, correlation and regression analysis	Rwanda		PS			PI			
Design for Clean Technology Adoption: Integration of Usage Context, User Behaviour, and Technology Performance in Design	2020	Pakravan and MacCarty	Regression analysis	Uganda								
Dis-adoption of Household Biogas technologies in Central Uganda	2017	Lwiza et al.	Anova	Uganda	PS							PS
Does peer use influence adoption of efficient cookstoves? Evidence from a randomized controlled trial in Uganda	2015	Beltramo et al.	Regression analysis	Uganda								
Driving forces for households' adoption of improved cooking stoves in rural Tanzania	2018	Kulindwa, Lokina and Ahlgren	multinomial logit and mixed logit	Tanzania					PS			
Evaluating the relative strength of product-specific factors in fuel switching and stove choice decisions in Ethiopia. A discrete choice model of household preferences for clean cooking alternatives	2021	Takama et al.	Discrete choice and standard logit model	Ethiopia	PS							
Facilitators and barriers to improved cookstove adoption: a community-based cross-sectional study in Northwest Ethiopia	2020	Adane et al.	Logistic regression	Ethiopia								
Factors associated with sustained use of improved solid fuel cookstoves: A case study from Kenya	2017	Tigabu	Regression analysis and ordered logit regression	Kenya			PS	PS				
Factors influencing the adoption of biochar-producing gasifier cookstoves by households in rural Kenya	2018	Gitau et al.	ANOVA and chi-square test	Kenya						PI	PS	
Measuring and increasing adoption rates of cookstoves in a humanitarian crisis	2016	Wilson et al.	Correlation coefficient and paired t test	Sudan			PS		PS			
Reducing energy poverty through increasing choice of fuels and stoves in Kenya: Complementing the multiple fuel model	2015	Treiber et al.	ANOVA and Tukey's Honest Significant Difference	Kenya								
Stoves or sugar? Willingness to adopt improved cookstoves in Malawi	2016	Jagger and Jumbe	Multilevel models and regression analysis	Malawi				PI				PI
Technological innovation and dispersion: Environmental benefits and the adoption of improved biomass cookstoves in Tigray, northern Ethiopia	2017	Gebreegziabher	Regression analysis	Ethiopia								
The impact of the household decision environment on fuel choice behaviour	2014	Van der Kroon et al.	Mixed Logic model and Pearson correlation	Kenya								
The intensive margin of technology adoption–Experimental evidence on improved cooking stoves in rural Senegal	2015	Bensch and Peters	Regression analysis	Senegal		PI			PI	PI		PI
User perceptions about the adoption and use of ethanol fuel and cookstoves in Maputo, Mozambique	2018	Modombi et al.	ANOVA, Post-hoc test and descriptive statistics	Mozambique					PI	PI	PI	
Why do households forego high returns from technology adoption? Evidence from improved cooking stoves in Burkina Faso	2015	Bensch et al.	Regression analysis and multinominal logit	Burkina Faso								

*classified under financial enabler given the context how more wealth/income removes financial barriers

Appendix C

Complete list of items per category extracted during the key-informant interview transcript analysis.

