REPUBLIC OF KENYA
MINISTRY OF ENERGY

CCAK
CLEAN COOKING ASSOCIATION OF KENYA

KENYA HOUSEHOLD COOKING SECTOR STUDY

Assessment of the Supply and Demand of Cooking Solutions at the Household Level

FOREWORD

Kenya's Sustainable Energy for All (SEforALL) Action Agenda envisions that universal access to modern cooking solutions for all Kenyans will be achieved by 2030. One of the actions flagged as necessary to support the target is collection of data, specifically gender disaggregated data. This year, we undertook the 6th national census from which we expect to have, among others, data on the clean cooking sector especially on usage of clean cookstoves and fuels by households.

Since 2017, the Ministry has been involved in the collection of data for the clean cooking sector. The data has brought about deeper understanding of the needs of the sector and provided a framework upon which critical decisions, including budgetary allocation made to the sector. For instance, the Kenya Off Grid Solar Access Project (KOSAP) supported by the World Bank, has a clean cooking component which is anticipated to lead to increased uptake of clean cookstoves among populations in underserved counties. Similarly, the National BioEnergy Strategy (under formulation) has also benefitted from data derived from these research initiatives.

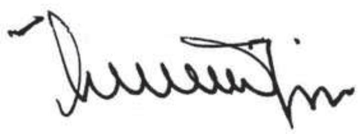
This **National Cooking Sector Study** provides answers to many questions raised about the clean cooking sector, and meets key data needs outlined in the SEforALL agenda. It provides a powerful baseline for the sector in 2018 showing the status of both household and market elements of cooking.

The study has shown that many Kenyans still require interventions that will increase their access to improved and clean cooking solutions. Statistics from the study show that 93.2% of the rural populations still rely on solid fuels as their primary fuel source. This means that there is need to deeply look into the clean cooking sector and visualize a shift to alternatives for all populations, especially vulnerable populations.

Kenya commits to shift to clean cooking through development of efficient cooking solutions thereby projecting an abatement potential of 7.3 Mt $C0_2e$ by 2030 as a means to mitigating climate change. Using clean cooking solutions will support the move by the Government to restore Kenya's forest cover to 10% up from the current 7%. Furthermore, Household Air Pollution (HAP) brought about by cooking using inefficient cooking solutions is a key health risk to populations, and statistics from the Ministry of Health on cooking should motivate us to increase uptake of clean cooking solutions in the country. It is expected that clean cooking will reduce the country's annual disease burden attributable to HAP from 49% (21,560) to 20%.

This report will guide the Ministry of Energy in decision making for the clean cooking sector. It will also guide the Inter Ministerial Committee on Clean Cooking in planning for all related activities. The report should however not be limited to just this Ministry. It should be read by policy makers, researchers and planners across all sectors, and by anyone interested in making a change in the clean cooking sector.

I am glad to unveil it for public use.



Hon. Charles Keter, EG
Cabinet Secretary
Ministry of Energy

PREFACE

For the longest time, low income countries like Kenya have grappled with the challenge of getting adequate data that can aid the formation of new cooking habits. The public and private sector recognizes the effect of unclean cooking to the environment and health that is affecting over 36 million people in Kenya. The harmful gases emitted such as methane, carbon monoxide and black carbon have created a lot of health concerns. This makes the introduction of clean cooking methods a matter of national priority and this Clean Cooking Study very timely. This Clean Cooking Study recognizes that a wide range of social, cultural and technical issues are the major determinants of cooking behavior that needs to be addressed. This can be done through a clean cooking intervention framework of behavior change communication and by the establishment of relevant information, social support systems, as well as well grounded monitoring and evaluation frameworks.

Further, as the study findings confirms, woodfuel (charcoal and firewood) is the most commonly used primary cooking fuel, currently being used by 75% of Kenyan households. Similarly, 93.2% of rural households use woodfuel (fuelwood or charcoal) as their primary fuel. This indicates great exposure to harmful pollutants emitted from burning wood and charcoal. Household Air Pollution (HAP) is one of the largest health risk factors for mortality in Kenya with about 21,560 deaths attributed to HAP annually; this is more than the average number of deaths caused by road accidents.

The Government of Kenya through the Ministry of Energy recognizes the negative impact of the cooking methods such as three stone open fire and other traditional stoves. The Ministry has partnered with other government agencies and other Stakeholders through Inter-Ministerial Committee on Clean Cooking-which Clean Cooking Association of Kenya (CCAK) is a co-convener-to help identify and switch from these rudimentary forms of cooking to improved, cleaner and efficient technologies and fuels.

It is our hope that the findings of this study will contribute greatly towards formulating better policies, standards and regulation that will help in identifying, designing, executing, evaluating and monitoring of the cooking technologies and fuels in the market environment.

The Ministry of Energy with collaboration with the CCAK would like to express our sincere appreciation for the cooperation and contribution from all the respondents towards the study. Our special gratitude to our Study Steering Committee (Ministry of Energy, CCAK, GIZ - EnDev-K, SNV, Practical Action and the Clean Cooking Alliance) for all the technical and financial support. We are also grateful to EED Advisory and the Stockholm Environment Institute (SEI) for their invaluable support towards the initiation and completion of the study.

Dr. Eng. Joseph Njoroge, CBS Principal Secretary
Ministry of Energy

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We appreciate the EED Advisory and Stockholm Environment Institute (SEI) team who led in the research and compilation of this study. In particular, special thanks to Murefu Barasa EED Advisory Team Leader and consortium lead, team members –Ida Githu, Beryl Ajwang', Brian Kinuthia, Michael Mwangi (GIS Expert) Ruth Gichuhi (Project Manager) and Grace King'ori (Graphic Designer). In addition, we would like to appreciate St Rocio A. Diaz-Chavez (PhD), Robert Bailis (PhD) and Hannah Wanjiru, all of Stockholm Environment Institute for their valuable technical input in the study.

Jechoniah Kitala
Chairman
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LIST OF ACRONYMS

AECF ------------------ Africa Enterprise Challenge Fund

CAP ------------------- Country Action Plan

CAPI ------------------ Computer-Assisted Personal Interviewing

CBO ------------------- Community Based Organisations

CCA ------------------- Clean Cooking Alliance (The Alliance)

CCAK ----------------- Clean Cooking Association of Kenya

CCT ------------------- Controlled Cooking Test

CDM ------------------ Clean Development Mechanism

CET ------------------- Common External Tariff

CIESIN ---------------- Centre for International Earth Science Information Network

COPD ----------------- Chronic Obstructive Pulmonary Diseases

CRA ------------------- Comparative Risk Assessment

DALYs ---------------- Disability-Adjusted Life Years

DANIDA -------------- Danish International Development Agency

DFID ------------------ Department for International Development

DHS ------------------- Demographic and Health Surveys

EA -------------------- Enumeration Area

EAC ------------------- East African Community

EED ------------------- EED Advisory Limited

EnDev Kenya --------- GIZ Energising Development Kenya Programme

EPRA------------------ Energy and Petroleum Regulatory Authority

ESMAP ---------------- Energy Sector Management Assistance Programme

fNRB------------------- Fraction of Non-Renewable Biomass

GIZ ------------------- Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH

GACC----------------- Global Alliance for Clean Cookstoves (The Alliance)

GDC ------------------ Geothermal Development Corporation

GDP ------------------ Gross Domestic Product

GHG ----------------- Green House Gas

GIS ------------------- Geographic Information Systems

GLONASS ------------ Global Navigation Satellite System

GLPGP ---------------- Global LPG Partnership

HAP ------------------- Household Air Pollution

HH -------------------- Household

IAP ------------------- Indoor Air Pollution

ICS ------------------- Improved Cookstove

IER ------------------- Integrated Exposure Response

IHD ------------------- Ischemic Heart Disease

ISO ------------------- International Organisation for Standardisation

IWA------------------- International Workshop Agreement

KCJ ------------------- Kenya Ceramic Jiko

KEBS------------------ Kenya Bureau of Standards

KENGO --------------- Kenya Energy and Environment Organisation

KenGen --------------- Kenya Electricity Generating Company

KES ------------------- Kenya Shillings

KIRDI ----------------- Kenya Industrial Research and Development Institute

KNBS------------------ Kenya National Bureau of Statistics
KOSAP ---------------- Kenya Off-Grid Solar Access Project
KWFT------------------ Kenya Women Microfinance Bank
LDC ------------------- Least Developed Countries
LEAP------------------- Long Range Energy Alternative Planning Model
LPG-------------------- Liquefied Petroleum Gas
LULUCF--------------- Land Use Land-use Change and Forestry
MENR ----------------- Ministry of Environment and Forestry
MFI -------------------- Micro Finance Institutions
MoE ------------------- Ministry of Energy
MoH------------------- Ministry of Health
MTF ------------------- Multi-Tier Framework
NGO------------------ Non-governmental Organisation
NRB ------------------- Non-Renewable Biomass
ODK------------------- Open Data Kit
MOU------------------ Memorandum of understanding
NDC ------------------ Nationally Determined Contributions
NGO------------------ Non-Governmental Organisation
PAYG ------------------ Pay-as-you-go
PSUs------------------- Primary Sampling Units
SACCO --------------- Savings and Credit Cooperatives
SCODE --------------- Sustainable Community Development Services
SDG------------------- Sustainable Development Goals
SEDAC ---------------- Socioeconomic Data and Applications Centre
SEI -------------------- Stockholm Environment Institute
SEP -------------------- Special Energy Programmes
SEforALL -------------- Sustainable Energy for All
SIDA------------------- Swedish International Development Cooperation Agency
SMEs ------------------ Small and Medium-sized Enterprises
SNV ------------------- Netherlands Development Organisation
SPSS------------------- Statistical Package for Social Sciences
TOR ------------------- Terms of Reference
TSOF------------------ Three Stone Open Fire
RAG ------------------- Red Amber Green
RBF -------------------- Result Based Financing
RVO ------------------- Netherlands Enterprise Agency
UN -------------------- United Nations
UNFCC --------------- United Nations Framework Convention on Climate Change
UNAM ---------------- National Autonomous University of Mexico
UNDP----------------- United Nations Development Programme
USAID----------------- United States Agency for International Development
USD ------------------- United States Dollar
WBT ------------------- Water Boiling Test
WHO------------------ World Health Organisation

TERMINOLOGY

Although there are no universally accepted definitions of the terms "improved cookstoves", "improved cooking solutions" and "clean cooking solutions", this study adopts the definitions used by a World Bank (ESMAP) report on the state of the global clean and improved cooking sector[1]. These definitions, given below, were guided by the ISO IWA tiers of performance.

- *Cooking solution:* Any combination of technology and fuel used for cooking.
- *Traditional cooking solutions:* Baseline cooking technologies that employ no functional considerations for fuel and/or thermal efficiency. Examples include the three stone fire, open U-shaped clay or mud stoves, metallic charcoal stoves, and unvented coal stoves.
- *Improved cooking solutions:* Cooking solutions that improve, however minimally, the adverse health, environmental, or economic outcomes from cooking with traditional solid fuel technologies. This definition encompasses clean cooking solutions and the entire range of improved biomass cookstoves.
- *Improved biomass cookstoves:* Biomass stoves that improve on traditional baseline biomass technologies in terms of fuel savings via improved fuel efficiency. Some improved cookstoves also lower particulate emissions through improved efficiency of combustion, but the critical distinction from "clean" cooking solutions is that "improved" stoves may not reach sufficiently low emissions levels to generate meaningful health benefits. Examples include basic chimney improved cookstoves (ICS), basic portable ICS (e.g. Kenya Ceramic Jiko), and intermediate ICS (e.g. rocket cookstoves).
- *Clean cooking solutions:* Cooking solutions with low particulate and carbon monoxide emissions levels (IWA ISO Tier 3-4 for the indoor emissions indicator, within the Global Alliance's Monitoring and Evaluation framework). These include stoves based on petro-chemical fuels (LPG, natural gas, kerosene), electric stoves and electromagnetic induction cookstoves. Biofuel cookstoves powered by ethanol and other plant-based liquids, oils or gels, and biogas cookstoves are also included in this category. Solar cookers and retained-heat cooking devices are also considered clean cooking solutions.

The terms of reference for this study requires an evaluation of both cooking technologies and cooking fuels. While the structure of this report discusses the approaches and findings largely based on these two components of cooking, the distinction is less obvious in cooking solutions that are not packaged as such. For example, cooking solutions like the 3kg and 6kg complete LPG cylinders (with grill and regulator) and biogas systems which are sold as consolidated units combining technology and fuel. On the other hand, some cooking solutions are designed for specific fuels (e.g. the Mimi Moto gasifier for pellets) and therefore any meaningful discussion will have to be done within that context.

Further, the following terms and phrases are also frequently used in this report:

- *Primary cooking solution:* the cooking solution that is most used (frequency of use).
- *Secondary cooking solution:* the second most commonly used cooking solution for households (frequency of use).
- *Use rate:* Percentage number of households in possession of and using a technology or fuel.

[1] Putti, V., Tsan, M., Mehta, S. & Kammila, S. (2015). The State of the Global Clean and Improved Cooking Sector. Retrieved from http://prdrse4all.spc.int/system/files/state_of_global_clean_improved_cooking_sector_0.pdf

- *Branded stoves*: Cookstoves manufactured or imported by formally registered entities that have a distinct product name. These stoves are standardized and typically have a warranty.
- *6 kg complete LPG cylinder:* This is a 6 kg gas cylinder complete with a burner and grill.
- *Technology and fuel stacking*: This phrase describes the use of multiple devices and fuels to satisfy household energy needs
- *Woodfuel*: A compound word that includes all types of solid biomass cooking fuels including firewood, charcoal, agricultural residues and others.
- *Fuelwood*: Solid biomass fuel from wood sources. The word is used synonymously with firewood.

The following stove definitions are also adopted:

Cookstove	Description
Traditional cooking solutions	
Three stone open fire	Most basic form of cooking solution that uses stones as the stove (to support cooking appliance) and firewood.
Artisanal metallic charcoal stove	These are traditional metallic charcoal stoves that do not include a ceramic / clay liner or any other component to help with fuel and thermal efficiency.
Improved cooking solutions	
Fixed biomass stove	Unmovable firewood stove designed with improvements, however minimal, to the thermal efficiency of the three stone open fire. This may range from stone and concrete cooking areas to units incorporating a clay/ceramic liner and chimney. Examples include Rocket stoves, Jiko kisasa and Maendeleo stoves.
Improved artisanal portable firewood stove	Improved artisanal portable firewood stoves that have incorporated a clay/ceramic liner for improved thermal efficiency. The most dominant stove was the Kuni mbili stove.
Branded firewood stove (manufactured)	Improved and branded portable firewood stoves whose production is standardized, and factory based. Examples include BURN's Kuni Okoa, EcoZoom's Dura and Envirofit's supersaver wood stoves.
Improved artisanal portable charcoal stoves	Charcoal stoves that have incorporated a ceramic liner for improved thermal efficiency. The Kenya Ceramic Jiko (KCJ) is the most common stove of this category.
Branded charcoal stoves	Improved and branded portable charcoal stoves whose production is standardized, and factory based.
Other non-improved cooking solution	
Kerosene wick stove	Stoves that use wicks to draw kerosene from a tank to the burner. A common design incorporates a series of wicks, usually made of loosely twisted or woven cotton placed in a holder such that they can be moved up and down by a control lever or knob.

Exchange rate at the time of reporting, 1 USD = KES 100

EXECUTIVE SUMMARY

Introduction

In line with the Sustainable Development Goal number 7 (SDG 7), Kenya has an ambitious target of achieving universal access to modern cooking solutions by 2030. These solutions include LPG, electricity, biogas, bioethanol and improved solid fuel cookstoves. Clean Cookstoves Association of Kenya (CCAK) in collaboration with Ministry of Energy, SNV (Netherlands Development Organisation), RVO (Netherlands Enterprise Agency), Practical Action and GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) commissioned this study to determine the state of cooking in Kenya at the household level. This builds on a body of research spread over the last three decades. The purpose of this study is to establish baseline indicators for the cooking sector, raise the conceptual understanding of the cooking sector among stakeholders, attract strategic private and public investments and guide the process of policy formulation. Multiple data collection approaches including literature and data review, household surveys, real-time remote monitoring, geo-spatial analysis and key informant interviews have been applied. The household survey, which is the main component of this study, covered 3,512 household interviews done by over 250 data collection assistants across all 47 counties between 1st October and 14th November 2018. Interviews were done using CAPI (Computer Aided Personal Interviews) and household selection guided by SW Maps which is a geospatial tracking application. Interviews were also conducted with supply side actors including technology and fuel suppliers. In addition, six case studies were conducted to provide specific and in-depth insights to various aspects of cooking.

Overview of general access rates

Although several national energy supply and demand surveys have been carried out, this is the first study that focuses solely on cooking solutions. Other studies such as Nyang' (1999) and Kamfor (2002) while covering household-based cooking also examined energy access issues more broadly. While interpreting the statistics provided in this study or comparing these findings with previous studies, it is important to note the working definitions applied. In various studies *access rates*, for example, indicates the proportion of households that use a cooking appliance as the primary cooking solution while in others, this term simply means the existence of an appliance as part of the cooking options. This study assesses both *owned* and *used* cooking solutions, *primary* and *non-primary* cooking technologies as well as various combinations of types of technologies (in classes such as *clean, improved and traditional*). The Three Stone Open Fire (TSOF) has historically been and remains the most commonly used fuelwood-based cooking option in Kenya. About 58% in 2019 compared to 76% in 1999 of households in Kenya use the TSOF. Although the proportion of household users has dropped, the aggregate number has increased from 4.7 million households to about 7.3 million households. Approximately, 70% of households in Kenya still use a type of woodstove as either their *primary or secondary* cookstove, with a greater prevalence of 92% in rural areas. From the study, 93.2% of rural households use woodfuel (fuelwood or charcoal) as their primary fuel.

This study divides the charcoal stoves into three main groups; improved artisanal charcoal stoves (including the Kenya Ceramic Jiko (KCJ), artisanal metallic charcoal stove, and the branded charcoal stoves (including Jikokoa, Jiko Bora, Jiko Fresh, SuperSaver Charcoal, SmartSaver Charcoal and others). The

KCJ is still the most prominent charcoal stove in Kenya with an estimated 4.2 million households (33.8%) reporting owning at least one. 0.9 million households (7.3%) report owning a metallic charcoal stove and about 386,000 households (3.1%) own a type of branded charcoal stove. 10.3% of households in Kenya, approximately 1.3 million, use a type of charcoal cookstove as their *primary* cookstove. Mean annual national charcoal consumption among households that use charcoal is roughly 395.2 kg/ per year. Data on weekly charcoal expenditure collected from responding households indicates that the annual market value of charcoal consumed by the residential sector alone is KES 68 billion: twice the amount spent on LPG (as reported by the respondents) and almost 40% more than what all domestic customers paid to Kenya Power in 2018 (according to Kenya Power's annual report).

Over the last two decades (1999-2018), the number of households using LPG has increased about six times from an estimated 0.6 million to 3.7 million. Nyang (1999) estimated that the LPG household use rate was 9% (20% urban and 4% rural) in 1999. The Kamfor study estimated this to be 8% (23% urban and 1.8% rural) about two years later. Data from this study indicate that nearly 3.7 million households, or nearly 30% of the population (54% urban and 18% rural) use LPG and 2.4 million households, 19% of households nationwide, consider it their primary fuel. Only 3% of households own an electric cooking appliance such as mixed LPG-electricity stove, electric coil stove and microwave. This is largely attributed to the high cost of the stoves (the survey reported an average retail price for the mixed-LPG stove at KES 28,920 and KES 39,250 for urban and rural users respectively) and cost of electricity. Kerosene use for cooking is still prevalent in urban low-income areas. This study finds that 1.7 million households in Kenya (14% of the total population) cook with kerosene (27.7% and 3.2% of urban and rural households respectively). Alternative cooking technologies like ethanol stoves, biogas, briquettes, pellets and solar cookers remain very rare, and are collectively used by less than 1% of Kenyan households.

Primary and secondary cooking solutions

About one in every two (49%) households use only one type of stove while 36% use two types of stoves. The remaining 15% have three or more options. 80% of the estimated 6.2 million households that use only one cooking option rely solely on either charcoal or fuelwood. The use of multiple solutions to satisfy a household's energy needs is commonly known as stacking. Over the years, energy researchers have observed that when new cooking solutions are introduced in a household, existing options are rarely displaced. Rather, it is more common to see new options incorporated into the mix of cooking solutions. This study finds that households using LPG as the primary fuel still use, on average, 42% of the amount of charcoal used by households that depend on charcoal as the primary fuel. The primary cooking solution is a common indicator of energy access in census data and demographic and health surveys (DHS). The working definition of primary cooking solution in this report is "the cooking solution that used most frequently". With data on primary and secondary cooking options, the survey provides information on the most common household fuel mixes. The Table ES 1 is a matrix of primary and secondary cooking options as reported during the survey. The table is read starting with the information on the rows (primary use) followed by the information on the columns (secondary use). For example, 6.6% of all households in Kenya have LPG as a primary stove and no other appliance as a secondary stove (cell A1). 22.9% of households use wood and charcoal as their primary and secondary cooking solution respectively (cell E5). The largest proportion of households (34.5%) of households use wood stoves as the only cooking solution (cell A5) closely followed by those that combine wood and charcoal. This (cell A5) translates to 4.3 million households depending solely on fuelwood for cooking.