	Count	% Codes	Cases	% Cases
Adoption barrier HH				
Financial AB				
Lack of affordablity	22	1.8%	13	76.5%
Additional cost compared to free firewood fuel	19	1.5%	9	52.9%
Lack of subsidy	5	0.4%	5	29.4%
High fuel costs	6	0.5%	5	29.4%
Lack of financial benefit compared to investment required	10	0.8%	6	35.3%
Can only afford fuel for certain tasks	3	0.2%	2	11.8%
Time to collect fuel is more available than money	4	0.3%	4	23.5%
Technology AB				
Fails to meet HH cooking needs/practices	39	3.2%	15	88.2%
Marginal benefits	22	1.8%	11	64.7%
Requires additional work	20	1.6%	8	47.1%
Poor usability	10	0.8%	6	35.3%
Loss of traditional cooking benefits	8	0.6%	5	29.4%
Inability to replace all aspects of traditional cooking method	27	2.2%	13	76.5%
Previous bad experience with ICS	2	0.2%	1	5.9%
Does not fit context	8	0.6%	7	41.2%
Information AB				
Not aware of technology	5	0.4%	3	17.6%
Do not know how to use stove	4	0.3%	3	17.6%
Not aware that current cooking technology is a problem / no desire to switch	5	0.4%	5	29.4%
Limited understanding of benefits	8	0.6%	6	35.3%
Poor communications and expectation management	6	0.5%	3	17.6%
Social AB				
Attached to traditional cooking methods	2	0.2%	2	11.8%
Does not match cultural cooking practices	9	0.7%	8	47.1%
Lack of trust	3	0.2%	2	11.8%
Lack off, or slow social acceptance	4	0.3%	3	17.6%
Do not like the taste	3	0.2%	3	17.6%
Purchase decision made by men while women cook	4	0.3%	2	11.8%
Reluctance to switch fuel	1	0.1%	1	5.9%
Market AB				
Lack of HH access	6	0.5%	4	23.5%
Limited or low quality options available for HH	6	0.5%	6	35.3%
Limited focus on fuel versus stove	11	0.9%	5	29.4%
Lack of market-based approach	4	0.3%	3	17.6%
Lack of sustainability in products	1	0.1%	1	5.9%
Limited manufacturer flexibility to change design	1	0.1%	1	5.9%
Supply chain issues	5	0.4%	5	29.4%
Motivation AB				
Comfortable with current way of cooking / no incentive	10	0.8%	6	35.3%
No fuel challenges	5	0.4%	4	23.5%
No demand - outside push	3	0.2%	3	17.6%
Benefits of switch are not a priority	4	0.3%	3	17.6%
Programme AB				
Funding challenges	9	0.7%	5	29.4%
Incorrect targeting	26	2.1%	9	52.9%
Lack of local context and assessment	20	1.6%	10	58.8%
Lack of criteria for stove selection	3	0.2%	3	17.6%
Lack of standards for ICS	4	0.3%	4	23.5%
Lack of expertise among programme designers	3	0.2%	2	11.8%
Lack of documentation of failures because of reputational risk	1	0.1%	1	5.9%
Lack of follow-up and feedback	9	0.7%	6	35.3%
Disonnect between donorr objectives and need	5	0.4%	4	23.5%
Policy AB				
Lack of Government support or interest	15	1.2%	9	52.9%
Lack of urgency - focus on different energy issues	5	0.4%	3	17.6%
Lack of supportive enabling policy	18	1.5%	9	52.9%
Lack of tax incentives and subsidies	5	0.4%	3	17.6%
Policy driven by lobby groups with other interests	2	0.2%	2	11.8%

Sustained use barrier HH				
Financial SB				
High operational costs	6	0.5%	5	29.4%
Expensive solutions lead to theft	1	0.1%	1	5.9%
Financial constraints to replace stove	3	0.2%	2	11.8%
Lack of warranty provided	5	0.4%	2	11.8%
Free distribution limits perceived value	4	0.3%	3	17.6%
Technology SU				
Poor usability from HH perspective	8	0.6%	7	41.2%
No perceived benefits	5	0.4%	4	23.5%
No maintenance or repair options	41	3.3%	13	76.5%
Lack of durability	4	0.3%	4	23.5%
Lack of training	12	1.0%	3	17.6%
Lack of quality	8	0.6%	5	29.4%
Poor trade-off between usability and efficiency	2	0.2%	2	11.8%
Market SU				
No sustainability in stove models	7	0.6%	4	23.5%
Risks with financing mechanisms	7	0.6%	4	23.5%
Focus on sales not long-term use	1	0.1%	1	5.9%
Linking development actors with private sector	6	0.5%	4	23.5%
No sustainable fuel supply	9	0.7%	7	41.2%
Programme SU				
Lack of long-term vision	13	1.1%	10	58.8%
Short-term funding	4	0.3%	3	17.6%
Lack of scale	2	0.2%	2	11.8%
Lack of accountability development sector	8	0.6%	6	35.3%
Lack of monitoring and follow-up	11	0.9%	6	35.3%
Policy SU				
Lack of subsidy to sustain fuel use	8	0.6%	5	29.4%
Lack of enabling policies specifically for cooking energy	12	1.0%	8	47.1%
Lack of Government support	6	0.5%	5	29.4%
Enabling factor Adoption HH				
Affordability EA				
Financing mechanisms	7	0.6%	6	35.3%
Availability of low priced stoves	15	1.2%	7	41.2%
Warranty provision	4	0.3%	2	11.8%
Competitive or cheaper than other fuels	11	0.9%	5	29.4%
Appropriate technology EA				
Service for maintenance and repair	4	0.3%	3	17.6%
Fits local households needs and cooking practices	40	3.2%	14	82.4%
Upgraded fuel solutions	7	0.6%	5	29.4%
User friendly technology	19	1.5%	8	47.1%
Locally made stoves or local presence	12	1.0%	7	41.2%
Demonstratable immediate benefits	15	1.2%	8	47.1%
Knowlegde EA				
User training	16	1.3%	7	41.2%
Marketing and communications to create demand	25	2.0%	9	52.9%
Outline benefits and set clear expactations	10	0.8%	7	41.2%
Behaviour change campaigns	4	0.3%	4	23.5%
Establish trust	4	0.3%	3	17.6%
Market access EA				
Market driven approach	13	1.1%	8	47.1%
Non market based approach for last mile beneficiaries	5	0.4%	4	23.5%
Choice in stove solutions and fuels	7	0.6%	6	35.3%
Supply chain improvement				
Motivation EA				
Limited firewood available / high fuel prices	7	0.6%	6	35.3%
Programme EA				
Gender considerations in targeting	7	0.6%	3	17.6%
Improved feedback from lessons learned	10	0.8%	7	41.2%
Long-term funding	2	0.2%	2	11.8%
Improved targeting	5	0.4%	4	23.5%
Development context specific solutions and selection criteria	10	0.8%	7	41.2%
Policy EA				
Stove and fuel subsidy and tax incentives	9	0.7%	8	47.1%

Enabling factor sustained use HH				
Affordability ES				
Income generation through ICS livelihood development	10	0.8%	6	35.3%
Subsidize stove and fuels	15	1.2%	10	58.8%
Financing mechanisms to replace stove	6	0.5%	5	29.4%
Warranty provided	6	0.5%	2	11.8%
Follow-up ES				
Repair and maintenance access	16	1.3%	10	58.8%
Monitoring and programme / design feedback	24	1.9%	12	70.6%
Technology mix ES				
Support stacking	20	1.6%	10	58.8%
Emphasis should be placed on context specific stove and fuel selection	15	1.2%	11	64.7%
Train the user how to use the stove	12	1.0%	6	35.3%
Adress loss of additional benefits from traditional cooking such as heating and lightning	13	1.1%	4	23.5%
Focus on stove development for most cooking intensive practices	1	0.1%	1	5.9%
Technology functions				
Simple in use requiring little training	5	0.4%	4	23.5%
Requires limited maintenance	5	0.4%	4	23.5%
Quality stove	6	0.5%	5	29.4%
Long lifespan	5	0.4%	5	29.4%
User reward ES				
Meet expectations of stove/ fuel	4	0.3%	2	11.8%
Experience value over time	14	1.1%	10	58.8%
Market sustainability ES				
Link with carbon credits	2	0.2%	1	5.9%
Market based approach where economically viable	14	1.1%	7	41.2%
Focus on sustainability in supply chain	21	1.7%	8	47.1%
Distribution for very low on non income households	5	0.4%	4	23.5%
Programme ES				
Long-term vision and planning	9	0.7%	9	52.9%
Improve understanding of local context	5	0.4%	4	23.5%
Improved community consultations and stove selection criteria	15	1.2%	6	35.3%
Support manufacturers with supply chain development	3	0.2%	3	17.6%
Focus on local production where possible	8	0.6%	6	35.3%
Funding to researched programmes and not just innovation	1	0.1%	1	5.9%
Linking ICS with sustainable natural resource management	8	0.6%	7	41.2%
Policy support ES				
Policy alignment	15	1.2%	8	47.1%
Fuel and stove subsidy	8	0.6%	4	23.5%
Government support and decision on cooking energy use fuels	20	1.6%	11	64.7%
Tax incentives and private sector support	17	1.4%	6	35.3%