Table ES 1: Percentages of pri. and sec. pairings of cooking options nationwide

	Secondary stove → Primary stove↓	No 2nd stove (%)	LPG (%)	Electric (%)	Kerosene (%)	Charcoal (%)	Wood (%)	Other (%)	Total (%)
1	LPG	6.6	1.3	0.3	2.2	6.5	2.0	0.1	19.00
2	Electric	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.20
3	Kerosene	3.3	0.2	0.0	0.0	1.9	0.2	0.0	5.60
4	Charcoal	4.9	2.0	0.0	1.1	0.3	2.0	0.0	10.30
5	Wood	34.5	5.4	0.0	0.8	22.9	1.1	0.0	64.70
6	Other	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.10
	Total	49.40	9.00	0.30	4.10	31.60	5.40	0.10	99.90

Types of Cooking Technologies

The household survey identified 23 specific categories of cooking technologies *used*. These are shown in the Table ES 2 as aggregated (6 classes) and constituent categories (22 classes). This analysis is related to but different from the discussion above on the *primary cooking solutions* and offers a deeper analysis into the various categories used. Table ES 2 shows appliances used (use rate) regardless of whether it is a primary, secondary or less frequently used option.

Table ES 2: Categories of cooking technologies identified in the national HH survey (use rate)

Aggregate Category	% of HHs currently using			Specific category	% of HHs currently using		
	Urban	Rural	Total		Urban	Rural	Total
Woodstoves	25.9	90.5	69.6	Three stone open fire	21.8	75.4	58.1
				Fixed biomass stove	3.9	14.2	10.9
				Improved artisanal portable firewood stove	0.4	2.4	1.8
				Branded firewood stove	0.2	0.6	0.4
				Gasifier stoves	0.0	0.0	0.0
Charcoal stoves	47.0	40.1	42.3	Improved artisanal portable firewood stove	39.9	30.8	33.8
				Branded charcoal stove	3.6	2.8	3.1
				Artisanal metallic charcoal stove	4.6	8.6	7.3
				Nyama Choma Grill	0.3	0.0	0.1
LPG stoves	54.2	18.0	29.7	6kg complete cylinder	39.1	15.0	22.8
				LPG stove (multiple burner)	13.6	2.0	5.8
				Mixed LPG-Electricity stove	4.9	0.3	1.8
Kerosene stoves	27.7	3.2	11.1	Kerosene wick stove	27.7	3.2	11.1
				Pressurized kerosene stove	0.0	0.0	0.0
Electrical appliances	7.4	0.5	2.8	Mixed LPG-Electricity stove	4.9	0.3	1.8
				Microwave	2.2	0.2	0.8
				Electric coil stove	0.8	0.0	0.3
				Electric induction stove	0.0	0.0	0.0

Aggregate Category	% of HHs currently using			Specific category	% of HHs currently using		
	Urban	Rural	Total		Urban	Rural	Total
Other	0	1	0	Biogas stove	0.1	0.2	0.1
				Gel biofuel stove	0.0	0.1	0.1
				Liquid biofuel stove	0.0	0.0	0.0
				Solar cooker	0.0	0.0	0.0
				Retained heat cookers	0.0	0.3	0.2

From the supply side, this study analyses cooking technologies in two categories; branded (formal) and artisanal (informal). Formal sector players are registered companies or non-profits operating under an officially recognized name with a physical address in the form of an office or manufacturing/ assembly/distribution facility. They offer standardized and branded products, provide warranties and after-sales support. They are also registered with the Kenya Revenue Authority and remit the mandated taxes, levies and fees. These include organisations such as Biogas International, Envirofit, Scode, EcoZoom, Ramtons, Wisdom Stoves, Consumer's Choice, Koko Networks and BURN Manufacturers. The three leading firms in the distribution of solid biomass stoves are BURN (which manufacture locally), EcoZoom (which imports fully assembled stoves) and Envirofit (which assembles stoves locally from imported prefabricated components). Wisdom Energy Hub and SCODE are also prominent formal players in solid biomass stoves. The market has a choice of at least 25 different brands of biomass cookstoves from these five main companies. Informal sector players are an important source of cooking technologies but unlike the formal organisations, they neither label their products nor offer them in standardized versions. Informal manufacturers and entrepreneurs use tried and tested business models having existed for several years; the enterprises interviewed have been operating for an average of 17 years. There are opportunities to further improve the quality and methods of product delivery including semi-automation of some of the production processes; research and development on stoves designs particularly wood stoves; market development; standardisation and branding of products; appropriate business skills training; and supporting product testing.

Preference, cost of appliances and amount spent on fuels

When the respondents were asked to select their most preferred stove, 26.5% and 20.9% of the respondents selected the LPG 6kg complete cylinder and the TSOF respectively. These are the top two most preferred cooking technologies. The TSOF's popularity was significantly higher in rural households, of which 28.6% preferred it compared to only 4.8% in urban areas. The KCJ is the third most preferred stove nationally at 13% but with a lower preference among urban households (8.6%) relative to rural households (15.1%). Respondents were further asked if they owned their most preferred stoves, and if not, what was the main limiting factor of ownership? Almost all the respondents whose most preferred stove was the TSOF were already using TSOF. For the 4% who preferred the TSOF but weren't using it, the main limiting factors were availability of firewood (45%), cost of stove and safety concerns (30%). The main limiting factor for all other stoves was the cost of the stove itself. At 99% and 97% in urban and rural areas respectively, almost all the purchased stoves were acquired on an upfront cash payment basis. This is unsurprising given that at 82%, retail stores (kiosks, supermarkets, wholesale retail shops and open markets) represent the largest proportion of last mile distribution channels for stoves. This report provides, for the first time, information on the prevalence of fuel transporters improving the last mile access for

LPG. More than one in three urban households and one in five rural households now have their LPG refills transported to their houses.

Most fuels, except for LPG, are purchased in small quantities and used within a few days. For these, the survey asked respondents about their expenditure and quantity consumed in the immediate week before the survey. These quantities were divided to obtain a unit cost as either KES per kg of fuel sold by mass or KES per litre of kerosene. For LPG, respondents were asked about the size of the cylinder that they typically purchase (3 kg, 6kg, 13kg and others), its cost and how long, on average, the cylinder lasts. These quantities were computed to estimate the equivalent weekly costs. Prices reported for firewood only constitute purchased firewood and is not an average of purchase and collected firewood.

Market enablers

There are several international, regional, national and sub-national level policies, regulations and standards that influence the cooking sector. The SDGs, UNFCCC Paris declaration and the SEforALL initiative are examples of international interventions. At the regional level, policies such as the custom union integration pillar and the common market integration pillar are being implemented across the East Africa Community. The custom union integration pillar for instance, is the tool through which taxes on cookstoves are set. Several policy and legislative initiatives are implemented at the national and subnational level. Key regulations and legislation include the Energy Act of 2019, the Energy (Liquified Petroleum Gas) regulations of 2009, and the Forest Conservation and Management Act of 2016. Standards affecting cooking include the ISO Harmonized Laboratory Test Protocols at the international level; at the national level are KS 1814-2018 Biomass stoves – Performance Requirements, KS 2759 – 2018 Ethanol fuel cooking appliances; KS 2520 – 2014 Domestic biogas stoves specification, among others.

In addition, financing is key across all stove and fuel value chains - manufacturers need working capital to produce the stoves, distributors need financing to purchase stock while the target consumers require money to buy the stoves. Results based finance, grants, concessional loans, carbon finance and public sector finance are all used in the cooking sector. Cash sales remain the most common method of acquiring stoves. Innovative business models including pay-as-you-go, lay-away and grassroots distributor groups are however, being tested. For example, Wisdom Innovation hub leverages the social infrastructure created by existing women groups as points of distribution. Wisdom brand ambassadors identify these groups, bundle them per region and then set out monthly meeting schedules to demonstrate use of and sell the Wisdom gasifier stove.

Social, health and environmental costs

Based on household residential fuel, the estimated annual emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) from combustion of residential cooking fuels as 13.6 $MtCO_2e$ per year split 2:1 between rural and urban populations. Adding carbon monoxide (CO), black and organic carbon aerosols (BC and OC) and nitrogen oxides (NO_x) increases the total impact to 20.5 $MtCO_2e$, with a similar ratio between rural and urban households. In July of 2015, the Ministry of Environment and Natural Resources submitted to the UNFCCC Kenya's Nationally Determined Contribution (NDC). This document sets the 2010 baseline total greenhouse gas emissions at 73 $MtCO_2e$ including LULUCF (Land use, land-use change, and forestry). The Second National Communication to the UNFCCC, submitted in 2015, has this at 69.5 $MtCO_2e$ for the same year (2010). Household level cooking is therefore a prominent contributor to total national emissions. The National Climate Change Action Plan (2018-22) notes that uptake of improved cookstoves with higher conversion efficiency have the largest potential for GHG emission reductions highlighting the importance of the cooking sector in Kenya's quest to meet her NDC.

One of the leading sources of Household Air Pollution (HAP) is the use of solid fuels and kerosene in traditional and inefficient/simple stoves such as open fires, which leads to emission of large amounts of pollutants such as particulate matter (PM), carbon monoxide (CO), hydrocarbons, and oxygenated and chlorinated organic compounds. It is estimated that HAP in Kenya claims 21,560 lives per year according to the Ministry of Health. Lower Respiratory infections such as pneumonia and acute bronchitis have been the greatest contributor to HAP related deaths in Kenya. Overall, acute lower respiratory infections are considered the second largest cause of death and are linked to 26% of all deaths reported in hospitals in Kenya. Other diseases linked to HAP exposure include ischemic heart disease (IHD), chronic obstructive pulmonary diseases (COPD) and stroke.

Barriers

The choice of cooking technologies and fuels is a composite process with several secondary and tertiary contributing factors. At the heart of the cooking problem is the use of traditional cooking technologies and fuels. Drivers of the prevalent choice of traditional cooking solutions include high cost, limited or non-

Table ES 3: RAG Rating on barriers to fuel access

	Fuel	Policy/ Regulations	Upstream	Midstream	Downstream
SOLID	Charcoal	Charcoal regulations (2009)	Significant unsustainable production; low technology pyrolysis	Well established distribution channels	High adoption of improved stoves
	Woodfuel	Forest Act (2009)	Unsustainable production; informal production systems	Well established distribution channels	Low adoption of improved stoves;
	Briquettes	Unclear policy and regulations	Limited feedstock sources; charcoal is a leading source of feedstock	Incomplete distribution channels	Low adoption of improved stoves;
GAS	LPG	Zero-rated LPG (Finance Act 2016 +)	Well established distribution channels	Well established distribution channels	Incomplete distribution channels
	Biogas	Domestic biogas stoves standards	Nascent ecosystem of manufacturers	Incomplete distribution channels	Incomplete distribution channels; low technology adoption
LIQUID	Kerosene	Restrictive policy and regulations	Well established distribution channels	Well established distribution channels	Low adoption of improved stoves;
	Ethanol	Ethanol standards	Nascent ecosystem of manufacturers	Incomplete distribution channels	Incomplete distribution channels; low technology adoption
	Biodiesel	Unclear policy and regulations	Limited sources of fuels	Incomplete distribution channels	Incomplete distribution channels; low technology adoption

Mild Barriers   Moderate Barriers   Critical Barriers existent distribution channels, lack of awareness, and inappropriate technological designs of alternatives. The impact of the prevalent use of traditional forms of cooking is negative health consequences, sustained GHG emissions and environmental degradation. As demonstrated by the information collected in this study, other attributes including physical location (rural vs urban), size of household, access to fuels, socio-cultural practices, cost of technologies and fuels, choice of meals, past dependency, and size and location of cooking areas all contribute to various technologies and fuels used. Fuel specific barriers are summarized in the Table ES 3 using the Red, Amber and Green (RAG) rating meaning critical, moderate and mild barrier types respectively. For example, charcoal is constrained at the upstream stage but has very few barriers elsewhere. Briquettes on the other hand face several barriers along the value chain, most of which are critical.

Conclusion and call to action

Sustained efforts to transform the cooking sector from one that is highly dependent on traditional cooking solutions to one where the majority have access to clean solutions has yielded mixed results. While the use of TSOF remains prevalent, the uptake of LPG is one positive outcome associated with policy and legislative interventions as well as market-based innovations such as last mile transportation. Fuels and technologies such as electricity, briquettes, pellets, liquid ethanol, gel ethanol, biogas, solar cookers and fireless cookers have been promoted over several decades. Their prevalence and use at the household level remain marginal. This study finds that access to cleaner technologies does not mean displacement of traditional forms of cooking or the elimination of health and environmental costs. As demonstrated above, households that use clean cooking solutions often supplement their cooking mix with traditional sources. Emphasis should therefore be placed on access but also on use. Incentives should be two-prong in nature – promoting access and use simultaneously. Although cost is the most important determinant of access and use, other critical factors such as ease of use, availability of fuels, distances to fuel sources, last mile distribution options, availability of longer-term payment plans, nature and structure of cooking area,

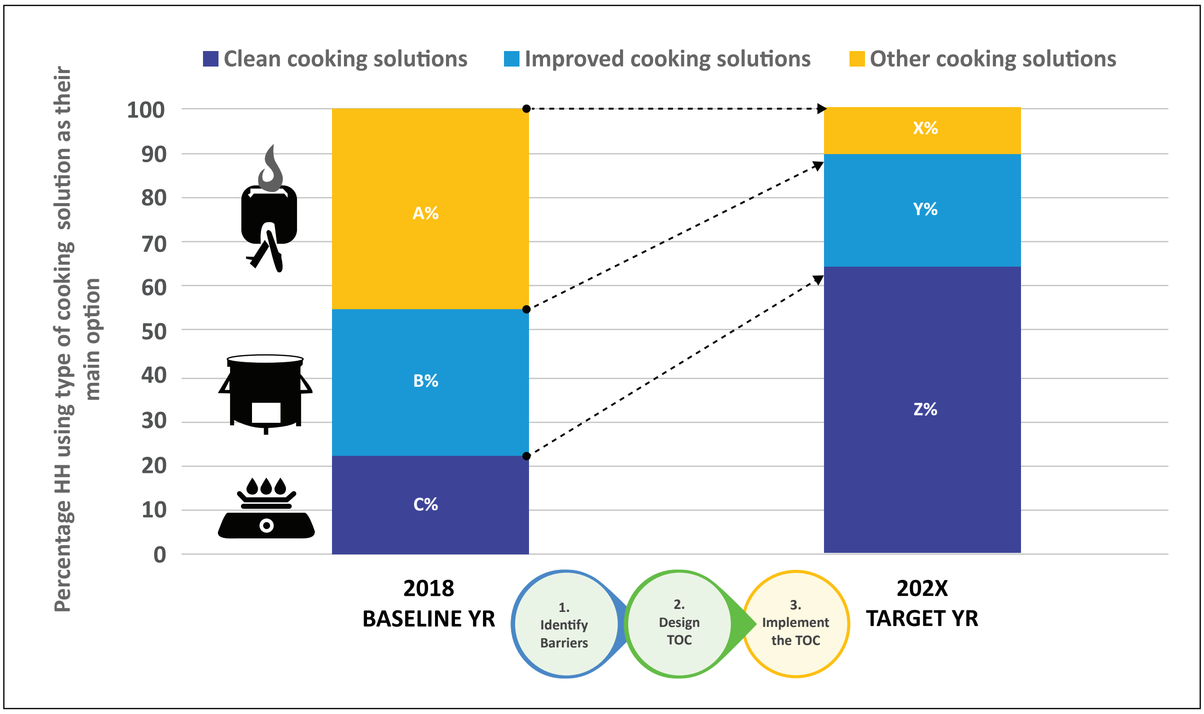


Figure ES 1: Illustration on a path to market transformation types of food and number of household members all contribute to the hypercomplex matrix of choice. "Ease of use" is a compound factor that includes the following capabilities: direct ignition, systematic heat regulation, systematic fuel use, allowance for partial fuel refill, non-smoking clear flame/heat, and fuel level detection. This for example, beyond cost, explains why a low-income urban household will use a kerosene stove to prepare two cups of tea rather than a charcoal stove. The kerosene stove offers direct injection and systematic fuel use features which a charcoal stove would not. There are also major gaps in understanding the social, health and environmental costs of various cooking solutions. The key recommendation from this study is a call for the development and implementation of a cooking sector market transformation programme. The purpose of this programme would be to fundamentally change the cooking sector – beyond the aim of increasing the number of stoves sold - into a clean, sustainable and profitable enterprise. This study establishes a baseline elaborating the status of access to fuels and cooking appliances but also provides information that begins to explain the reasons informing the current situation. Moving the sector from this baseline to a desired end within a stated period and through clearly defined strategic interventions as shown in Figure ES 1 should be the aim of the programme. While programmes that seek to promote the uptake and use of technologies focus on secondary and tertiary aspects, market transformation programmes focus on the primary issues.

A summary of the key statistics and findings is provided below.

1. **59%** of households in Kenya use the TSOF compared to **76% twenty years ago** and although the proportion of household users has dropped, the aggregate number has increased from **4.7 million households to about 7.3 million households;**

2. **64.7%** **(8.1 million)** of households in Kenya still use wood as their primary cooking fuel, followed by LPG at 19% (2.4 million) and charcoal at 10% (1.3 million);

3. **4.3 million** households depend solely on fuelwood for cooking;

4. **80%** of the estimated **6.2 million households** that use only one cooking option rely solely on either charcoal or fuelwood;

5. **71%** of households in Kenya still use a type of woodstove as either their primary or secondary cookstove, with a greater prevalence of **92% in rural areas;**

6. This study estimates that the annual market value of charcoal consumed at the domestic level alone is **KES 68 billion;**

7. This study finds that **1.7 million households** in Kenya (14% of the total population) **use kerosene for cooking with 27.7%** and **3.2% of urban and rural populations respectively reporting use;**

8. Over the last two decades (1999-2018), the number of households using LPG has increased about six times from approximately **0.6 million to 3.7 million** (54% urban and 18% rural households respectively now use LPG);

9. Households using LPG as the primary fuel still use, on average, 42% of the amount of charcoal used by households that depend on charcoal as the primary fuel;

10. Only **3%** of households own an electric cooking appliance such as mixed LPG-electricity stove, electric coil stove and microwave;

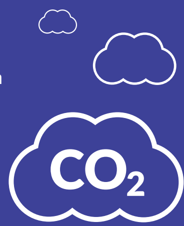
11

5.5 million households own at least one charcoal stove with **1.3 million (10.3%)** reporting using a type of charcoal stove as their primary cooking solution. KCJ is still the most prominent charcoal stove in Kenya with an estimated **4.2 million households (33.8%)** reporting using at least one;

12 Households using LPG must travel nearly twice as far (5.3 km) on average to purchase the fuel than kerosene users (2.9 km) even though twice as many households nationwide cook with LPG than with kerosene. This willingness to travel longer distances could be due to the convenience of use but also due to the frequency of purchase. While kerosene may need to be purchased weekly or even daily, LPG refills would almost always require less frequent travel to purchase;

13 **17,900** biogas systems had been installed at the household level at the time of this study;

14 Annual greenhouse gas (GHG) emissions from combustion of residential cooking fuels are 13.6 MtCO2e per year split 2:1 between rural and urban populations (estimates from the demand side);



15 **99% and 97%** of urban and rural households respectively acquired their cooking appliance through an upfront cash payment demonstratingthe limited access to financial services;

16 71% of households are willing to pay for a 6kg complete LPG cylinder if priced at KES 1,125 compared to 69% who are willing to pay for a Burn stove at KES 973;


6 Kg

1. INTRODUCTION

1.1 Background

Approaches and attitudes towards cooking solutions have been evolving. In the late 1970s to the mid-1990s, cooking in the context of developing countries was commonly framed as an environmental crisis linked to deforestation and forest degradation. Informed by several prominent publications including a series of papers from the Beijer Institute, this led to the first wave of improved cooking initiatives promoting the use of more efficient charcoal stoves, biogas, pellets and briquettes[2,3,4]. As part of this movement, the Kenya Energy and Environment Organisation (KENGO) was founded in 1982 as a national network of NGOs with a mandate to coordinate the planning and implementation of initiatives supporting the uptake of renewable energy in Kenya[5]. One of the outstanding successes of this effort was the widespread adoption of the Kenya Ceramic Jiko (KCJ). Other stoves followed including the *upesi, maendeleo, jiko kisasa* and a set of rocket stoves promoted in partnership with the Ministries in charge of agriculture and energy. During this period GIZ, then known as GTZ, in collaboration with the Ministry of Energy and Regional Development initiated the Special Energy Programme (SEP)[6]. One of the programme's main objective was to promote the use of biogas technology among livestock keeping communities using the zero-grazing method. The outcome was the installation of at least 800 systems mostly in the Meru region.

In the early 2000s, systematic measurement and documentation of household air pollution led to greater understanding of the impact of traditional cooking solutions on health. Although the study of exposure to indoor smoke and its impacts on respiratory diseases started in the 1960s, it was only at the start of the 21st century that systematic emissions monitoring and exposure assessment began being translated into mortality rates[7]. Discussions on clean cooking then centred around the global health crisis. Due to its importance, the World Health Organisation (WHO) started publishing guidelines for indoor air quality in 2006[8]. WHO estimates that over 3.8 million premature deaths occurred globally because of air pollution associated with the use of traditional cooking fuels and methods[9]. Around the same time carbon finance emerged as a high potential source of financing for improved and clean cooking solutions. In Kenya, 32 cooking sector projects had been developed and registered under the Clean Development Mechanism and the Gold Standard by 2014[10]. By the late 2000s, cooking in developing countries was not only seen as an environmental or health problem but as a multi-dimensional developmental challenge. In 2010, the Global Alliance for Clean Cooking – now Clean Cooking Alliance (The Alliance) was established to "support the development, sale, distribution, and consistent use of clean cooking solutions that transform lives by improving health, protecting the environment,

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[5]Kammen, D. (2011). *Research, Development and CommEPRAialization of the Kenya Ceramic Jiko and Other Improved Biomass Stoves in Africa.* Retrieved from https://www.solutions-site.org/node/50
[6]GTZ-SEP. (1987). *Dissemination of Biogas in Rural Areas of Kenya.* Nairobi: German Technical Cooperation.

creating jobs and income opportunities, and helping consumers save time and money". Health, environmental protection, employment creation, entrepreneurship and associated social benefits were now constituent aims of promoting improved and clean cooking solutions. To further advance these efforts, the Global LPG Partnership (GLPGP) was formed in 2012 under the UN Sustainable Energy for All initiative, to "aggregate and deploy needed global resources to help developing countries transition large populations rapidly and sustainably to liquefied petroleum gas (LPG) for cooking".

Unlike in the past, multimillion-dollar investments in production and distribution of cooking solutions are now led by commercial entities. In addition to the informal sector (jua kali) that has consistently supplied the market with various forms of improved stoves, there are now production centres in Ruiru (BURN), Nyandarua (Wisdom) and Nakuru (SCODE). As evidence of the commercial viability of this sector continues to be demonstrated, these companies are now attracting debt and equity investments in addition to grants and other forms of development finance. Innovative business models supported by technology are emerging and are expected to transform the cooking sector including various versions of the pay-as-you-go model.

The ratification of the 2010 Constitution, adoption of the SEforALL Action Agenda and Investment Prospectus, and adoption of the Energy Act 2019 are further transforming the energy sector in Kenya. The devolution of certain functions to the county governments also presents a watershed moment. Under the new constitution and as outlined in the Energy Act, certain functions including the regulation and licensing of charcoal production will be devolved to the counties. One of the limitations to effective national and sub-national planning is the lack of comprehensive empirical information on the state of the cooking sector in Kenya. This is in part, due to the characterisation of most cooking solutions as traditional thus diminishing the need and ability to systematically collect information. This study is a first step in addressing this gap. Biomass, which accounts for about 69% of total national primary energy production,[11] does not have an institutional home outside the Ministry of Energy except for Kenya Forestry Service (KFS) and Kenya Forestry Research Institute (KEFRI) which focus on upstream issues including production. This compared to, for example, the electricity sub-sector that has at least five dedicated government agencies (Kenya Power, KenGen, Rural Electrification Authority, Kenya Transmission Company and Geothermal Development Corporation) supporting and guiding the sub-sector. Most biomass-based cooking solutions are quasi or non-commercial and are distributed outside the conventional value chains. Therefore, consistent data collection including total annual sales that could provide meaningful comparison to commercial energy sources are intermittent. The responsibility of collecting energy data is in part a function of the county governments. This is expected to result in a synchronized approach in information management requiring close collaboration between the national and sub-national governments. Already, the Ministry of Energy together with the 47 counties has embarked on developing a county energy-planning framework, which will detail and standardize the process of county energy planning. This study will contribute to the existing body of knowledge on the cooking sector.

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[7] Ezzati, M. & Kammen. D. (2002). The health impacts of exposure to indoor air pollution from solid fuels in developing countries: Knowledge, gaps, and data needs. Environmental Health Perspectives,110 (11),1057–1068. doi.org/10.1289/ehp.021101057.

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1.2 Purpose of the Study

The Kenya SEforALL Action Agenda embraces the objectives of the SEforALL initiative, key of which is ensuring universal access to modern energy services by 2030. CCAK in collaboration with Ministry of Energy, SNV, RVO, Practical Action, GIZ and Clean Cooking Alliance commissioned this household cooking sector study to determine the status of the sector in Kenya. The study builds on a body of research spread over the last three decades. While previous investigators adopted different approaches and focused on varying themes (see Table 1), the publications listed augmented the understanding on aspects of cooking at the household. The table provides a summary of these publications and their key findings relevant to this study.

The purpose of this study is to establish the baseline sector performance indicators, raise the conceptual understanding of the cooking sector among stakeholders including decision makers, attract strategic private and public investments and guide the process of policy formulation. Setting a baseline will also form the basis of tracking progress towards the SEforALL goal of ensuring universal access to clean cooking by 2030.

Table 1: Summary of key research undertaken in the cooking sector in Kenya

#	Author/s, Institution	Year	Title	Comments and Findings
1.	Philip O'Keefe, Paul Raskin, and Steve Bernow (Beijer Institute)	1981-4	Energy and Development in Kenya: Opportunities and Constraints	Projected mass deforestation and degradation attributed to fuelwood consumption if the base case was maintained. The analysis was based on an energy accounting system, LEAP (Long Range Energy Alternative Planning Model) Projected that wood resource requirements would increase from 20.4 million tonnes in 1980 to 49.7 million tonnes by 2000, with a shortfall of 11 million tonnes and 33 million tonnes by 1990 and 2000 respectively.
2.	UNDP/ World Bank (Energy	1985	Kenya Peri-Urban Charcoal and Fuelwood Survey	Supply side approach Over 300 interviews carried out with producers, transporters and vendors Proposed a large-scale forestry development programme to supply Kenya's future fuel demand to avert an environmental crisis building on the Beijer institute study.
3.	Mike Bess (Ministry of Planning and National Development)	1989	Kenya charcoal survey	Supply side approach (charcoal) An econometric model developed that estimated the charcoal demand per district Found that charcoal is largely produced as a by-product of land use changes not deforestation, departing from the Beijer institute study to a great extent. Concluded that there is need to disaggregate charcoal sources as some could be sustainable

#	Author/s, Institution	Year	Title	Comments and Findings
4.	Frederick Nyang (University of Amsterdam)	1999	Household energy demand and environmental management in Kenya	Demand side approach with a sample size (n) of 1,200 households across 8 representative districts Penetration rates for various fuels were: kerosene - 94%; firewood - 74%; charcoal - 57%; electricity - 19%; and LPG - 9%. Provides an analysis of fuel stacking.
5.	Kamfor Limited (Ministry of Energy)	2002	Study on Kenya's energy demand, supply and policy strategy for households, small scale industries and service establishments	Demand side approach Nationally representative sample size (n) of 2,300 households based on the NASSEP II sampling frame spread across 15 rural districts and 5 major urban areas Annual per capita firewood consumption estimated at 741 kg and 691 kg in rural and urban areas respectively Annual per capita charcoal consumption estimated at 156 kg and 152 kg in rural and urban areas respectively
6.	Stephen Mutimba and Murefu Barasa (Energy for Sustainable Development)	2005	National charcoal survey: Exploring the potential for a sustainable charcoal industry in Kenya	Supply side approach (charcoal) with over 4,000 (n) interviews done with charcoal producers, transporters and vendors Total annual charcoal consumption estimated at 1.6 million tonnes Total annual market value of charcoal estimated to be over KES 32 billion
7.	KIPPRA (Energy Regulatory Commission)	2010	A Comprehensive Study and Analysis on Energy Consumption Patterns in Kenya	Both demand side and supply side approach Both demand side and supply side approach Sample size (n) of 3,665 households, 1,663 enterprises and 857 energy providers. 70% of consumers use biomass-based energy
8.	Camco Advisory Services (Kenya Forest Service)	2013	Analysis of the charcoal value chain in Kenya	Study focused on the supply side Annual contribution of charcoal to the economy is estimated at about KES 135 billion Charcoal pricing increases from a low of KES 250/bag at the producer level to a high of KES 2800/bag at the consumer level

#	Author/s, Institution	Year	Title	Comments and Findings
9.	Mareco Limited (GVEP)	2013	Assessment of the briquette market in Kenya	Survey covered 35 briquette entrepreneurs Small commercial and institutional consumers, such as poultry farms and restaurants form the main markets for briquettes Charcoal dust was the most common type of feedstock (26/35 respondents)

2. APPROACH AND METHODS

2.1 Approach

This study employed multiple data collection approaches including literature and data review, households survey, real-time remote monitoring and tracking, geo-spatial analysis and key informant interviews as summarized in Figure 1. These approaches aimed to build the conceptual understanding of five main aspects of the cooking sector: (i) technology and fuels; (ii) socio-cultural contexts; (iii) markets and business models; (iv) environmental and health costs; (v) enabling factors including access to finance, policy, standards and regulations.

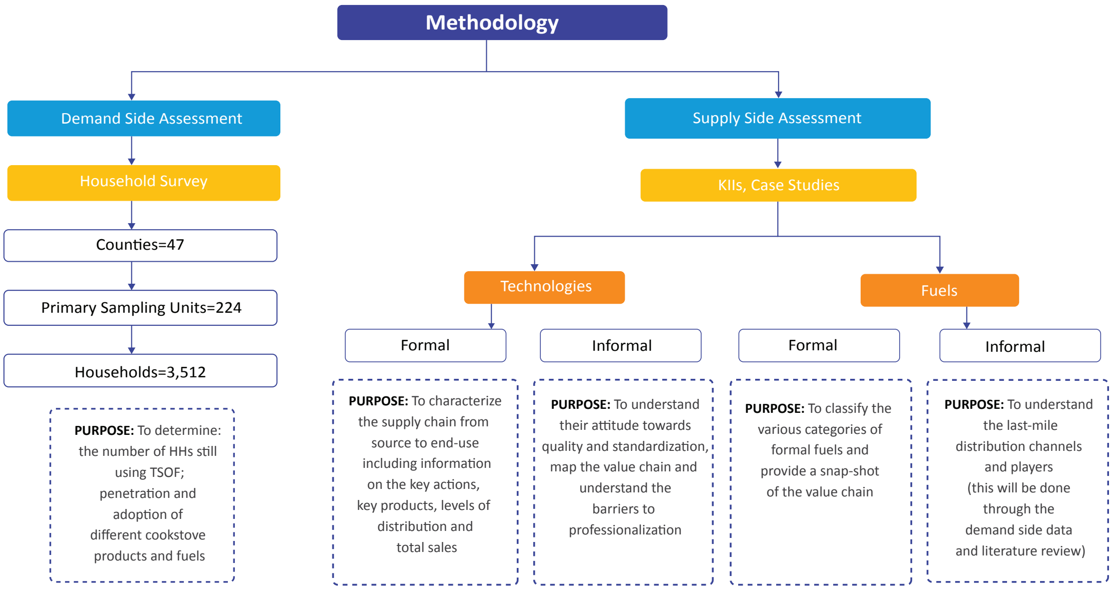

Figure 1: Summary of Approach

2.2 Demand Side Survey

2.2.1 Sampling Frame and Data Collection

The sampling frame used for the household survey is based on a methodology developed by the EED/SEI team in collaboration with GIS experts at the National Autonomous University of Mexico (UNAM) while carrying out the SEforALL/World Bank Multi-Tier Framework (MTF) Survey in Kenya (Y2016-17). The method used a publicly available gridded mapping of Kenya's population produced by NASA's Socioeconomic Data and Applications Centre (SEDAC). The dataset is consistent with Kenya's 2009 national census and was updated to match the 2015 Revision of UN World Population Prospects[12].

[12] CIESIN. Gridded Population of the World, Version 4 (GPWv4): Population Count Adjusted to Match 2015 Revision of UN WPP Country Totals. In: Centre for International Earth Science Information Network - CIESIN - Columbia University, editor. Palisades, NY: NASA Socioeconomic Data and Applications Centre (SEDAC); 2016.

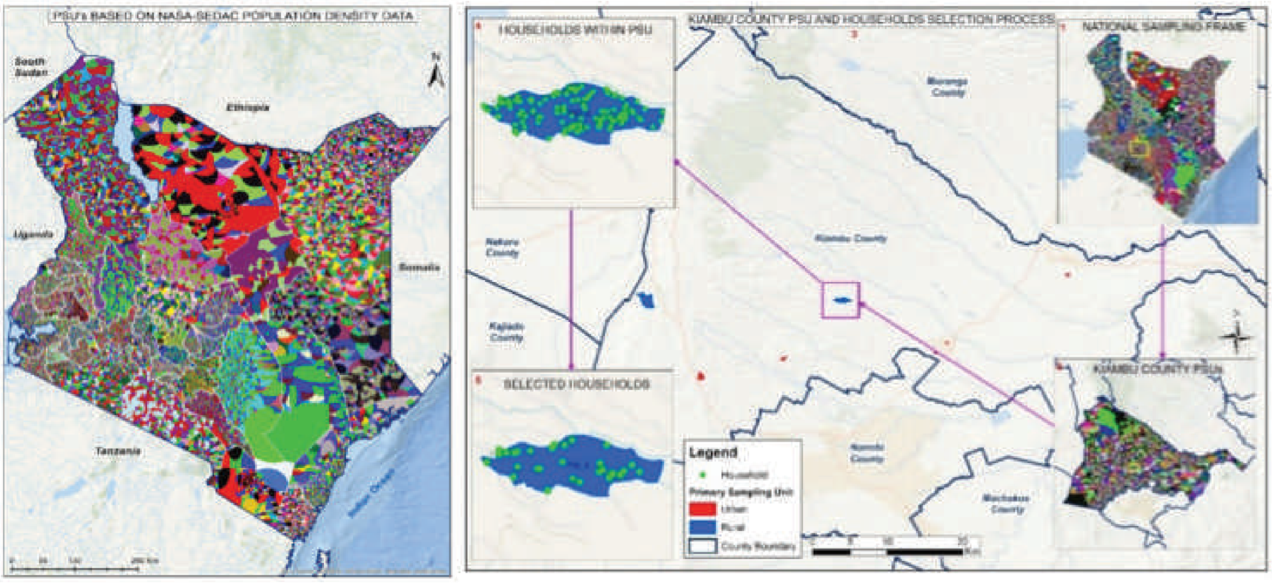

Figure 2: Primary Sampling Units (left) and HH selection in Kiambu County

Using a spatial algorithm written in R, the method defines discrete Primary Sampling Units (PSUs) within each of Kenya's 7,149 sub-locations[13]. Each PSU is continuous in space and contains roughly 200 households. Figure 2 shows PSUs (left) and an example of household selection within PSUs in Kiambu County (right).

The Terms of Reference for this study asked that key indicators such as "number and percentage of households still using three stones or open fire", "the penetration and adoption of cookstove products", and "penetration, use and adoption of the different types of cooking fuels" be quantified, which required a statistically representative sample from the national population. To do this, the team calculated the sample size required to achieve representation among rural and urban populations independently as well as nationwide with minimal margins of error and acceptable confidence. The calculation resulted in a sample of 3,488 households distributed between urban and rural areas (Table 2) to attain a statistically significant sample at the national, urban and rural level. The households were selected in clusters of 16 from 224 primary sampling units (PSUs) distributed proportionally by population among Kenya's 47 counties (Table 3). Sampling occurred in two stages: first, PSUs were selected randomly from each county after which households were selected from within each PSU using satellite imagery which supported random selection (see section 2.2.2). A selected PSU then becomes an Enumeration Area (EA). A total of 3,512 interviews were completed.

[13] The script is open-source and available on request.

Table 2: Sampling formula

$$n = \frac{z^2 r(1-r) fk}{e^2} = \frac{z^2 r(1-r)[+\rho(m-1)]k}{e^2}$$ Where

Symbol	Value	Description
z	1.96	Statistics corresponding to the level of confidence desired. The commonly used level of confidence is 95% for which z is 1.96
r	0.5	Estimate indicator of interest to be measured by the survey (50% is most conservative for calculating n)
f	3.9	Sample design effect. It represents how much larger the squared standard error of a two-stage sample is when compared with the squared standard error of a simple random sample of the same size. The sample design effect has been included in the sample size calculation formula and is defined as: $f = 1 + \rho (m - 1)$.
ρ	0.2	Intra-cluster correlation coefficient. It is a number that measures the tendency of HHs within the same Primary Sampling Unit (PSU) to behave alike in regard to the variable of interest.
m	16	Average number of HHs selected per PSU
k	1.1	Factor accounting for non-response (assume 10%)
e	5%	Margin of error (5% is standard)
n	3,488	Sample size in terms of number of HHs to be selected[14]
N	218	No. of PSUs required

Table 3: Target no. of EAs and HHs per county

County	No. of EAs sampled within each County			No. of HH sampled within each County			Total HH (Done)
	Rural EAs	Urban EAs	Total EAs	Rural HHs	Urban HHs	Total HHs (Target)	
Baringo	2	1	3	32	16	48	50
Bomet	2	1	3	32	16	48	48
Bungoma	4	1	5	64	16	80	82
Busia	2	1	3	32	16	48	49
Elgeyo Marakwet	1	1	2	16	16	32	36
Embu	2	1	3	32	16	48	48
Garissa	1	1	2	16	16	32	32
Homa Bay	3	1	4	48	16	64	65
Isiolo	1	1	2	16	16	32	32
Kajiado	2	3	5	32	48	80	81
Kakamega	5	1	6	80	16	96	97
Kericho	2	2	4	32	32	64	66
Kiambu	3	9	12	48	144	192	184

[14] The equation yields a sample size of 3,392, which would be divided between 212 PSUs. However, the actual sample size is slightly higher to ensure that at least one PSU is selected from every county.

County	No. of EAs sampled within each County			No. of HH sampled within each County			Total HH (Done)
	Rural EAs	Urban EAs	Total EAs	Rural HHs	Urban HHs	Total HHs (Target)	
Kilifi	3	3	6	48	48	96	98
Kirinyaga	3	1	4	48	16	64	64
Kisii	3	2	5	48	32	80	81
Kisumu	2	4	6	32	64	96	96
Kitui	3	1	4	48	16	64	66
Kwale	2	1	3	32	16	48	48
Laikipia	2	1	3	32	16	48	48
Lamu	1	0	1	16	0	16	16
Machakos	2	5	7	32	80	112	114
Makueni	3	1	4	48	16	64	65
Mandera	1	1	2	16	16	32	36
Marsabit	1	1	2	16	16	32	31
Meru	6	1	7	96	16	112	108
Migori	3	2	5	48	32	80	82
Mombasa	0	9	9	0	144	144	147
Muranga	4	1	5	64	16	80	79
Nairobi	0	33	33	0	528	528	518
Nakuru	5	6	11	80	96	176	177
Nandi	3	1	4	48	16	64	64
Narok	3	1	4	48	16	64	59
Nyamira	2	1	3	32	16	48	53
Nyandarua	2	1	3	32	16	48	48
Nyeri	3	2	5	48	32	80	95
Samburu	1	0	1	16	0	16	16
Siaya	3	1	4	48	16	64	64
Taita Taveta	1	1	2	16	16	32	32
Tana-River	1	0	1	16	0	16	16
Tharaka-Nithi	1	1	2	16	16	32	32
Trans Nzoia	3	1	4	48	16	64	64
Turkana	3	1	4	48	16	64	64
Uasin Gishu	2	3	5	32	48	80	80
Vihiga	1	1	2	16	16	32	32
Wajir	1	0	1	16	0	16	16
West Pokot	2	0	2	32	0	32	33
TOTAL	106	112	218	1696	1792	3488	3512

Although the rural population is higher than the urban population, the number of interviews done in these two segments were at a ratio of approximately 1:1. This oversampling was deliberate to attain a statistically significant sample in urban areas. The effect of this on the national averages was weighted accordingly as described in detail in section 2.2.3 (sample weights) to address any potential skew toward urban averages. Data was collected through a network of 253 trained enumerators across all the 47 counties. These enumerators reside in the local survey areas, speak the local languages, understand the local socio-cultural context and are trained in research methods. They also have previous data collection experience and are familiar with CAPI data collection techniques specifically using the ODK platform, GIS tools and SW maps which is a geospatial tracking application. Several field supervisors (fulltime EED and SEI staff) trained, deployed and supervised groups of enumerators working in designated regions. A draft household survey tool was developed based on an ongoing global effort to standardize household cooking energy surveys led by the World Bank and the World Health Organisation. Pre-testing was done in Kawangware, Lavington, Westlands, Gikambura, Githurai and Kilimani. These are a combination of low, middle and high-income areas.

Through the ODK platform, data collected was uploaded to a cloud server upon completion of the interview (in areas with internet connection) or saved on the tablet then uploaded as soon as the enumerator was within an area with a connection. A set of pictures depicting various groups of stoves were shown to respondents when asking about their types of stoves, knowledge of stoves, willingness to pay and preference. Enumerators had these pictures displayed on the tablets as well as on a laminated piece of paper to reduce miscommunication on the types of cooking appliances referenced.

2.2.2 Household air quality monitoring

As an addition, and something outside the designated TOR, we evaluated exposure to indoor air pollution (IAP) by installing a system that assesses not only indoor pollution levels but also exposure relative to different household members through a pilot experiment. This system includes i) particulate matter sensors that collect, record and transmit concentration levels (pollution levels), and ii) movement trackers in the form of smart bracelets that are worn by various household members (exposure). The bracelet records the time the individual enters and leaves the cooking area thus showing exposure durations. An analysis of the pollution levels at the time of the exposure in terms of duration and concentration is made against recommended WHO standards. The report with the findings of this experiment is presented in the annex A1.8.

2.2.3 Geospatial Methods

Using the 2009 KNBS urbanisation status dataset, the PSUs were categorized into urban and rural where the urban-rural split stood at 26% and 74% respectively. Core-urban and peri-urban areas were grouped into urban while rural-urban and rural areas were grouped as rural. Figure 4 shows Kenya's urbanisation status categorized into core-urban, peri-urban, rural-urban, and rural areas. Figure 3 shows the PSUs categorized into urban and rural based on the urbanisation dataset. From these PSUs, enumeration areas were proportionally and randomly selected across rural and urban areas. In this study selected PSUs become the enumeration areas. Respondents were randomly pre-selected using publicly available high resolution (30M or 1 arc-second) population distribution mapping of Kenya developed by CIESIN in collaboration with Connectivity Lab at Facebook and Digital Globe[15]. This is a raster dataset of Kenya's settlements derived from a land use/cover classification of Kenya using Landsat satellite imagery where each pixel represents a building or structure on the earth's surface. Converted to point data, these settlements dataset provided a household listing in each enumeration area from which the random selection of the target households was done. The household selection procedure involved crosschecking of the selected households on Google Earth to eliminate commercial and institutional buildings from our sample. A 50% non-response rate was factored into the selection and therefore each enumeration area, addition to the selected 16 households, had 8 pre-selected substitute households to compensate for inaccessible households, unavailable respondents, non-responsive respondents or where the selected location was not a household.