BA = Barrier Adoption

BS = Barrier Sustained use

EA = Enabler Adoption

SA = Enabler Sustained use

Appendix D

Complete results from the expert survey analysis per question.

Q1 I understand that there is no benefit to me by participating and no penalty to me for declining to participate in this survey. By taking this survey I acknowledge that my answers can be used anonymously for the purpose of the research project.

	Choice	Totals
•	Yes	30
•	No	0

Q2 What is the main used cooking method among rural households in the lowlands of Lesotho to prepare meals? (Please select the most predominantly used method)

Multiple Choice

	Choice	Totals
•	Three stone open fire (firewood)	12
•	Traditional cookstove (biomass/ firewood)	10
•	Charcoal stove	0
•	Improved cookstove using biomass	0
•	LPG stove	4
•	Electric cookstove	1
•	I do not know	0
•	Other, please specify	3

Q3 What is the primary source of energy for cooking and heating among rural households in the lowlands of Lesotho? (select the most common source of fuel)

Multiple Choice

	Choice	Totals
•	Firewood	17
•	Other forms of Biomass (grass, agricultural waste)	5
•	Biomass briquettes	0
•	Charcoal	0
•	Animal Dung	2
•	LPG	1
•	Electricity	3
•	Kerosene	1
•	I do not know	0
•	Other, please specify	1

Q4 How do the majority of households in the rural lowlands obtain their fuel? [Select all that apply]

Multiple Choice

	Choice	Totals
•	Purchase at market	5
•	Purchase from individual firewood sellers	10
•	Connection via electricity grid	2
•	Collect for free	23
•	Barter fuel for other items	3
•	Provided for free by government	1
•	Provided for free by Humanitarian agency	0
•	I do not know	0
•	Other, please specify	1

Q5 What do you perceive as the biggest wood fuel challenges in the rural lowlands of Lesotho, for those dependent on firewood? [Select all that apply]

Multiple Choice

	Choice	Totals
•	Insufficient wood fuel	29
•	Localized environmental degradation	22
•	Low quality of wood fuel	2
•	Health concerns due to emissions	10
•	High cost of wood fuel	6
•	I do not know	0
•	Other, please specify	3

Q6 Please rate the level of adoption and sustained use of stoves for rural households in Lesotho on a scale from very low (1) to very high (5).

Scoring

	Choice	Score	Average
•	Initial adoption of improved biomass cookstoves	68	2.27
•	Sustained use of improved biomass cookstoves	72	2.4
•	Adoption of cleaner cookstoves (e.g., Electricity, LPG, ethanol)	85	2.83
•	Sustained use of cleaner cookstoves (e.g., Electricity, LPG, ethanol)	79	2.63

Q7 Which of the following statements are key barriers that hinder the adoption of improved cookstoves (ICS) in rural households in the lowlands of Lesotho? Please rate each statement from ‘strongly disagree’ to ‘strongly agree’.

Scoring

	Choice	Score	Average
•	High initial purchasing costs	123	4.1
•	High fuel costs (in case of non-bio-mass stove)	110	3.67
•	Additional costs if it includes a fuel switch away from firewood/biomass that can be collected for free	93	3.1
•	No interest to switch fuels	80	2.67
•	Lack of financing mechanisms to purchase stove	120	4
•	Limited knowledge/awareness of ICS	97	3.23
•	Stoves not available on markets	93	3.1
•	No incentive to change (no problems with current cooking methods)	84	2.8
•	Not convenient in use	71	2.37
•	Limited benefits of stove (little savings, does not make it worth the investment)	66	2.2
•	People prefer traditional cooking methods	93	3.1
•	Loss of additional benefits of traditional cooking (heating, lighting, insect deterrent)	91	3.03
•	Low quality of stoves available	65	2.17

Q8 Which of the following factor are key barriers that hinder the sustained use of ICS in rural households after initial adoption? Please rate each statement from 'strongly disagree' to 'strongly agree'.