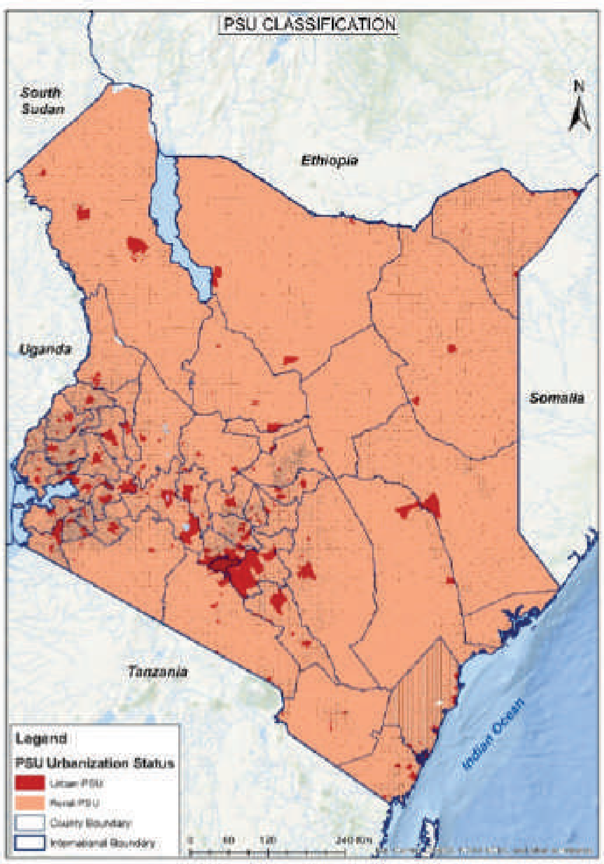

Figure 3: Split of urban and rural PSUs

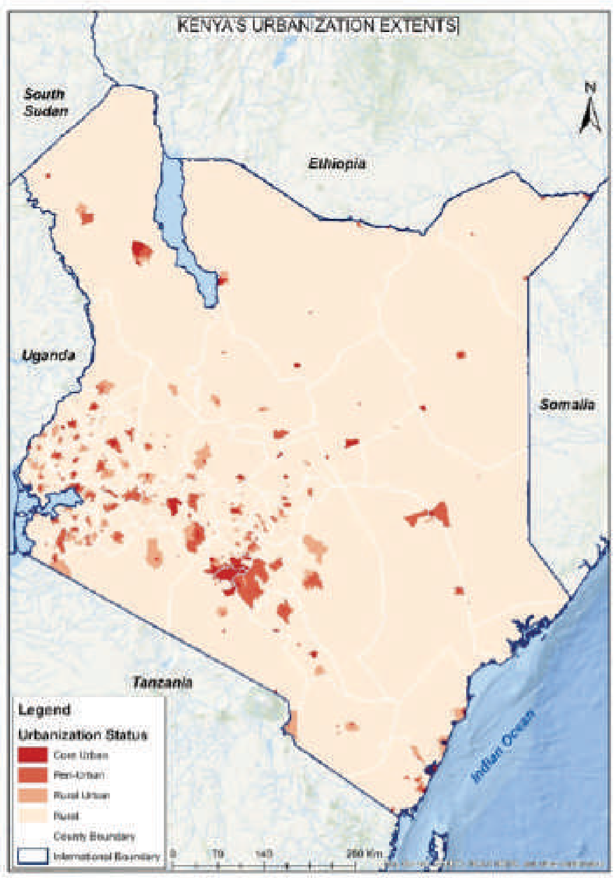

Figure 4: Kenya's urbanization map

[15] Facebook Connectivity Lab and Centre for International Earth Science Information Network - CIESIN - Columbia University. 2016. High Resolution Settlement Layer (HRSL). Source imagery for HRSL © 2016 DigitalGlobe.

elected households were loaded onto SW-Maps, an android-based application that allows for visualisation of spatial data and real time navigation through GPS and GLONASS. This enabled the enumerators to view and navigate their way within the enumeration area and to the pre-selected households.

2.1.1 Sampling Weights

The sample frame was designed to achieve representative samples independently in both rural and urban areas as well as nationally, with PSUs drawn from all counties roughly in proportion to their population. This design led to oversampling in urban areas as well as some sparsely populated counties. This oversampling was adjusted when analysing national level statistics by applying sample weights, which are defined as the normalized inverse probabilities of selection. This sample frame had two stages, therefore weights are calculated for both, and the overall weight is the product of the weights from each stage.

The first stage weight is defined for rural and urban areas of each county as follows:

$$w_{1,i(R,U)} = \frac{1}{P_{1,i(R,U)}}$$

Where $P_{1,i(R,U)}$ is the probability of selecting PSUs in rural or urban regions of county i. This is defined as the ratio of the of PSUs selected to the total PSUs in county i:

$$P_{1,i(R,U)} = \frac{n_{PSU,i(R,U)}}{N_{PSU,i(R,U)}} \text{ so } w_{1,i(R,U)} = \frac{N_{PSU,i(R,U)}}{n_{PSU,i(R,U)}}$$

The second stage is defined for HH selection within each PSU as follows:

$$w_{2,j(R,U)} = \frac{1}{P_{2,j(R,U)}}$$

Where $P_{2,j(R,U)}$ is the probability of selecting rural or urban HHs in PSU j, defined as the ratio of rural or urban HHs selected $n_{HH,j(R,U)}$ to total HHs $N_{HH,j(R,U)}$. We estimated total HHs assuming each PSU contains ~1000 people, divided by average rural or urban HH size within that PSU.

$$P_{2,j(R,U)} = \frac{n_{HH,j(R,U)}}{N_{HH,j(R,U)}} = \frac{n_{HH,j(R,U)}}{1000/HH_{j(R,U)}} \text{ so } w_{2,j(R,U)} = \frac{1000}{n_{HH,j(R,U)} \times HH_{j(R,U)}}$$

And the total weight is the product of both:

$$w_{1\times2} = w_{1,i(R,U)} \times w_{2,i(R,U)} = \frac{N_{PSU,i(R,U)}}{n_{PSU,i(R,U)}} \times \frac{1000}{n_{HH,j(R,U)} \times HH_{j(R,U)}}$$

As a final step, we normalize the weights so that the sample size is not artificially inflated when calculating summary statistics. To normalize, we simply multiply each weight by a normalization factorv, which is equal to the ratio of actual sample size and sum of previously calculated weights:

$$v = \frac{\sum n_{HH,j(R,U)}}{\sum w_{1\times2}}$$

Extrapolations are based on 2018 demographic projections done by UNICEF, estimating the number of rural and urban households at 7,419,542 and 5,157,150 respectively[16].

Data analysis was done using MS Excel, SPSS and R.

[16]UNICEF. (2018). UNICEF Data: Monitoring the situation of children and women: Kenya population projections. Retrieved from https://data.unicef.org/resources/resource-type/datasets/

2.3 Supply Side Assessment

The supply side interviews were divided into 2 main categories: cookstove technologies and fuel manufacturers/distributors/importers. Interviews with each subcategory were done for the purposes listed in Figure 5.

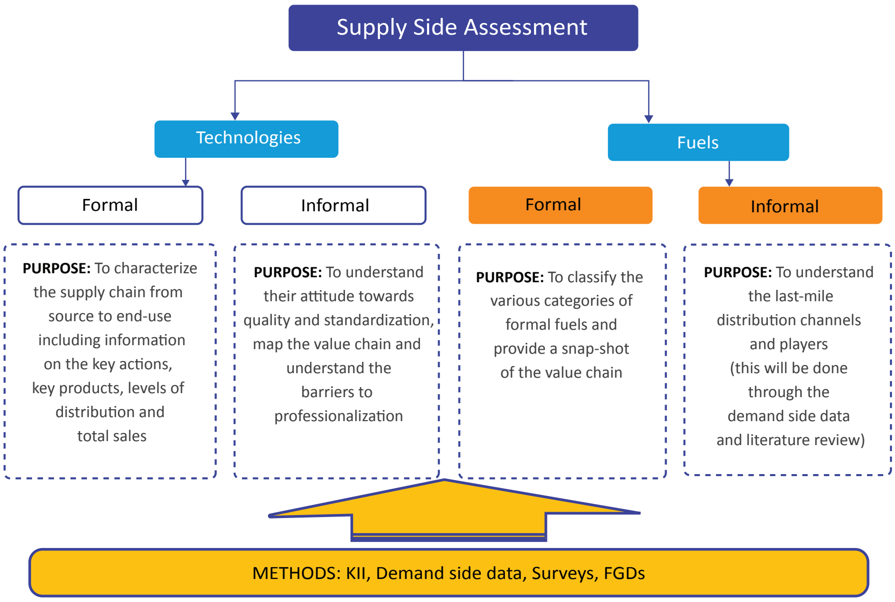

Figure 5: Purpose of the interviews: Supply Side

2.3.1 Formal cookstove manufacturers surveys

To map and characterize the cooking technologies' supply chain, semi-structured interviews were carried out with the formal cookstove manufacturers and importers in Kenya. A sample representing the suppliers of various cookstove types (LPG, kerosene, briquettes, pellets, ethanol-liquid and ethanol-gel stoves) was drawn from online searches, literature review and discussion with sector partners. A total of 7 cookstove manufacturers/importers were interviewed (see annex A1.5 for full list). The interviews captured details of the different distribution channels, quantities sold through the different channels, business models, success factors, challenges and barriers in the sector and opportunities for investments.

2.3.2 Fuel-producers/manufacturers Surveys

The aim of this survey was to give a snapshot of the supply chain of the different formal fuel categories in Kenya. As with that of the formal cookstoves, a similar sample methodology using the same suppliers and drawn from the same resources: online searches, literature review and discussion with sector partners, was used. A total of 7 interviews were conducted. This approach was not matched to the charcoal, firewood and kerosene value chains as they are disjointed and predominantly informal. For these fuels, we leveraged on the literature available and identified the last mile distributors from the household surveys. Various characteristics of these informal fuels were captured in the demand side survey. Existing literature was also reviewed to assess the sources of cooking based on solar PV and grid-based electricity applications.

2.3.3 Informal cookstove manufacturers surveys

The purpose of this survey was to understand the informal sector's attitude and perception of quality and standardisation, reasons for maintaining an informal identity, and to provide a snapshot of the cookstove value chain. A total of 17 interviews with key informants were conducted across the four production regions/hubs in the country as shown in the Table 4. These included interviews with firewood liner producers (4), charcoal liner producers (4), cladders (3), installers (3) and other fabricators (3). Information on the cost and types of informal stoves and fuels was collected through the demand side assessment.

Table 4: Summary of informal cookstove manufacturers interviews conducted

Regional Hub	Business Name	County	Category	Products
Western	Ebwariro Ceramic Project	Kakamega	Liners/Installer	Jiko Kisasa
	Valonji Women Group	Kakamega	Liners/Installer	Jiko Kisasa
	Munasio Youth Pottery	Kakamega	Liners	Jiko Kisasa
	Watokambali	Kakamega	Liners/Installers	Jiko kisasa
	Kaveye Women Group	Vihiga	Liners/Cladding	Jiko Kisasa, Rocket stoves, KCJ
Lake Victoria	Bowaya Women Group	Kisumu	Liners/Installer	Rocket, Upesi
	Koitama Women Group	Bomet	Liners/Installer	Jiko Kisasa, Institutional stoves, Rocket
	Thokyombi	Siaya	Liners/Cladding	Rocket, Kisasa, KCJ, Uhai
	Nyalore Impact	Homabay	Other	Jiko Smart
	Keyo Women Group	Kisumu	Liners/Cladding	Uhai, KCJ, Kisasa, Rocket, Two in One Kisasa
Eastern and Central				
	East Kyemundu	Makueni	Liners/Installer	Rocket, Kisasa
	Bruce Mukuru	Muranga	Liners/Cladding	KCJ, Rocket, Institutional
	SOS Production Center	Muranga	Liners/Cladding	KCJ, Multipurpose Jiko, Kisasa, Jiko Smart, and Rocket
	Burners PET Energy Saving Stoves Limited	Muranga	Liners/Cladding	Institutional, KCJ, Multipurpose

Regional Hub	Business Name	County	Category	Products
	Cinda Juakali Center	Muranga	Liners/Cladding	KCJ, Multipurpose Stove, Jiko Kisasa
Nairobi	Kamukunji Fabricators	Nairobi	Fabricators	KCJ, metallic stove
	Gikomba	Nairobi	Fabricator	KCJ

To gather perspectives on the different dynamics that exist within the production hubs including leadership, financing, quality management processes and acquisition of skills, Kamukunji hub was identified as a suitable case study. Since most of the hubs are quite similar and face typical challenges, and based on discussions with stakeholders, Kamukunji hub – the largest in the country – was found to provide information and insights that would be largely representative of the experiences in the other hubs across the country.

2.4 Key Informants Interviews (KIIs) and case studies

Semi-structured questionnaires were used to adequately capture the views of individuals with relevant experience in improved cooking interventions in the cooking sector. The key informants were drawn from the various sector stakeholder groups including government officials, development agencies, research institutions and formal financing institutions in the cooking sector, cookstove programme coordinators and managers, NGOs and CBOs. The list of key informants is included in the Annex A1.5.

Six case studies have been highlighted in the report covering a range of subjects in the cooking sector. These have been used to provide specific details, insights, examples or emphasize key issues building on findings from the fields and from literature review.

3. COOKING: A CONCEPTUAL FRAMEWORK

3.1 Classes of Cooking Solutions

This section provides an overview of various classes of cooking solutions as an introductory discourse. Cooking has predominantly been examined in a binary approach that considers cooking devices (stoves and appliances) on one hand and fuels (liquid, gaseous, solid and other including electricity and solar powered options) on the other. The brief provided here, which discusses cooking solutions from a complementary perspective, will be supplemented by technology-specific and fuel-specific discussions in chapter 4 and 5 respectively.

3.1.1 Fuelwood based solutions

The Three Stone Open Fire (TSOF) has historically been and remains the most commonly used fuelwood based cooking option. The TSOF, also known as the open-hearth, open-fire or three-stone hearth, has remained the most common form of cooking technology for decades and continues to defy efforts to displace it as the centre of cooking especially in rural areas. As of 2018, about 59.4% of households in Kenya use the TSOF compared to 76% in 1998[17] and although the proportion of household users has dropped, the aggregate number has increased from 4.7 million households to about 7.3 million households[18] due to the overall population growth. Several efforts have been introduced to displace or reduce the use of TSOF. Upesi Jiko is one of the earliest improved wood stove technologies introduced to Kenya. Also referred to as *Maendeleo Jiko or Jiko Kisasa,* this technology was introduced in the country by the Intermediate Technology Development Group (now Practical Action) in collaboration with the Ministry of Energy and Agriculture and GIZ in 1995. Its main goal was to improve the fuel efficiency of the wood stoves and consequently reduce the amount of firewood used. It was piloted in the western region of the country and was produced by women groups involved in pottery[19]. The earliest group was Keyo Women Group, which has evolved over the years to become Keyo Pottery Group and now works closely with GIZ EnDev Kenya Programme. While the original stove would be installed and remained fixed, portable forms of the stoves are now available through cladding. The Kuni Mbili stove is one such potable form which bears the characteristics of both the Kenya Ceramic Jiko and the Upesi Jiko. In addition to the Upesi/Maendeleo woodstoves, there are Rocket stoves that can be built from either mud or brick.

Figure 6: Basic improved firewood stoves

[17]Nyang, F. (1999). *Household Energy Demand and Environmental Management in Kenya.* University of Amsterdam.
[18]Republic of Kenya. (1999). *Kenya 1999 Population and Housing Census.* Nairobi: Central Bureau of Statistics.
[19]Njenga, B.K. (n.d.). Upesi Rural Stoves Project-Kenya. Retrieved from http://www.bioenergylists.org/stovesdoc/Kenya/05_Kenya.pdf

Between 2013-2015, efforts were made to come up with cookstoves of superior quality in terms of fuel efficiency and emissions. Working with 12 enterprises across the country and using Upesi Jiko and KCJ as the base cookstoves, the Jiko Smart cookstove was designed and launched into the market. This was made possible through the Spark Fund managed by GVEP International (now Energy for Impact) under the project improving the *performance of locally manufactured biomass cookstoves in Kenya.* Jiko Smart is currently available in the market for both charcoal and wood[20].

Figure 7: Locally manufactured Jiko Smart

Since then, advanced technologies have emerged including the gasifiers sold by WISDOM Energy Hub and SCODE and the portable woodstoves manufactured by various players including Burn, EcoZoom and Envirofit among others. are imported. WISDOM Energy Hub and SCODE gasifiers are produced locally and can combust both wood and pellets. Mimi Moto gasifier stoves (currently being tested on a pilot basis in Kiambu county) are an imported brand.

In addition to woodstoves, there is a growing interest in the use of pellets as a more sustainable biomass option for cooking. This has spurred local manufacturing of pellets. Currently, only WISDOM and the SCODE gasifiers are produced locally and can burn both wood and pellets while other pellet stoves such as Mimi Moto (being piloted in Kiambu)

This study found that 71% of households in Kenya still use a type of woodstove as their primary or secondary cookstove with a greater prevalence in rural areas at 92%. About 7.3 million households use the TSOF, 1.4 million use fixed biomass stoves (including the rocket, Jiko kisasa, Upesi and Maendeleo stoves), 260,000 use Kuni Mbili and 53,000 use branded wood

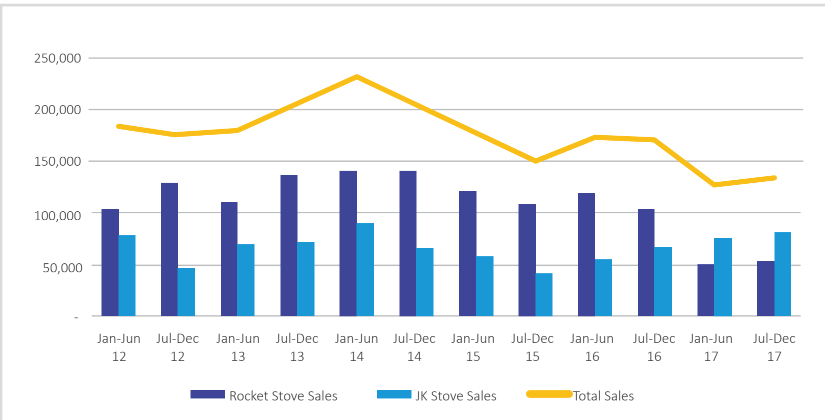

Figure 8: Total Rocket Stoves and Jiko Kisasa sold between Jan 2012 and Dec 2017

[20] GVEP International. (2015). *Improving the performance of locally manufactured biomass cook stoves in Kenya.* Retrieved from https://cleancookstoves.org/binary-data/RESOURCE/file/000/000/437-1.pdf

stoves. Based on data from the GIZ/EnDev Kenya programme, an estimated 2.1 million Jiko kisasa / maendeleo jiko and rocket stoves were reported as sold between Jan 2012 and Dec 2017 [cite the source]. (See Figure 8 for the trends over the years).

The firewood supply chain is not as elaborate as those of other fuels such as kerosene, charcoal and LPG. This can be explained, in part, by the fact that most households using firewood collect rather than purchase firewood for domestic use and are in rural areas. Figure 9 shows a summarized firewood (purchased) supply chain highlighting the channels by which the fuel is sourced and distributed. Collected firewood being non-commercial is typically obtained from the source by the end-user.

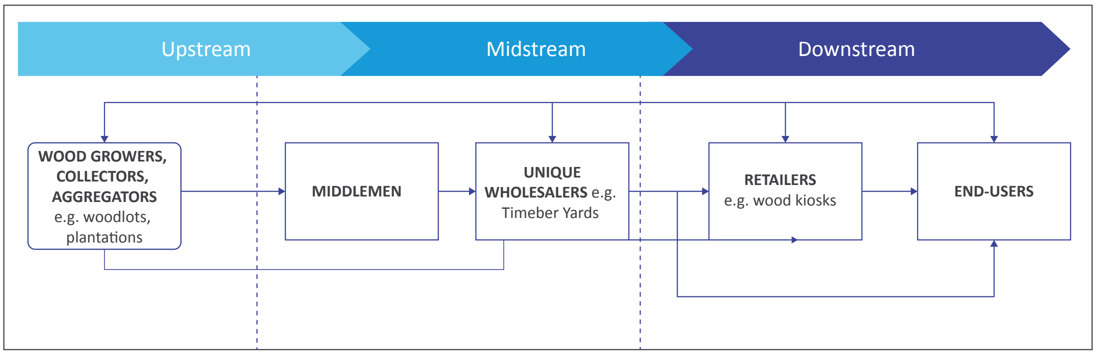

Figure 9: Summary of purchased firewood supply chain

3.1.2 Charcoal

This study divides the charcoal stoves into three main groups, which include the improved artisanal charcoal stove (KCJ, jiko smart and jiko upesi)[21], metallic (traditional) charcoal stove and the branded charcoal stoves (including Jikokoa, Jiko Bora, Jiko Fresh, SuperSaver Charcoal, SmartSaver Charcoal and others). The metallic charcoal stove was introduced to East Africa in the 19th century by Indian railway construction workers[22]. Research conducted in the 1970s and 1980s on methods of improving the efficiency of the then prominent cooking technologies (open fire and the metallic charcoal stoves) led to the introduction of the Kenya Ceramic Jiko (KCJ)[23]. The Kenya Energy and Environment Organisation (KENGO), development agencies and NGOs such as GTZ, USAID, UNICEF, CARE and Bellerive Foundation played an important role in creating awareness and promoting the adoption of stoves in the 1980s. Up until the early 2010s, manufacturing of these stoves in Kenya was mostly done through artisanal production. Between 2011 and 2014, companies manufacturing and importing branded stoves started to emerge. These include Wisdom Energy Hub, BURN, EcoZoom and Envirofit. The Result Based Financing (RBF) programme, *"Clean Cookstove Market Acceleration Project"* implemented by SNV sought to promote the uptake of improved charcoal stoves in Kenya. The suite of stoves promoted under the project include BURN Jikokoa charcoal stove, Envirofit super saver charcoal stove and EcoZoom Mama Yao. The RBF Programme is discussed in more detail later in the report.

This study finds that the KCJ is still the most prominent charcoal stove in Kenya with an estimated 4.2 million households (33.8%) reporting owning at least one.

[21]See the discussion of jiko smart and jiko upesi in section 3.1.1

[22] Westhoff, B. & Germann, D. (1995). *Stove images: A documentation of improved and traditional stoves in Africa, Asia And Latin America.* Retrieved from https://energypedia.info/images/6/69/Stove_Images.pdf

[23] Kammen, D.M. (2006). *In-Depth Solution Coverage - the Kenya Ceramic Jiko and other Improved Biomass Stoves in Africa.* Retrieved from http://www.solutions-site.org/docs/2_60/2_60.htm

This compared to 1.2 million households (9.7%) who report owning a metallic charcoal stove and about 386,000 households (3.1%) reporting ownership of a type of branded charcoal stove. The study also finds that 10.3% of households in Kenya use a charcoal cookstove as their primary cookstove. This may be comparable to the sum of households using charcoal stoves as their primary stoves reported by KIHBS 2015/16 as 9.1%. The high adoption rate for the KCJ is attributed to, among other factors, affordability, higher efficiency, availability and decentralized production making it ubiquitous across the country. Approximately 5.5 million households own at least a one charcoal stove with 1.3 million report using charcoal as their primary fuel. Mean annual national consumption is estimated as 395.2 kg/household. This is a much lower consumption estimate compared to the Kamfor study and can be attributed to, among

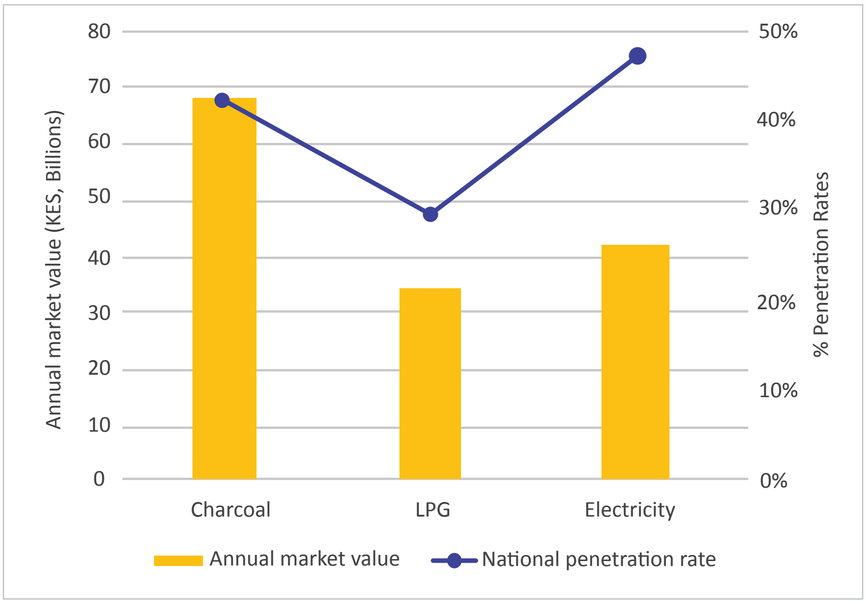

Figure 10: Market of charcoal used by households relative to LPG and electricity

other factors, the increase in use of LPG which was reported at 9% by Kamfor in 2001 compared to 29.7% by this study. Based on weekly monetary spend on charcoal reported by the respondents, this study estimates that the market value of charcoal consumed at the domestic level alone was KES 68 billion in 2017 - 2018. To provide a comparable context, this is two times the amount spent on LPG (as reported by the respondents) and almost 40% more than what all customers on the domestic tariff pay to Kenya Power in 2018 for their total electricity consumption[24] as shown in Figure 10.

With the enactment of the Charcoal Regulations of 2012, charcoal producers are required to operate through registered Charcoal Producer Associations (CPA). Data obtained from the Kenya Forestry Research Institute (KEFRI) shows that there are at least 48 CPAs spread across 8 counties including Kwale, Taita Taveta, Kitui, Narok, Tana River, Garissa, Baringo and Samburu (see Figure 11). Tana River County has 14 CPAs; the highest number per county. Further information on charcoal production in Kenya can be obtained from the study on sustainable charcoal economics policy and investment in East Africa commissioned by The Nature Conservancy (TNC) in 2018. Similarly, CCAK commissioned a related cooking sector study focussing on institutions. Figure 12 summarizes the main channel through which households obtain charcoal.

[24] Kenya Power and Lighting Company. (2018). Annual report and financial statements for the year ended 30th June 2018. Retrieved from https://www.kplc.co.ke/AR2018/KPLC%20Annual%20Report%2017_12_2018_Wed.pdf

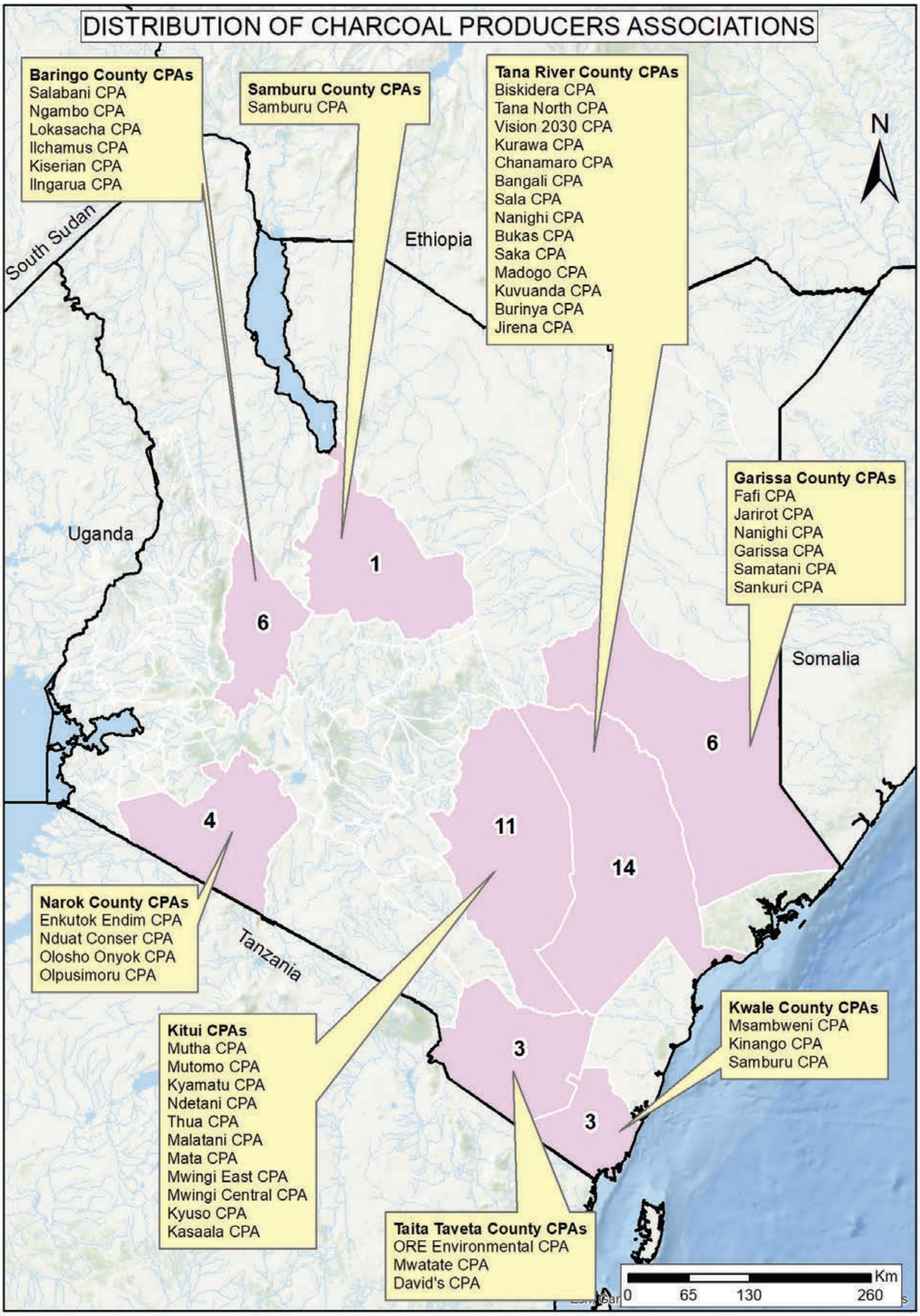

Figure 11: Number of CPA

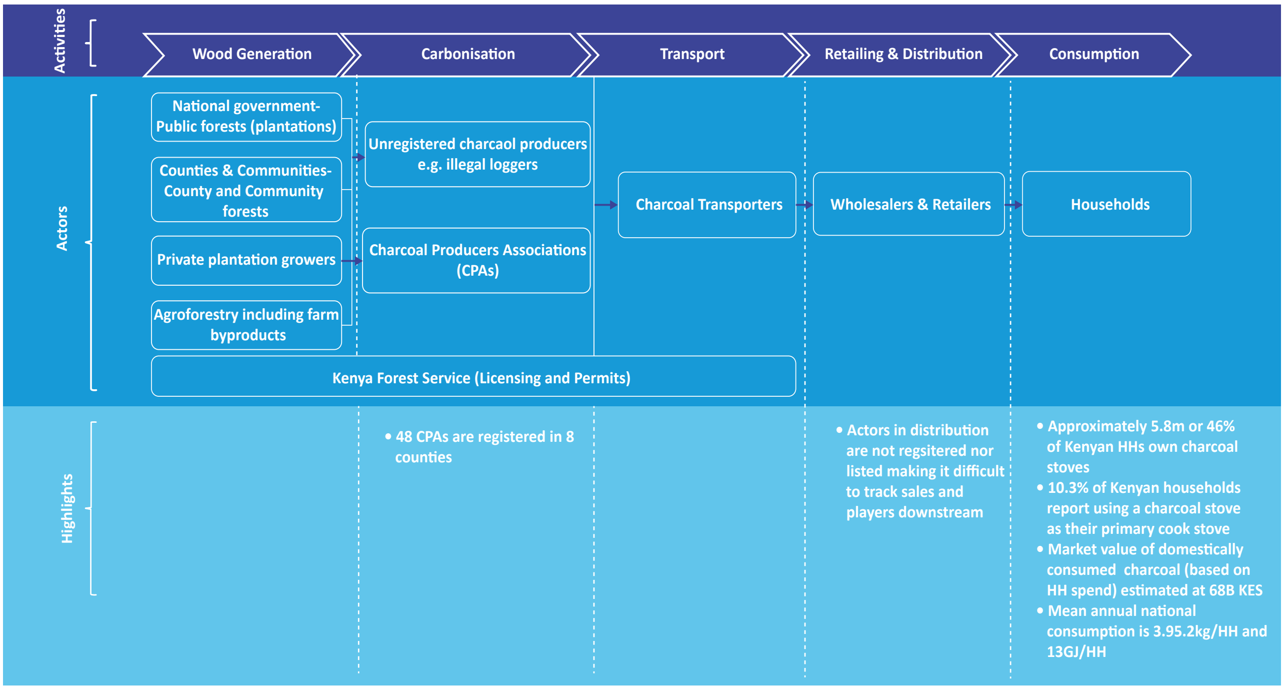

Figure 12: Domestic consumption charcoal supply chain

3.1.3 Briquettes

Briquettes have been promoted as a fuel that can potentially displace or reduce the use of unsustainable charcoal. FAO reports that the first initial promotion of briquettes in Africa started in the 1970s with briquetting machines known as Haussmann presses sold in Niger and Gambia for groundnut shells processing, later spreading to East Africa in the 1980s[25]. The term "briquette" is used to define a wide family of cooking fuels that vary in terms of processing, raw materials, shape, size, energy density and price. There are two main sub-types of briquettes (carbonized and non-carbonized). Carbonized briquettes are made from biomass raw material that has undergone pyrolysis after which it is mixed with a binding element, moulded into various shapes then dried. Non-carbonized briquettes are processed directly from biomass sources through various casting and pressing processes also known as compaction or solidification. The briquetting process can be summarized as show in Figure 13 (illustration adopted with modifications from Camco, 2012 [26]).

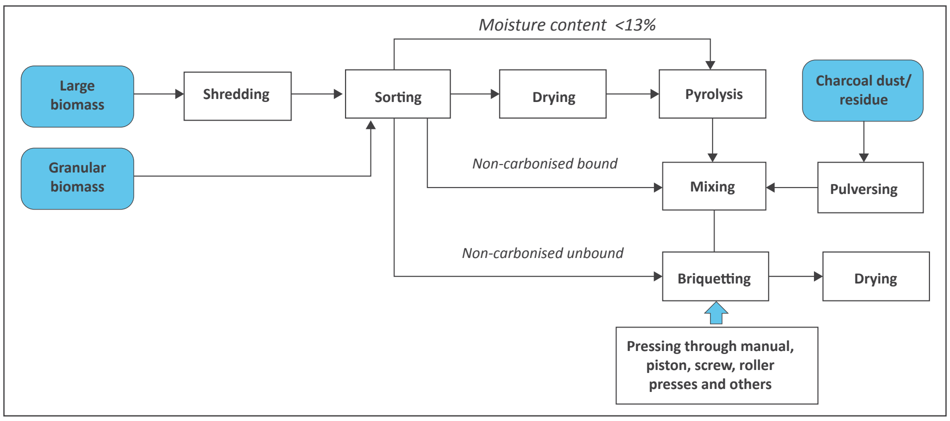

Figure 13: Summary of the briquetting process

[25] FAO. (1990). *The briquetting of agricultural waste for fuel.* Rome: Food and Agriculture Organisation of the United Nations; Environment and Energy Series.
[26] Camco. (2012). *Analysing briquette markets in Tanzania, Kenya and Uganda.* Gauteng, South Africa: Energy and Environment Partnership

Briquettes in Kenya are produced by sole entrepreneurs, limited companies, Community Based Organisations (CBO) and Faith Based Organisations (FBO). There are at least ten companies and small enterprises involved in the production of briquettes in Kenya. Some of the companies include Char dust, Global Supply Solution, Acacia Innovations, BrightGreen Renewable Energy and Tamua among others with most of them having started operations in the last three years. It is difficult to estimate the total number of manufacturers as many are informal and/or itinerant and produce limited quantities often adjacent to charcoal collection depots. A study by GVEP International (present day Energy for Impact) in 2013 interviewed at least 70 briquette entrepreneurs (those who were active, had intentions of joining the sector or have ever been part of producing briquettes)[27]. Several initiatives with the aim of creating awareness and promoting the use of briquettes in Kenya have been implemented with some still ongoing. The briquette commercialisation project by Practical Action, the Capital Access for Renewable Energy Enterprises (CARE2) project; the SNV project on improved charcoaling technologies and briquetting using agricultural waste; fuel from waste network by Middlesex University, Kenyatta University and Terra Nuov are examples of such initiatives. These initiatives target briquette entrepreneurs and train them on briquettes making (technical skills) and on business processes such as book keeping and marketing. The government, through the Ministry of Energy, has also set up energy centres to promote the uptake of sustainable energy in Kenya with briquettes being one such option. Recently, Hivos in partnership with the Greening Kenya Initiative Trust (GKIT) set up the National Biomass Briquettes Programme (NBBP), which aims to develop the briquette sector in Kenya[28] between 2018 and 2022. The programme, valued at an estimated USD 10 million, has set up a briquetting pilot in Nairobi whose lessons will be used to inform the implementation of the national programme. The main activities within the programme will include developing the supply chain and developing standards for both industrial and domestic briquettes. Perennial barriers still hinder the uptake of briquettes as a mainstream cooking solution within households. Key among these is the relative high cost of briquettes, constrained feedstock supply, disjointed or non-existent supply and distribution networks, and competition from alternative sources of cooking fuels.

Most formal briquettes manufacturers use supermarkets or direct sales as their main channel of distributing their products to households. Figure 14 gives a summary of the briquette supply chain for domestic consumption. Less than 1% of households reported using briquettes as part of their cooking mix over the last year at the time of the interview.

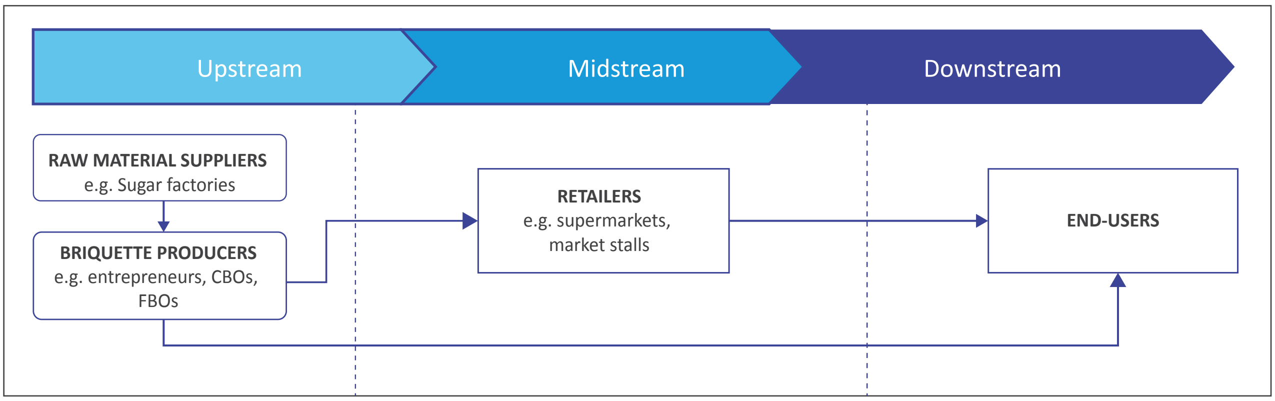

Figure 14: Summary of briquettes supply chain

[27]GVEP International. (2013). *Assessment of the Briquette: Market in Kenya*. Retrieved from https://www.energy4impact.org/file/1712/download?token=T4J_JRTl
[28]Hivos. n.d. National Biomass Briquettes Program. Retrieved from https://www.hivos.org/program/national-biomass-briquettes-program/

3.1.4 Pellets

Pellets, like briquettes, are not a new type fuel in Kenya's energy market although its use at the domestic level remains limited. Only 0.1% of households reported using briquettes as part of their cooking mix over the last year at the time of the interview. Two pilot studies were undertaken by SNV and EcoZoom to promote pellets as a cooking fuel. The SNV pilot, carried out between 2014 – 2015, aimed at increasing access and use of pellet stoves in urban and peri-urban markets. Pellets were tested on both locally manufactured gasifier stoves from WISDOM and SCODE and on imported ones like Philips and TERI. A key challenge observed in adoption of pellets was the high upfront cost of the stoves. To address this, SNV worked with three microfinance institutions and set up a result-based financing scheme for the micro lenders. At the end of the programme, about 1,500 households had bought the pellet stoves against a target of 2,500[29]. Similarly, the EcoZoom pilot study, conducted in 2015 in collaboration with The Alliance, tested the viability of pellet distribution models in Siaya and Kisumu Counties. The pilot, which sold pellets through community volunteer networks and neighbourhood deliveries, faced significant sustainability challenges and was eventually discontinued[30]. Pellets production in Kenya is still in its nascent stages and the pellets used in both the SNV and Ecozoon studies were imported. Other ongoing initiatives include; Lean Energy Solutions with support from SIDA setting up a pellet production facility in Naivasha; Green Steps Africa Limited supplying gasifier stoves for domestic and commercial use; Power Spot producing pellets and distributing gasifiers in Kakamega County while IKO BRIQ Limited and Eco-bora manufacturing and selling pellets to households.

3.1.5 LPG solutions

Liquified Petroleum Gas (LPG) constitutes of flammable hydrocarbons including propane and butane and is a product of oil refining and natural gas extraction. Liquified by pressurisation, LPG may be used for cooking, lighting and as auto-fuel. The Energy (Liquified Petroleum Gas) regulations of 2009 standardized the 1kg, 3kg, 6kg and 13kg LPG cylinders and their respective valves, sizes typically used at the household level. Review of various LPG distributors' websites indicates that cylinders are available in additional capacities including 35kgs by K-gas, 22.5kgs and 50kgs by Total, and 25kgs and 50kgs by Gulf Energy. The 1kg, 3kg and 6kg cylinders are used together with a cooking grill, a burner and

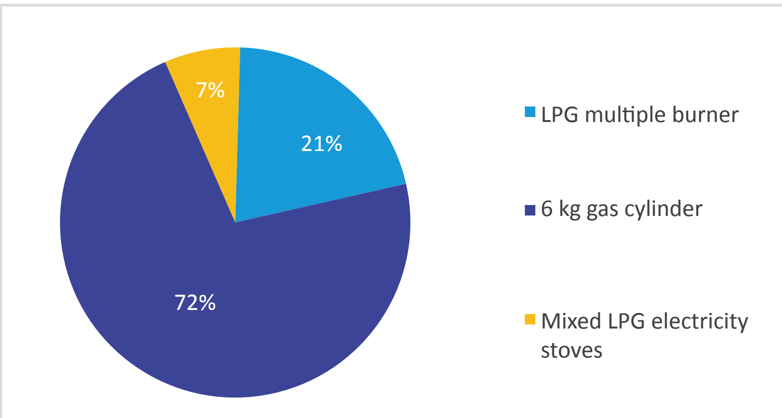

Figure 15: Distribution of types of LPG devices

[29] Bailis, R. and Wanjiru, H. (2015). *Mapping Pellet Stove Use in Kenya, Stockholm Environment Institute and Climate and Clean Air Coalition.* Retrieved from http:// www.ccacoalition.org/en/resources/mapping-pellet-stove-use-kenya

[30] GACC. (2016). *Pilot Innovation Fund for Clean Cooking Enterprises: Synthesis of Lessons Learned.* Retrieved from https://www.cleancookingalliance.org/binary-data/RESOURCE/file/000/000/507-1.pdf

a regulator to form a complete cooking solution. The cylinders may also be attached to a separate LPG stove or dual LPG and electricity stove. As seen in Figure 15, this study finds the 6kg complete LPG cylinder is the most commonly used LPG cooking solution with 72% of 3.7 million households that have an LPG based cooking solution reporting owning at least one.