	Choice	Score	Average
•	High fuel costs (in case of non-biomass stove)	108	3.6
•	No repair or maintenance options	98	3.27
•	Lack of training on ICS use	92	3.07

	Choice	Score	Average
•	Not convenient in use	74	2.47
•	Does not fit cultural cooking practices	84	2.8
•	Lack of stove warranty	64	2.13
•	Lack of sustainability in stove/fuel access in markets	71	2.37
•	Poor quality stoves	71	2.37
•	Does not provide sufficient benefits	73	2.43
•	Does not meet expectations of fuel savings	69	2.3

Q9 Which are enabling factors that can help adoption of ICS for rural households in Lesotho? (Please check the box ranging from strongly disagree to strongly agree)

	Choice	Score	Average
•	Stove should be user friendly / simple to use	140	4.67
•	Stove should not require extra work	129	4.3
•	Stove should be able to cook the majority of local dishes	136	4.53
•	Stove should not use biomass	76	2.53
•	Stoves should be more available in local markets	128	4.27
•	Stoves should be locally produced	126	4.2
•	Stove should be subsidized	119	3.97
•	Fuel should be subsidized (in case of non-biomass stove)	115	3.83
•	Marketing/communications campaign about stove benefits	123	4.1
•	Provide user training for stoves	127	4.23
•	Stove should demonstrate substantial and immediate benefits (fuel savings, cooking time savings)	134	4.47
•	Access to household financing mechanisms to purchase stoves/fuel	132	4.4

	Choice	Score	Average
•	High quality stoves	133	4.43
•	Affordable lower quality stoves	97	3.23

Q10 Which are enabling factors that can help the sustained use of ICS for rural households in Lesotho? (Please check the box ranging from strongly disagree to strongly agree)

	Choice	Score	Average
•	Stove and fuel subsidies	122	4.07
•	Access to repair and maintenance for stove	131	4.37
•	Addressing losses of traditional cooking benefits simultaneously (such as loss of heating, lightning)	120	4
•	Improved context specific stove and fuel selection (meets local cooking practices)	121	4.03
•	Improved expectation management of stove benefits	116	3.87
•	Improved monitoring and follow-up to be able to change stove design based on customer feedback	128	4.27
•	Sustainability in stove and fuel supply chain (continued market access)	125	4.17
•	Support the concept of stove and fuel stacking (clarifying that one stove/fuel might not meet all HH needs but improve parts of cooking and reduce fuel needs)	118	3.93
•	More choice on market for different stoves	121	4.03

Q11 Please share any barriers or enabling factors for the initial adoption or sustained use of improved cookstoves for rural households in the lowlands of Lesotho that you would like to add.

Date	Response
November 26, 2020	None.
November 26, 2020	Fear of change
November 25, 2020	absence of a well-defined delivery and financing models for ICS
November 25, 2020	None
November 25, 2020	Lack of finances is the main factor. However, adopting new changes also poses a lot of challenges, many people are resistant to changes.

Q12 Thank you kindly for participating in this survey. Your contributions are very valuable for this research. Please feel free to reach out to me with any questions via [redacted] or leave any comments or additional information you would like to share below.

Form

Date	Comment (optional)
November 26,	I highly love the study.
November 25,	For Cooking stoves and method of cooking I felt we should have provided for multiple answers for instance 88.6% of rural house use cowling and 84.2% use firewood. I felt I did not do justice to the question by just choosing one option.
November 23,	I have done my own research over the past years and will have another survey with German students end of 2021. I want to have access to your report and comment /review. if possible. my email is [redacted]
November 20,	Such a great survey! Great questions. Nothing to add.
November 18,	You are welcome and good luck with the survey and your studies