Kenya has a well-defined LPG distribution supply chain regulated and licensed by EPRA. EPRA provides for various kinds of licenses including: import, export and wholesale of LPG in bulk; transport of LPG in bulk; wholesale of LPG in bulk; and wholesale of LPG in cylinders. As at January 2019, EPRA had issued licenses to 33 importers, 41 storage facility operators, 91 transporters and 46 export and wholesale dealers. The LPG and kerosene supply chain is summarized in Figure 16. As seen, both have common upstream players, but this diverges at the midstream and downstream levels.

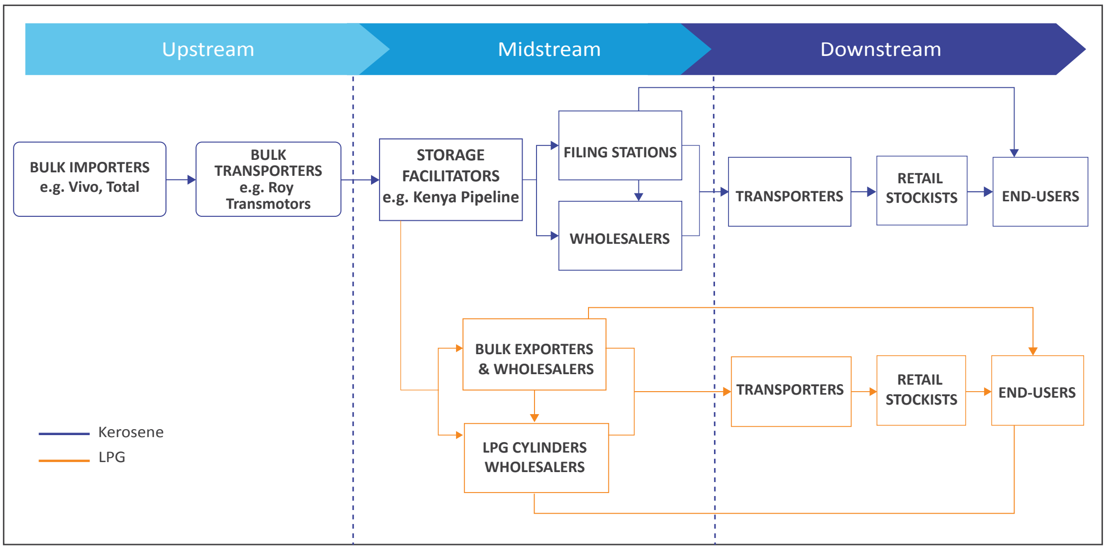

Figure 16: Summary of LPG and kerosene supply chains

3.1.6 Kerosene based solutions

Kerosene, also known as paraffin, is a product obtained from fractional distillation of petroleum and used globally for cooking, space heating, transportation (particularly aviation) and lighting. At the household level, kerosene remains an important fuel source for space heating in parts of Western Europe and North America[31, 32] but is typically used as a lighting or cooking fuel option in developing countries - especially in low-income households. The devices associated with kerosene use for lighting and cooking, but not necessarily the fuel itself, makes its use undesirable in many developing countries contexts due to the associated negative impacts[33]. However, there is limited understanding of the impacts of improved forms of use including pressurisation which allow burning in a cleaner way. Several factors have contributed to the continued use of kerosene among the urban segment. The most important is affordability of the technology and the fuel relative to other alternatives. The cost of kerosene-based cooking (technology and fuel) has remained low as compared to other fuels such as LPG, electricity, ethanol among others. Kerosene is also easily divisible and is sold in small quantities

[31] US Energy Information Administration (2019). Fuel oil and kerosene sales 2017

[32] US Energy Information Administration, Department of Energy, Washington & UPEI (2016) Oil heating: An efficient option for consumers, Brussels

[33] Lam N.L., Smith K.R., Gauthier A., and Bates M., (2012) Kerosene: A review of household uses and the hazards in low- and middle-income countries, Toxicol Environ Health B Crit Rev. 2012; 15(6): 396–432. doi:10.1080/10937404.2012.710134

making it useable for many households. It also has one of the most elaborate and extensive distribution networks in the country with an estimated 1500 kerosene dispensing units in Nairobi alone, for example, meaning that households travel shorter distances to acquire this fuel compared to others[34].

There are two main types of kerosene stoves used in Kenya; the wick and the pressurized kerosene stove. The wick stoves are the more prevalent of the two. This study finds that the average retail price of the wick stove is KES 503 and KES 675 in urban and rural areas respectively. The low cost of the wick stoves coupled with the well-developed distribution channels and the divisibility of the fuel make kerosene -based cooking solutions a convenient option for most end-users. Wick stove brands in the market include; Miyota wick stove, Uken wick stove, Big Wheel, Jumbo and Deluxe kerosene stoves. The study found that the Big Wheel kerosene stoves available in different models are the most common among the end-users. Cook `N' Lite is a company in Kenya that manufactures and exports the Jumbo and Deluxe kerosene stoves. Most of the other brands are imported from China or India.

Pressurized kerosene stoves, which are a lot less common (0.1% ownership), consist of a kerosene tank, a vaporizer and potholder. The vaporizer is pre-heated using an alcohol-based fuel that vaporizes the kerosene forcing it to pass through the nozzle and mix with air to produce a flame. Although the stove is more efficient than the wick stove and its thermal efficiency of 53% is comparable to that of LPG, which is 57%[35], the penetration rate is low. This may be due to the following reasons[36]: (i) high upfront cost of the device, (ii) the lighting process is tedious and has to follow an elaborate procedure which if not followed may cause explosions in the household, (iii) controlling the flame can also be problematic if proper training is not carried out, (iv) the vertically elongated design of the stove makes it unstable to use, (v) presence of impurities, which is common with kerosene adulteration, causes frequent blocking of the nozzle, and (vi) in addition to the kerosene, one requires an alcohol based liquid to burn the vaporizer to initiate the lighting process of the stove. In Kenya, Gundua Engineering Service manufactures the Parameko kerosene pressurized stoves. The company started its operations in 2012 and produces small size (3.5 litres) and medium size (10 litres) single burner stoves. In addition to the challenges outlined above, the initial cost of the stove is high with the price of the small size stove ranging between KES 3,000- 4,500 and the medium size retailing at KES 5,000.

This cooking solution, in its current form with dominant reliance on the wick stove, remains toxic, emits huge doses of carbon dioxide and is a great contributor to household air pollution. Additionally, it has an odour that tends to linger in the cooking area even after the stoves have been turned off[37]. The government, through the Ministry of Environment, has made attempts to eliminate the use of kerosene as a cooking fuel in Kenya. One of the campaigns launched in the country was the *Kerosene Free Kenya*[38] targeted at reducing the greenhouse gas emissions while improving the health of Kenyans.

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[34]Dalberg. (2018). Scaling up clean cooking in urban Kenya with LPG & Bio-ethanol, Market Policy Analysis. Retrieved from https://southsouthnorth.org/wp-content/uploads/2018/11/Scaling-up-clean-cooking-in-urban-Kenya-with-LPG-and-Bio-ethanol.pdf

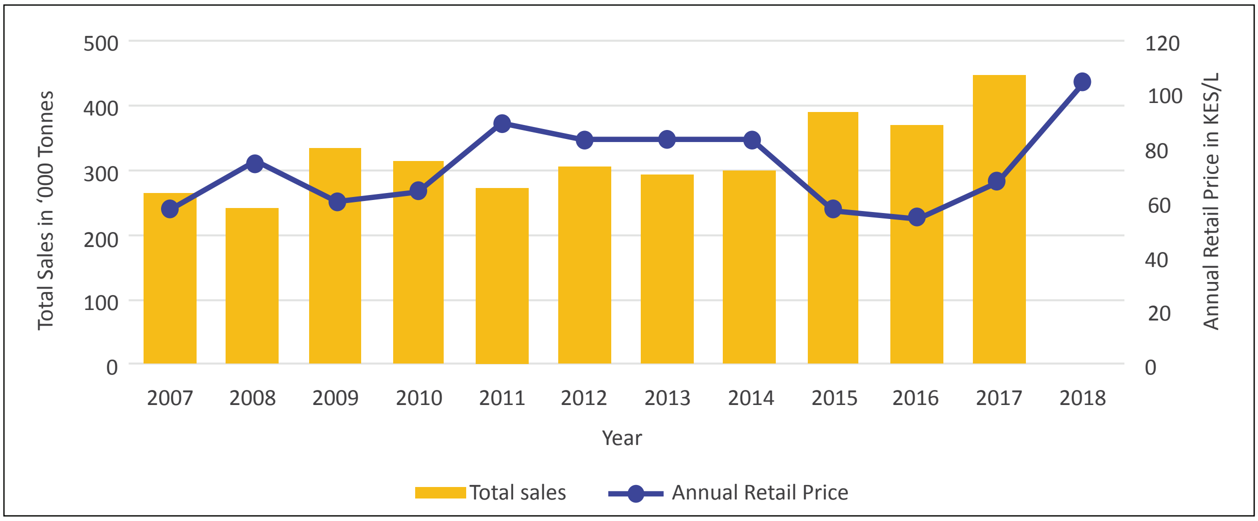
[35]Practical Action (2008). A technical brief on biomass as solid fuel. Retrieved from file:///C:/Users/Welcome/Downloads/53f3322f-5a30-408c-a92c-2a320a000075.pdf

[36]Floor, W. and Plas, R., V. (1991). Kerosene Stoves: Their performance, use and constraints. Retrieved from http://documents.worldbank.org/curated/en/529861468739217467/pdf/multi-page.pdf

[37] Dalberg. (2013). *Global LPG Partnership-Kenya Market Assessment.* Retrieved from https://cleancookstoves.org/binary-data/RESOURCE/file/000/000/234-1.pdf

[38] Lighting Africa. (2012). *Kerosene-free Kenya: Rio +20 agreement to increase access to clean energy.* Retrieved from https://www.lightingafrica.org/kerosene-free-kenya-rio-20-agreement-to-increase-access-to-clean-energy/

Other initiatives include the launch of the bioenergy and LPG strategy[39] that aims to increase the uptake of LPG for cooking among households. This was built upon the draft National Energy and Petroleum Policy 2015, which categorically states that the government will increase the adoption of LPG as a way of eliminating kerosene and reducing the use of traditional biomass for cooking in the country. Drastic shifts came with the Financial Act 2018, which saw an 8% VAT, a levy of 18 KES/litre, and excise duty at the rate of KES 10.31/litre applied on kerosene. The levy and the exercise duty, which in part were introduced to address the use of kerosene for adulteration of diesel, increased the price of kerosene which impacted its demand and use. Total sale of kerosene (for all uses) rose to 448,000 tonnes in 2017 as shown in Figure 17.



Source: KNBS Statistical Abstract 2017 and EPRA 2018

Figure 17: Total sales and Annual Retail Price of Kerosene over the past 10 years

This study finds that 1.7 million (14% of the total population) households in Kenya use kerosene for cooking. The numbers vary greatly between the rural and urban segment with 27.7% of the urban population using kerosene for cooking compared to 3.2% in rural areas.

3.1.7 Biogas solutions

The first biogas system in Kenya is reported to have been installed in 1957 by Tim Hutchinson, a coffee farmer, for domestic uses[40]. Observing that the bio-slurry recovered from the process played an important role in improving yields in his coffee farm, Hutchinson started the Tunnel Engineering Limited Company whose focus was installing biogas systems for bio-slurry production and with biogas as a by-product for household energy needs. The company installed 130 small biogas systems and 30 large biogas systems between 1960 and 1986[41]. Subsequent installations have been through various initiatives including a seminal programme by the Germany Development Organisation (GTZ now GIZ) and the Ministry of Energy implemented between 1987 and 1992 that led to the construction of 800 biogas systems largely in Meru county[42]and the Kenya Biogas Programme.

[39] Ministry of Energy and Petroleum. (2015). *Draft strategy and action plan for bioenergy and lpg development in Kenya*. Retrieved from https://kepsa.or.ke/download/draft-strategy-and-action-plan-for-bioenergy-and-lpg-development-in-kenya/?wpdmdl=12841

[40] Biogas for a Better Life Initiative (2007). Promoting biogas systems in Kenya: a feasibility study. Retrieved from http://kerea.org/wp-content/uploads/2012/12/Promoting-Biogas-Systems-in-Kenya_A-feasibility-study.pdf

[41] Mwirigi, K.E., Gathu, K. & Muriuki, S. (2018). Key Factors Influencing Adoption of Biogas Technology in Meru County, Kenya. IOSR Journal of Environmental Science, Toxicology and Food Technology,12(3),57-67. DOI: 10.9790/2402-1203015767

[42] GTZ-SEP. (1987). Dissemination of Biogas in Rural Areas of Kenya. Nairobi: German Technical Cooperation.

In 2009, the Kenya Biogas Programme (KBP) was started with the aim of commercially promoting the uptake of biogas at the household level. This initiative is part of the African Biogas Partnership Programme (ABPP) being implemented across five countries (Kenya, Tanzania, Uganda, Ethiopia and Burkina Faso). The programme is a public-private partnership between the SNV Netherlands Development Organisation, the Directorate General for International Co-operations of the Netherlands Ministry of foreign Affairs and Hivos. Kenya Biogas Programme (KBP) is the implementing agent in Kenya, SNV provides technical assistance and Hivos is the fund manager. The programme targets farmers in rural areas and employs the Biogas Marketing Hub Approach (BMH) to reach their target market. The model (summarized in Figure 18) targets formally organized groups such as SACCOS, MFIs (Micro Finance Institutions) and cooperative societies as their last mile marketing. Activities carried out in these groups (known as marketing hubs) include creating awareness among members, sales, monitoring and verification of the systems, and training.

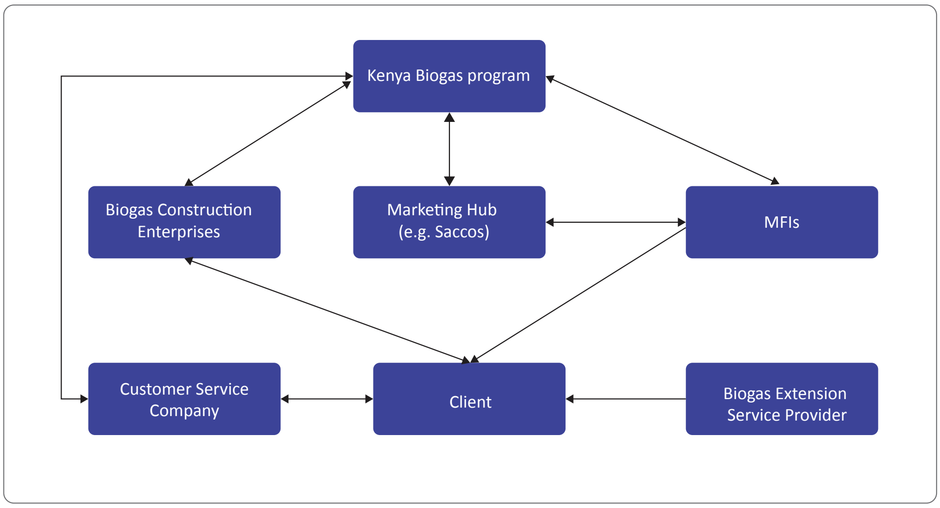


Figure 18: Summary of the Biogas Marketing Hub Approach

Discussions with KBP and SNV indicate that between 2009 and 2018, about 19,000 units were installed in the first phase (2009-2013) and initial part of the second phase (2015-ongoing). Discussions with KBP also revealed that there are at least 200 Biogas Construction Entrepreneurs (BCEs) in Kenya. The main biogas companies and include Sistema, Rehau, Biogas International, Taka Moto, Amiran, Kentainers (Blue Flame), and Sim Gas.

There are three main types of biogas technologies in Kenya; (i) the floating drum technology which consists of a digester and a moving gas holder (the drum) whose level rises with increasing volumes of biogas, (ii) fixed dome technology which has most of its components built underground with the gas piping, feedstock inlet and gas outlet being the only visible hardware, and (iii) plastic tubular digester consists of a plastic tube where the gas is generated and piped for use. There are several variations in the design of different systems, but most are classified under one of these categories. The sizes of the systems vary from small, medium and large depending on use.

Taken collectively, this study finds a reported (from literature and KIIs) estimate of 19,930 household systems installed since 1957; however, it remains unclear how many systems may have been installed but not reported. Factoring in systems that may have failed or have been abandoned with time, this number is comparable to the 17,900 installed systems estimated from the study's demand side survey.

Affordability is the main barrier to the uptake of biogas systems use in Kenya. The cost of installing a system ranges between KES 50,000 to 100,000 depending on the technology and the size of the system. Considering that the conventional target market is the rural subsistence farmer, then the cost of the systems becomes an important factor to consider when promoting the uptake of biogas technology in Kenya. Delivery models are based largely on upfront cash payment and credit terms although there are upcoming innovative solutions that have been tested in the market. Pay-as-you-go gas is one such solution tested by Takamoto gas. The other major limitation is the basic requirement of having a consistent supply of suitable biodegradable feedstock, which makes its use impractical in many urban low-income areas.

3.1.8 Electric solutions

Findings from this study indicate that only 3% of households own an electric cooking appliance such as dual LPG-electricity stove, electric induction stove, electric coil stove and microwave. This is largely attributed to the high cost of the cookstove (with the survey reporting an average retail price for the mixed-LPG stove at KES 28,920 and KES 39,250 for urban and rural users respectively) and the perceived high cost of electricity as a cooking option.

There have been various interventions promoting the use of electricity for cooking. In 2017, the Kenya Power started to promote the use of electric appliances such as induction cookers to increase electricity demand. A televised cooking programme dubbed *pika na power* which aired weekly on a local TV station aimed to create awareness and promote the use of induction cookers[43]. The cooker retails at KES 9,500 and could be bought at Kenya Powers outlets at Electricity House or the Stima Plaza in Nairobi. The Modern Energy Cooking Services (MECS), a five-year research programme (2018 – 2023) funded by DfID and led by Loughborough University, aims to promote the use of electricity and other modern fuels in Africa and South Asia. The programme will identify approaches that will rapidly accelerate a transition from traditional biomass among them being the promotion of Electric Pressure Cookers (EPC). EPCs are expected to be more efficient and safer compared to the ordinary pressure cookers due to their design, which includes an internal heat source and safety thermostats that regulate the cooking. The stove is also insulated so no burns can occur by touching the sides of the cooker. The target market for EPCs are households that have begun to adopt modern energy such as LPG but continue to rely on charcoal for their heavy meals. Three key adoption barriers are identified: people's perception of the cooker's safety, lack of awareness, and low availability of distribution points. The initial cost of the cooker is estimated at KES 7,000. If the cookstove is to be adopted in low-income areas, then instalment-based payment models would have to be developed to increase adoption.

3.1.9 Ethanol based solutions

Ethanol is produced from the fermentation of sugars from various crops, such as maize, sorghum, wheat, cassava and sugarcane. It is used for both domestic and industrial purposes. There are three major producers of ethanol in Kenya: Spectre International (30,000 m^3/year), Agro Chemicals and Food Corporation (18,000 m^3/year) and Mumias Sugar (16,000 m^3/year[44]. These however, mainly target the beverage market with about 20,000 m^3/year of the total production exported to Tanzania, Uganda and Democratic Republic of Congo[45]. As a fuel, past discussions on ethanol in the country have revolved around its use as a blend for petrol

[43] Kenya Power and Lighting Company. (2017). *Annual report and financial statements for the year ended 30 June 2017*. Retrieved from http://kplc.co.ke/img/full/GytMwKxeRgrt_KPLC%202016%20-%202017%20Annual%20Report%20Website.pdf

[44] AFRINOL. (n.d).*The Kenyan Market: Beverage Alcohol.* Retrieved from http://afrinol.com/the-kenyan-market/

[45] Ibid

in the transport sector[46]. In the recent past, ethanol is emerging as a fuel option complementary to LPG and with great potential to substitute or reduce the use of kerosene if key barriers are addressed. The fuel is currently available in liquid and gel form for cooking. Although there are several factors that contribute to the marginal use of ethanol for cooking, price, awareness, supply constraints and limited distribution channels are the most significant. Before the introduction of VAT on petroleum products, a litre of kerosene was retailing at KES 65-75 compared to a litre of ethanol at KES 85. The high cost of ethanol was attributed to 16% VAT and 25% import tariffs[47]. However, this is expected to change with the zero rating of tax on denatured ethanol in the 2019/2020 budget[48]. The importation of ethanol is driven by the fact that local production cannot meet the existing demand. It is estimated that only 1.8 million litres of viable technical bio-ethanol is produced in Kenya versus a potential demand of 120 million litres in Nairobi alone[49]. The other hindrance in the adoption of this fuel is the high cost of the cooking appliances. Some of the prominent promoters of ethanol in the market include KOKO Networks, Leocome, Prosol Limited and IR&D Africa Limited. The price of liquid ethanol stoves range between KES 3,000 and KES 7,000 depending on design and brand, while ethanol gel stoves start from KES 1,500 for a single burner.

Several pilot projects have been conducted in Kenya on ethanol production and use. In 2015, Project Gaia and Relief, Reconstruction, and Development Organization (RRDO) in partnership with United Nations High Commissioner for Refugees (UNHCR) launched a pilot study of Ethanol cookstoves in Daadab. 100 ethanol stoves were donated by CLEANCOOK Sweden AB while the ethanol was supplied by Mumias Sugar Company and Agro Chemical & Food Company Limited (ACFC). Project Gaia has distributed up to 300 ethanol cookstoves in Kenya.[50],[51]. In Kisumu, the Centre for Science and Technology in Africa is using the invasive water hyacinth to produce ethanol for cooking. Founded in 2016, the centre now supplies 560 households with ethanol for their domestic cooking at a retail price of KES 70[52].

About 0.2% of households in Kenya reported using ethanol at least once in the previous year before this survey as part of their cooking solutions. Innovative business and delivery models are being piloted by, among others, KOKO Networks. In their model termed the "Version 2.0 Smart Fuel ATM", KOKO Networks goes against the traditional approach of centrally bottled ethanol to distribution through vending machines called "KOKO points" where clients can refill their canisters based on their needs. They have also partnered with Vivo Energy to leverage the existing distribution networks and reduce the associated distribution costs.

3.1.10 Emerging Technologies

Other cooking solutions include solar cookers and heat retainers (fireless cookers). Solar cookers were first introduced in Kakuma refugee camp in 1995 under a pilot programme by Solar Cookers International[53]. The aim of the programme was to promote clean cooking while reducing the amounts and cost-burden of firewood used by the households. Ongoing initiatives in promoting solar cookers include the

[46] GTZ and Ministry of Agriculture. (2008). *A Road Map for Biofuels in Kenya*. Retrieved from http://kerea.org/wp-content/uploads/2012/12/A-Roadmap-for-Biofuels-in-Kenya_Opportunities-and-Obstacles.pdf

[47] Dalberg. (2018). *Scaling up clean cooking in urban Kenya with LPG & Bio-ethanol, Market Policy Analysis*. Retrieved from https://southsouthnorth.org/wp-content/uploads/2018/11/Scaling-up-clean-cooking-in-urban-Kenya-with-LPG-and-Bio-ethanol.pdf

[48] Deloitte. (2019). *Kenya Budget Highlights 2019/20*. Unravelling the Puzzle. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/ke/Documents/tax/Budget_highlights_KE_2019.pdf

[49] Ibid

[50] Project GAIA Energy Revolution. (n.d.) Retrieved from https://projectgaia.com/projects/refugees/https://projectgaia.com/projects/refugees/

[51] UNDP. (n.d). *Piloting Bioethanol as an Alternative cooking fuel in western Kenya*. Retrieved from http://www.ke.undp.org/content/kenya/en/home/operations/projects/environment_and_energy/bioethanol.html

[52] Rioba, B. (2018, December 19). *Investors Turn Kenya's Troublesome Invasive Water Hyacinth into Cheap Fuel*. Retrieved from http://www.ipsnews.net/2018/12/investors-turn-troublesome-invasive-water-hyacinth-cheap-fuel/

[53] Solar Cooker International. (n.d). Improved combustion stoves, Countries, Kenya, and 3 more. Retrieved from http://solarcooking.wikia.com/wiki/Kenya

project by *Farmers with a vision*, a community-based organisation based in Busia county that has actively engaged with schools, churches and communities teaching about solar cooking. It is reported that as of 2017, 1,500 households were already using solar cookers in the county[54]. Solar cooking is used marginally among households in Kenya mainly due to a mismatch in the cooking needs and the utility offered by the technology. Cooking is restricted by the availability of solar energy and therefore without energy storage options, its ability to displace other forms of energy is eroded. On-going research efforts, such as those being led by Gamos Ltd in collaboration with Loughborough University, are looking at the potential of developing solar electric cookers with the aim to promote this as a supplementary cooking option.

Heat retainers also known as fireless cookers or wonder baskets, though not considered a typical cooking technology, can contribute to cooking as they retain heat or preheat foods which translates to reduced demand for cooking fuels. Their ownership and use remain ultra-low among households in Kenya. Pilot projects have been done in various part of the country; examples include an initiative by the Kisumu Indoor Air Pollution Network (KIAPNET), which promoted the technology as a measure of conserving the environment through the reduction in demand for firewood. By 2013, it is reported that the group had sold over 1,000 fireless cookers[55]. Practical Action, Swedish Development Agency (SIDA), the Ministry of Agriculture and Arid Lands Information Network (ALIN) have been involved in the promotion of fireless cookers through various initiatives.

3.2 Technologies and Fuel Stacking

The data collected in this study about primary, secondary, and additional cooking options provides insight into the stove/fuel "stacking" phenomenon. Stacking describes the use of multiple devices and fuels to satisfy or optimize household energy needs.[56] It is common but is often overlooked reality of cooking and most surveys focus on the "primary" stove or fuel. Over the years, researchers have recognized that when households acquire new energy solutions,

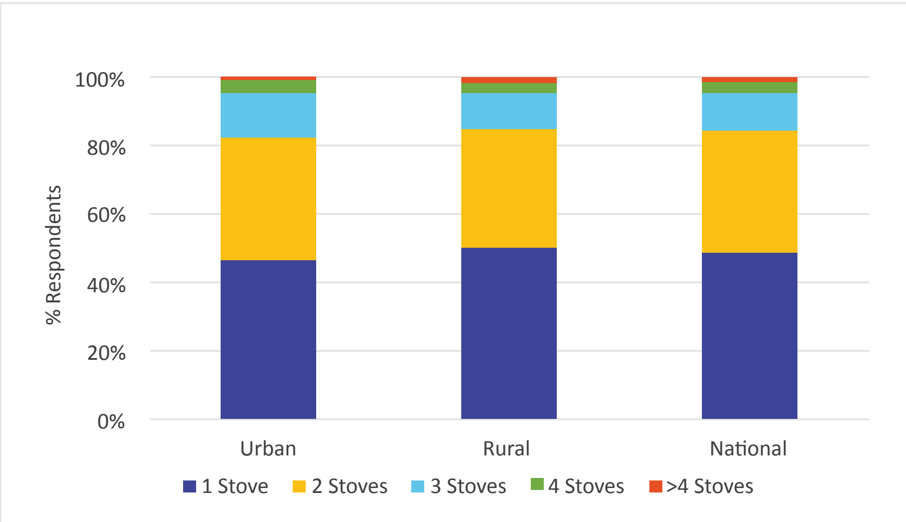


Figure 19: Number of stoves owned per household

[53] Solar Cooker International. (n.d). Improved combustion stoves, Countries, Kenya, and 3 more. Retrieved from http://solarcooking.wikia.com/wiki/Kenya
[54] Solar Cooker International. (2017). *Farmers with a Vision*. Retrieved from http://solarcooking.wikia.com/wiki/Farmers_With_A_Vision#News
[55] Business Daily, 21 July 2013 online edition, retrieved on 29th Jan 2019
[56] Masera, O., Bailis, R., Drigo, R., Ghilardi, A. and Ruiz-Mercado, I. (2015). Environmental Burden of Traditional Bioenergy Use. *Annual Review of Environment and Resources* 40(1): 121–150.

existing options are rarely displaced. Rather, it is more common to see new options incorporated into the cooking practices in combination with existing technologies.[57] This may involve using multiple technologies to prepare a single meal, using different devices to prepare different meals throughout the day, or other variations. It is therefore critical to understand penetration of technologies and fuels from a stacking perspective to accurately describe household cooking practices. For instance, the number of improved cookstoves in Kenya may be significantly higher than the Kenyan households using improved cookstoves due to stacking. As this survey demonstrates, stacking is widespread among Kenyan households with 51% of Kenyan households using more than one cooking device and one sixth using three or more devices (see Figure 19). About of the estimated 6.2 million households that use only one cooking solution rely solely on either charcoal or fuelwood.

With most Kenyan households using more than one form of cooking technology, it is critical to understand which ones are used most often and which serve a secondary or complementary role. To get this information, the survey asked detailed questions about the technology used most frequently by each family as well as the secondary technology, if applicable. First, we explore primary and secondary stove choices. Urban and rural households typically have different preferences for cooking technologies. In addition, there may be differences between households with and without grid access. Thus, we present primary and secondary stove choice disaggregated by both categories (Table 5).

Table 5: Pri. (top) and sec. (bottom) stove choice - rural and urban, w/wo grid access

Primary cooking technology	Urban - grid (%)	Urban - No grid (%)	All urban (%)	Rural - grid (%)	Rural - No grid (%)	All rural (%)	National - grid (%)	National - No grid (%)	National (%)
Woodstoves	10.7	62.8	20.8	74.3	91.2	85.9	39.1	87.8	64.9
LPG	55.7	6.7	46.2	14.9	1.8	5.9	37.5	2.4	18.9
Charcoal stoves	15.3	21.5	16.5	9.0	6.6	7.3	12.5	8.3	10.3
Kerosene stoves	17.8	8.6	16.0	1.2	0.4	0.7	10.4	1.4	5.6
Electric appliances	0.4	0.4	0.4	0.0	0.0	0.0	0.2	0.0	0.1
Other	0.1	0.0	0.0	0.6	0.0	0.2	0.3	0.0	0.1

Secondary cooking technology	Urban - grid (%)	Urban - No grid (%)	All urban (%)	Rural - grid (%)	Rural - No grid (%)	All rural (%)	National - grid (%)	National - No grid (%)	National (%)
No second stove	46.1	49.3	46.7	32.7	58.8	50.7	40.1	57.7	49.4
Woodstoves	3.6	6.9	4.2	10.5	3.8	5.9	6.7	4.2	5.4
LPG	10.5	4.4	9.3	19.5	3.9	8.7	14.5	3.9	8.9
Charcoal stoves	28.3	33.8	29.4	35.3	31.8	32.9	31.5	32.0	31.7
Kerosene stoves	10.4	5.6	9.5	1.5	1.7	1.6	6.5	2.2	4.2
Electric appliances	1.0	0.0	0.8	0.0	0.1	0.0	0.6	0.0	0.3
Other	0.1	0.0	0.0	0.4	0.0	0.1	0.2	0.0	0.1

[57] Quinn, A. K., N. Bruce, E. Puzzolo, K. Dickinson, R. Sturke, D. W. Jack, S. Mehta, A. Shankar, K. Sherr and J. P. Rosenthal (2018). An analysis of efforts to scale up clean household energy for cooking around the world. *Energy for Sustainable Development* 46: 1-10.

Primary stove choice is a common indicator of energy access in census data and demographic and health surveys (DHS). Results from this survey indicate that woodstoves are the most prominent primary cooking technology at 65% nationally, particularly among rural and off-grid households (86% and 88% respectively). Urban households and households with grid access show wider variety: LPG stoves are the most common (46%) primary cooking device in urban areas, but other options such as woodstoves (21%), charcoal (17%) and kerosene (16%) are also prominent. In households with grid access, the mix of primary cooking technologies is similarly varied, reflecting the urban and rural mix of households in this category. Perhaps surprising, just 17% of urban and 7% of rural households consider charcoal stoves their primary cooking option. Taking this data alone, one may infer that charcoal is no longer a major source of cooking energy in Kenya. However, when exploring secondary cooking options, we find that charcoal is the most prevalent option among households who rely on more than one cooking device: 32% nationwide with remarkable consistency across all categories in Table 5. Multi-fuel cooking solutions that include LPG and electric burners are classified both as an LPG and electric appliance. This explains why 0.4% of urban off-grid households report using an electric appliance.

As outlined in section 1.2 of this report, several studies have been done on various aspects of cooking. Many of these are framed as demand side or supply side assessment, which look at fuels, technologies or both.

Statistics provided in the cooking sector are also derived from generalized surveys not designed specifically for the cooking sector for example, the Kenya National Bureau inter-decadal censuses and Integrated Household Budget Surveys. When comparing the specialized and generalized surveys results and findings, it is important to consider (i) the date of the survey, (ii) the sampling approach and (iii) the aspect of analysis. Key statistics on primary technology used are compared by past national surveys done by the Kenya National Bureau of Statistics, Kenya Integrated Household Budget Surveys as shown in Table 6. Most of the statistics between the KIHBS and Clean Cooking Study are comparable except from numbers reported on ordinary jiko and kerosene stoves. There is a difference observed in values for ordinary jiko recorded by KIHBS 2015/2016 survey and those found by this study (see highlighted numbers). This variation may be due to definitional differences: the definition of the ordinary jiko is not as apparent as the definition of the other stove categories. In this study, the ordinary jiko is the metallic charcoal stove while the ceramic jiko is counted among improved charcoal stoves. There is a significant difference on the use of kerosene as the primary cooking solutions. Comparing the two sources, one could interpret the divergence as a sharp drop in the use of kerosene. This could be attributed to the increase in the price of kerosene due to the new levies and taxes as part of the Government's initiative to discourage the use of the fuel for domestic needs and an increase in alternatives, especially the LPG.

Table 6: Comparing the study results with KIHBS

	KIHBS 2005/2006			KIHBS 2015/2016			Clean Cooking Study 2018		
	National (%)	Rural (%)	Urban (%)	National (%)	Rural (%)	Urban (%)	National (%)	Rural (%)	Urban (%)
Traditional Stone Fire	60.8	78.0	9.1	46.4	71.7	13.7	53.5	71.0	17.1
Improved Traditional Stone Fire	8.4	10.9	1.0	8.2	12.8	3.0	11.0	14.9	3.7
Ordinary Jiko	7.1	4.0	16.6	9.1	5.7	13.5	1.1	0.7	1.7
Improved Jiko	6.5	3.9	14.3	6.2	3.7	9.3	9.2	6.6	14.8
Kerosene Stove	12.8	2.3	44.7	13.9	2.2	29.0	5.6	0.7	16.0
Gas Cooker/LPG	3.4	0.6	11.7	13.3	2.4	27.5	18.9	5.9	46.2
Electric Cooker	0.4	0.2	1.3	0.3	0.1	0.6	0.1	0.0	0.4
Other	0.6	0.3	1.3	1.8	0.9	2.9	0.1	0.2	0.0

3.3 State of Technologies and Fuels

A wide range of cooking technologies using varied fuels are available in Kenya today contributing to primary, secondary and tertiary cooking solutions. Beyond primary and secondary usage, this section looks at the universe of cooking solutions available within Kenyan households from an ownership and usage standpoint. The household survey identified 23 specific categories of cooking technologies as listed in Table 7. For simplicity, the cooking technology categories are based on the type of fuel used for aggregate categories – and this is further broken down into subsets of the aggregate category. For instance, there are five subsets or types of woodstoves: i) the traditional three stone open fire cooking solution; ii) fixed biomass stoves which include any built wood fuel stove; iii) Improved artisanal portable firewood stoves made within the informal sector; iv) branded firewood stoves are portable wood-fuel stoves manufactured by the formal sector and; v) biomass gasifiers which, as the name suggests, are designed for the gasification process. Annex A 1.7 provides more details on the categorisation approach. For clarity in this report, the aggregate categories are used in subsequent analyses.

Table 7 lists these specific and aggregate categories and the corresponding ownership rates. These percentages were reached by asking respondents to indicate all the types of cooking technologies they owned. The left half describes aggregated categories of technology by fuel type as owned by households; the right half shows specific types of technology owned. Note that in some cases the left and right do not add up as some households own multiple technologies within a single broad category.

Table 7: Categories of cooking technologies identified in the national HH survey – Ownership

Aggregate Category	% of HHs currently owning			Specific category	% of HHs currently owning		
	Urban	Rural	Total		Urban	Rural	Total
Woodstoves	26.9	92.1	71.0	Three stone open fire	22.8	77.0	59.4
				Fixed biomass stove	4.0	14.6	11.2
				Improved artisanal portable firewood stove	0.6	2.9	2.1
				Branded firewood stove	0.4	0.8	0.7
				Gasifier stoves	0.0	0.0	0.0
Charcoal stoves	52.9	47.1	49.0	Improved artisanal portable charcoal stoves	45.3	36.1	39.1
				Branded firewood stove	4.1	3.4	3.6
				Artisanal metallic charcoal stove	6.2	11.4	9.7
				Nyama Choma Grill	0.4	0.0	0.1
LPG stoves	54.3	18.1	29.8	6kg complete cylinder	40.5	15.9	23.9
				LPG stove (multiple burner)	13.9	2.1	6.0
				Mixed LPG-Electricity stove	5.3	0.4	2.0
Kerosene stoves	30.0	6.7	14.2	Kerosene wick stove	30.0	6.6	14.2
				Pressurized kerosene stove	0.1	0.1	0.1

[58] Enumerators were trained to select this option for any firewood-based stoves that were built into a permanent location. The categorisation did not differentiate the various approaches to fixed biomass stoves such as rocket stoves, built in ceramic liners, or concrete based cooking stoves.

Aggregate Category	% of HHs currently owning			Specific category	% of HHs currently owning		
	Urban	Rural	Total		Urban	Rural	Total
Electrical appliances	7.8	0.8	3.1	Mixed LPG-Electricity stove	5.3	0.4	2.0
				Microwave	2.4	0.4	1.0
				Electric coil stove	0.8	0.0	0.3
				Electric induction stove	0.1	0.0	0.0
Other	0.2	0.7	0.5	Biogas stove	0.1	0.2	0.1
				Gel biofuel stove	0.0	0.3	0.2
				Liquid biofuel stove	0.0	0.0	0.0
				Solar cooker	0.0	0.0	0.0
				Retained heat cookers	0.1	0.3	0.2

It is observed that ownership of a technology does not always translate to use. Respondents who indicated ownership of a given technology were asked if they were using the technology; Table 8 summarizes proportions of the population using given technologies. Ownership of stoves is greater than usage for all technologies.

Table 8: Categories of cooking technologies identified in the national HH survey – Usage

Aggregate Category	% of HHs currently using			Specific category	% of HHs currently using		
	Urban	Rural	Total		Urban	Rural	Total
Woodstoves	25.9	90.5	69.6	Three stone open fire	21.8	75.4	58.1
				Fixed biomass stove	3.9	14.2	10.9
				Improved artisanal portable firewood stove	0.4	2.4	1.8
				Branded firewood	0.2	0.6	0.4
				Gasifier stoves	0.0	0.0	0.0
Charcoal stoves	47.0	40.1	42.3	Improved artisanal portable charcoal stoves	39.9	30.8	33.8
				Branded charcoal stove	3.6	2.8	3.1
				Artisanal metallic charcoal stove	4.6	8.6	7.3
				Nyama Choma Grill	0.3	0.0	0.1
LPG stoves	54.2	18.0	29.7	6kg complete cylinder	39.1	15.0	22.8
				LPG stove (multiple burner)	13.6	2.0	5.8
				Mixed LPG-Electricity stove	4.9	0.3	1.8
Kerosene stoves	27.7	3.2	11.1	Kerosene wick stove	27.7	3.2	11.1
				Pressurized kerosene stove	0.0	0.0	0.0
Electrical appliances	7.4	0.5	2.8	Mixed LPG-Electricity stove	4.9	0.3	1.8
				Microwave	2.2	0.2	0.8
				Electric coil stove	0.8	0.0	0.3
				Electric induction stove	0.0	0.0	0.0

Aggregate Category	% of HHs currently using			Specific category	% of HHs currently using		
	Urban	Rural	Total		Urban	Rural	Total
Other	0.1	0.5	0.4	Biogas stove	0.1	0.2	0.1
				Gel biofuel stove	0.0	0.1	0.1
				Liquid biofuel stove	0.0	0.0	0.0
				Solar cooker	0.0	0.0	0.0
				Retained heat cookers	0.0	0.3	0.2

The study finds that fuelwood and charcoal stoves remain the most prevalent types of cooking technologies used nationwide. However, LPG has gained popularity, particularly in urban areas where it is used in more than half of all the households (54%). Like LPG, kerosene remains a popular option among some urban families (28%). On the other hand, despite recent gains in grid access, relatively few households use electricity for cooking. Alternative cooking technologies like ethanol stoves, biogas and solar cookers remain very rare, used collectively by less than 1% of the population.

Recognizing the stacking phenomenon discussed in the section above, it is important to understand the incidence of clean cooking solutions and improved biomass solutions at the household level. This is especially key in tracking SEforALL commitments where Kenya targets to have universal access to modern cooking solutions by 2030. These include LPG, electricity, biogas, bioethanol-based solutions and highly improved solid fuel cookstoves As seen in Figure 20, 30% of households in Kenya currently use a certain form of Tier 4 (by total emissions) cooking solution; 11% of households have an improved biomass stove but no clean cooking solution. This observation has critical implications in the design of programmes aimed at achieving SEforALL targets. While ownership of improved biomass stoves (KCJ and branded stoves) is over 36% nationally, it is likely that households with these types of stoves also own Tier 4 stoves (by total emissions). Interventions should therefore target adoption at the household level rather than number of stoves sold.

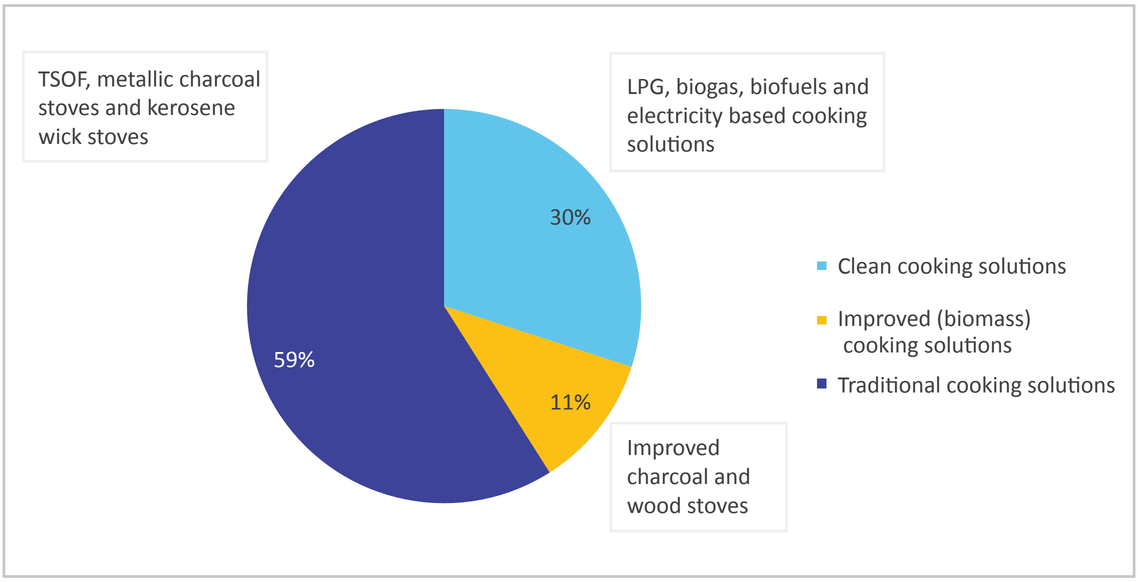


Figure 20: Proportion of households with access to clean cooking solutions, ICS and traditional cooking solutions

4. COOKING TECHNOLOGIES

This section discusses the types and reported units of cookstove technologies available in the market. The Kenyan cookstove market is supplied by various players including manufacturers, assemblers, importers, installers and distributors. These are classified as formal and informal operators. Formal sector players are registered companies or non-profit organizations operating under an officially recognized business/organisational name, registered with the Kenya Revenue Authority and set up to remit the mandated taxes, levies and fees. They brand and offer standardized products; provide warranties and after-sale support; and have a physical address in form of an office or manufacturing/assembly/distribution hub. Examples include organisations such as Biogas International, Envirofit, SCODE, EcoZoom, Ramtons, Wisdom Stoves, Consumer's Choice, Koko Networks and BURN Manufacturers. Informal sector players are an important source of cooking technologies but unlike the formal organisations, they typically neither brand their products nor offer them in standardized versions. They may pay for business and operating licences but commonly operate outside the taxation boundaries. These include manufacturers and assemblers in various jua kali production hubs across major towns. The types and reported units in the Kenyan market are discussed below as branded (formal) and artisanal (informal) technologies.

4.1 Branded Technologies (Formal)

The formal sector landscape is well understood and documented with many of the players being members, partners or associates of Clean Cooking Association of Kenya (CCAK) and/or The Alliance. In characterising the formal sector market players and technologies, this study aggregates the products in the market into six categories as shown in Table 9. The table also provides examples of products found in the market and the estimated number of households using the specific technology.

Table 9: Main stove categories and brands (formal sector)

#	Aggregate category	Specific category	Examples of products	Examples of manufacturer/ distributors	Est. no. of Households using these Stoves
1	Woodstoves	Manufactured wood stove Biomass gasifier	Kuni Okoa, Jiko Dura"24cm", Jiko Dura "28 cm", Model 2-M2, SmartSaver Wood, SuperSaver wood, Kuni mbili	Burn, EcoZoom, Envirofit, Wisdom, SCODE	54,000
2	Charcoal stoves	Manufactured charcoal stoves	Jikokoa, Jiko Bora, Jiko Fresh, SuperSaver Charcoal, SmartSaver Charcoal	BURN, EcoZoom, Envirofit, Wisdom	386,000
3	LPG stoves	Meko (single burner) LPG stove (multiple burner)	Total, Kobil, Pro-gas, K-gas, Hashi, Afrigas, Oil Libya, Lake Gas, Mid Gas e.t.c	Total, Kobil, Oil Libya, Pro-gas	3.7 million

#	Aggregate category	Specific category	Examples of products	Examples of manufacturer/ distributors	Est. no. of Households using these Stoves
4	Kerosene stoves	Kerosene wick stove Pressurized kerosene stove	Parameko, Fire wheel Brand Kerosene Wick Stove, Generic Handy Portable 8 Wicks Kerosene Stove	Gundua Engineering Services	1.4 million
5	Electrical appliances	Electric coil stove Electric induction stove Microwave Mixed LPG-Electricity stove	LG, Samsung, Ramtons, Hotpoint, Beko, Ariston, Mika Bruhms, Armco	Ramtons, Aniston, Hotpoint,	350,000
6	Other	Biogas stove Gel biofuel stove Liquid biofuel stove Retained heat cookers Solar cooker	Ethanol stove, Moto safi	Consumer Choice, Koko networks, Flexi Biogas International	50,000

In addition to the demand side data, this study interviewed 7 organisations that import, distribute or manufacture various types of cooking technologies. Other than charcoal and wood stoves, most of the other branded stoves in the market are imported or part-assembled in the country then delivered through the various channels as shown in Figure 21. The three leading firms selling solid biomass stoves - BURN, EcoZoom and Envirofit manufacture locally, import and assemble respectively. There are about five main organisations that import or manufacture solid biomass stoves. These are BURN Manufacturing, EcoZoom, Envirofit, Wisdom Energy Hub and SCODE. The market has a choice of at least 25 different brands of biomass cookstoves from these five main companies.

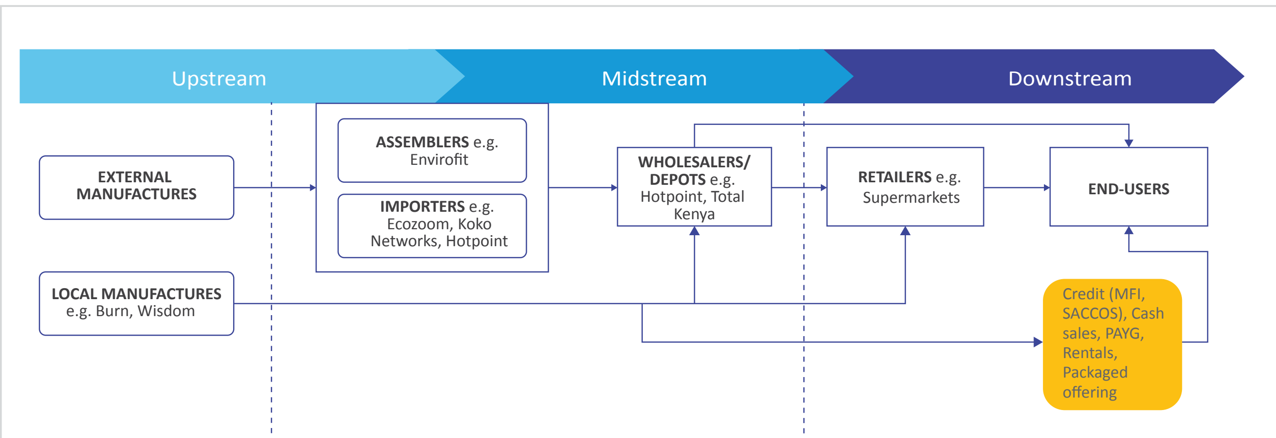


Figure 21: Schematic of the value chain (formal sector)

Manufacturers are constantly revising existing models and developing new ones based on customer feedback, preference and rates of uptake. For example, Wisdom Innovation developed the Model 2 (M2) stove to address the issue of stability and durability that were key concerns in the first stove known as Malaika Jiko; BURN Manufacturers introduced the Jiko poa extra, which is bigger in size compared to the Jiko poa and can hold larger cooking pots; Eco-zoom introduced a wood stove of 28 cm in diameter which was bigger in size than the previous model of 24 cm.

The retail price of the wood stoves above ranges from KES 2,800 to 3,600 while that of improved charcoal stoves from KES 2,990 to 5,300. The one burner ethanol gel is the least expensive and is sold at KES 2,300. High production costs contribute significantly to the price of the stoves. One of the wood stove manufacturers mentioned that the cost of production takes up 40% of the final cost of the cookstove without factoring in other expenses such as the cost of last mile distribution. Import duty is an important cost on imported stoves but this is typically passed on to the end-users. All the 7 manufacturers/importers interviewed provide warranty ranging between 4 months and 2 years for the cookstoves. Within this period, the cookstove can either be replaced or repaired depending on the issue.

Sales of an estimated 154,900 branded wood and charcoal stoves were reported for 2017 from BURN, Envirofit and EcoZoom – the three leading companies by volumes sold (see Table 9). From 2014-2017 at least 425,275 improved biomass cookstoves were reported sold from the same companies. This is comparable to the number of units currently in use, which was estimated to be 386,000[59]. Stoves sold to non-domestic users including businesses and institutions, and stoves that are no longer in service could account for the difference. One of the manufacturers reported higher sales of their woodstove among non-domestic consumers especially among businesses that sell cooked food.

For LPG stoves (other than the cylinder-based devices), respondents reported various brands of LPG stoves and mixed LPG and electricity cookers. Ramtons was the most commonly reported brand at 36% followed by LG at 22%.

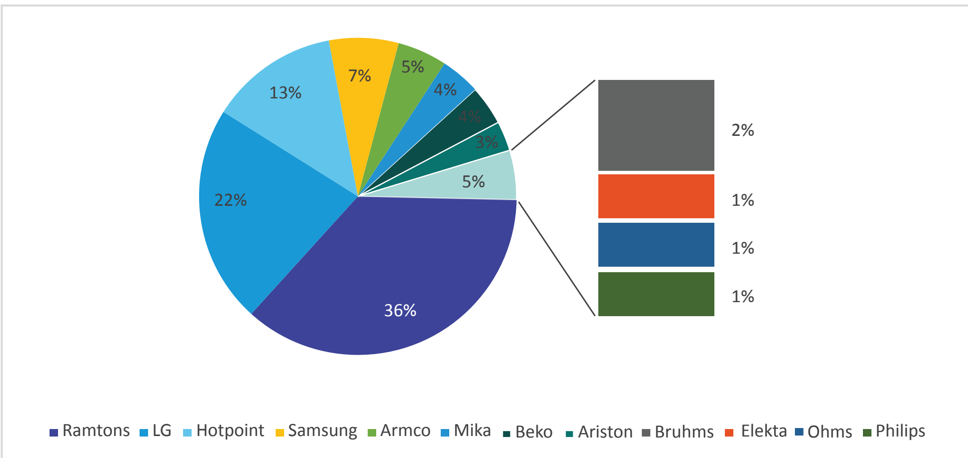


Figure 22: Prevalence of LPG cooking brands in Kenya

[59] Excludes kuni mbili estimated at 215,262 as some are not branded

4.2 Artisanal Technologies (Informal Sector)

In addition to being the most important source of cooking technologies in Kenya, the informal stoves manufacturing sector also provides employment opportunities for many. This study estimates that 1.4 million households use various types of artisanal wood stoves including rocket stoves, Jiko kisasa and Maendeleo stove as shown in Table 10. The KCJ is the most widely used stove with an estimated 4.2 million households reporting using it as part of their cooking mx.

Table 10: Main categories of non-branded stoves - used (informal)

#	Aggregate category	Specific category	% of HH using artisanal stoves	Est. no. of Households using these Stoves
1	Woodstoves	Fixed Biomass Stoves	11	1.4 million
		Kuni Mbili stoves	2	270,000
2	Charcoal stoves	Kenya Ceramic Jiko	34	4.2 million
		Metallic Charcoal Stove	7	1.2 million

Manufacturers of unbranded stoves and cooking appliances in the informal sector are concentrated in the jua kali sector hubs spread across the major towns in Kenya and are mainly involved in production of charcoal and firewood cookstoves. From the survey conducted with 17 cookstove producers and producer groups, majority of the businesses have been in operation for more than 10 years, with the oldest business having been in operation for over 30 years. This demonstrates the maturity and sustainability of this sector. The interviews reveal that the businesses are structured as either sole proprietorships or groups. Sole proprietorship is more common in the central region of Kenya while groups (both women and youth) are prevalent around the western region. The groups have an average membership of 12 people and employ between 4-60 people on both permanent and short-term basis. Very few members of the group depend solely on the business as their source of livelihood. The 17 businesses interviewed employ about 380 people both permanent and short-term. Farther, while some manufacturers are single dealers, most of them are involved in the production of multiple products including cladding and liner production. Other products produced include pots, vases and decorative artefacts.

14 of the 17 businesses interviewed are not formally registered as businesses. While those unregistered aspire to become formal businesses, discussions with these businesses pointed to the conclusion that many do not perceive registration as having a transformational value to their operations. Those set up as groups seem to be content with registration as a social welfare group done under the Ministry of Social Services. The key question asked was, “how will formalizing my business impact my operations and further my profitability?” The lack of standardized designs and labels by the informal manufacturers reduces the ability of customers to hold the manufacturers to account for the quality of their products. This is also a disadvantage to the manufacturers who would like to distinguish their products in terms of quality, price or both. The incentive to do so is diluted by the anonymity of the products.

A general awareness among the manufacturers on the importance of cookstove quality was observed where the quality of products is gauged from customer feedback. While there are no ongoing quality tests for their cookstoves, these manufacturers have conducted anecdotal tests on their stoves in the past. One manufacturer, Burners PET Energy Saving Stoves Limited in Muranga, mentioned having had his stoves tested by KIRDI while others such as Keyo Pottery Group have obtained the quality mark from KEBS indicating that their stoves have met certain required standards. More informal tests are carried out by most manufacturers and include controlled cooking, boiling water and durability (such as water immersion taught by GIZ). Additionally, manufacturers reported having had their soils tested (shrinkage test) before they began operations to ensure soils had the right moulding characteristics. In general, though, there seems to be no incentive for manufacturers to actively engage in quality management such as stove testing. From the discussion, the informal manufacturers can produce higher quality stoves but like any other business, the rights incentives need to drive this process. The market needs to demand higher quality products and be willing to pay for the additional costs associated with such products. The notion that externally imposed standards will transform the market may not be immediately practical. Voluntary industry standards where a group of manufacturers agree to produce, label and market their products are meeting some basic requirements of quality could be a better alternative. The market needs to know that there are differentiated products, the expected minimum requirements and how to distinguish these products. Like the World Bank Lighting Global voluntary verification processes which allow consumers to purchase quality assured solar PV products, such an organic process will incentivize manufacturers ready to improve the quality of their products to sign up. Quality assurance, standardisation and scalability of production will be key for markets where basic improved cookstoves have become baseline cooking technology as is the case in Kenya[60].

4.2.1 Artisanal Cookstoves Value Chain

Our findings reveal that the value chain of various informal stoves varies greatly between sources and regions. Upstream on the value chain are suppliers of raw materials and transporters of the same, liner producers (who can also be referred to as stove technicians) and fabricators of the cladding materials used in the stove production. Midstream and downstream on the chain are the various distributors including retailers and wholesalers. There is a marked difference between woodstove value chain and the charcoal stove value chain. For woodstoves, installers are a key part of the value chain as is in the case of the Jiko Kisasa and the rocket stoves while for charcoal stoves, the households can use their products directly once they have purchased it. (See Figure 22 and Figure 23 below). However, in some instances, installation of the woodstoves is done either by the manufacturers, distributors or end-users.

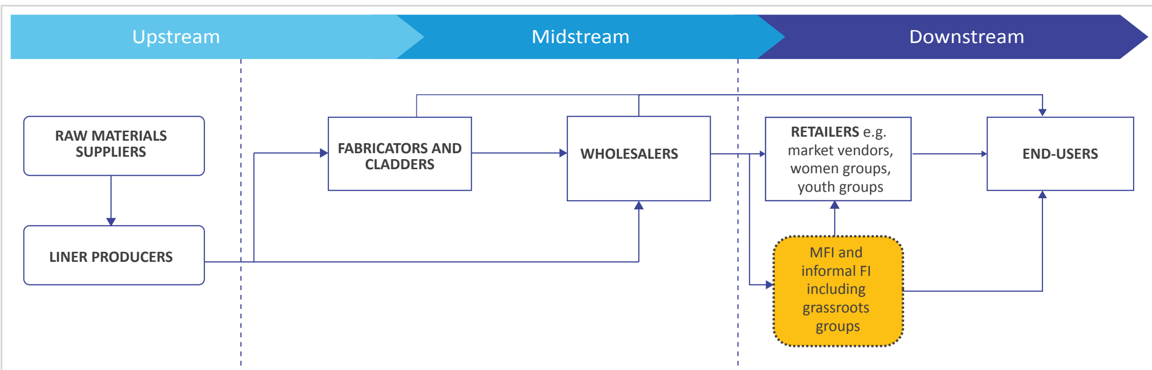


Figure 23: Distribution of the KCJ

[60] Putti, V.,R., Tsan, M., Mehta, S. & Kammila, S. The State of the Global Clean and Improved Cooking Sector. Washington DC: World Bank, Energy Sector Management Assistance Programme.

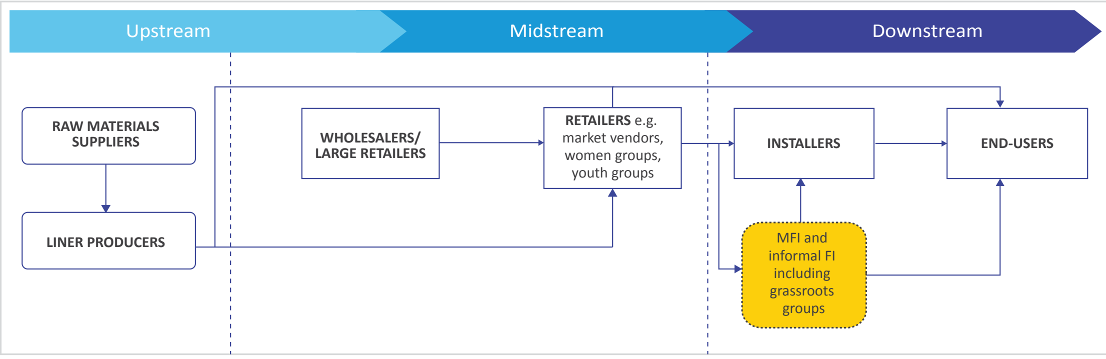


Figure 24: Distribution of Jiko Kisasa (Maendeleo Stove)

From the interviews done with the set of informal manufacturers, three out of four of these businesses sell most of their products through wholesalers while the rest sell through individual orders. The businesses have relatively shorter value chains as the products simply flow from the manufacturers to retailers and then to the end consumers or directly to end users from the manufacturers. However, in some cases the manufacturers sell to wholesalers who then sell to retailers and finally to the end user. This value chain is common with KCJ as some businesses do not engage in the cladding process and so they sell the liners in wholesale to the fabricators who then sell the complete products to retailers in different places and then to final consumers. Almost all (8 out of 10) the businesses interviewed have relied on self-financing to start and operate their business with the remainder using a combination of self-financing, grant and loans. Loans have been mainly from the Agricultural Finance Corporation and Women Enterprise support programmes (set up under Ministry of Public Service, Youth and Gender Affairs) while grants have been from development agencies such as GIZ, Practical Action among others. Lack of business development finance and working capital was cited as a critical barrier to expansion and diversification. Failure to attract substantial commercial finance can be attributed to the informal nature of most of the businesses perceived to be risky, modest profitability (unattractive returns on investment) and limited scale.

Informal manufacturers and entrepreneurs operate tried and tested business models as these have existed for several years (average years of operation is 17) with little or no external support. There are opportunities to further improve the quality and methods of product delivery including semi-automation of some of the production processes; aggregation of production and marketing; research and development on stoves designs especially among the woodfuel stoves; market expansion; standardisation and branding of products; appropriate business skills training; and supporting product testing. Any training programme needs to be tailored and demand-driven as opposed to generic offerings that may have limited benefits to these very experienced entrepreneurs.

4.2.2 Case 1: Context from the Kenya Ceramic Jiko Experience

The KCJ is the most common and widely used informal cookstove. This study estimates that 39% (45.3% urban and 36.1% rural) of all households own it. Users of the KCJ were asked how long they been using their current stove and about 3% of all households stated as having purchased their KCJ in the last one year. Based on this, the study estimates the sale of KCJ to be about 343,000 units per year with an annual market value of KES 134 million (US$ 1.3 million). This is comparable to the annual export value of fluorspar or manufactured wood products as shown in Figure 24 below. It is also about a fourth of the value of cashew nuts exported. Export figures are sourced from the KNBS 2018 statistical abstract[61].

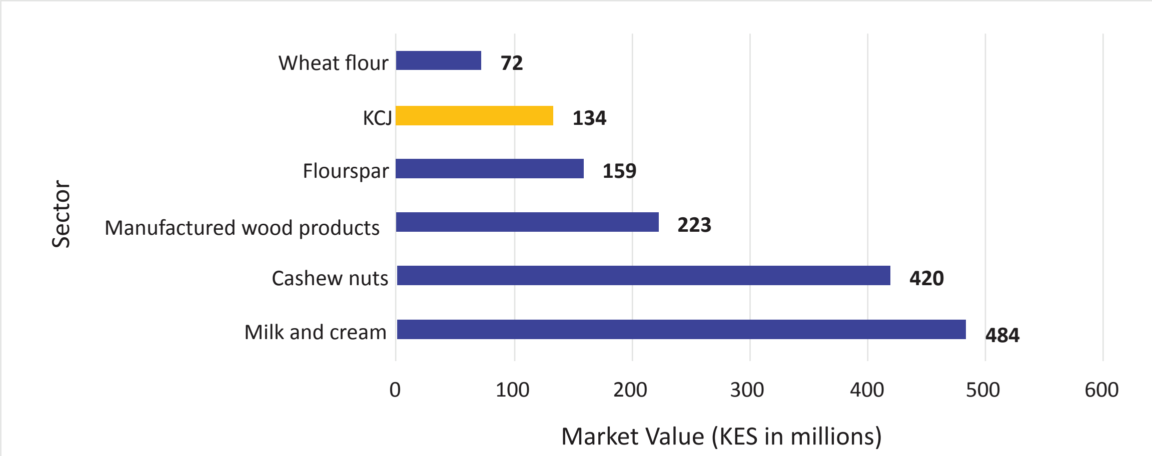


Figure 25: Market value of KCJ relative to a select export product (in KES millions)

Estimating the number of persons employed in the KCJ value chain is constrained by various factors. First, many of the actors do not solely produce the KCJ but produce them as part of a mix of commodities. Second, some actors are only engaged on a periodic basis and default to other livelihood options for example crop agriculture during certain seasons. Third, production is often on demand basis and in response to orders, which fluctuates greatly across the year. Fourth, KCJ manufacturers although well organized, operate on an informal basis with no central depository of persons engaged. In this context, this study estimates the number of full-time employment positions supported by the KCJ value chain. Demand side data is used to estimate the annual sales while supply side data gathered from interviews with several informal manufacturers assist with estimating the production capacity per person working on a full-time basis disaggregated at the various stages of production – production of liners, cladding, assembly and distribution. Manufacturing of KCJ provides full-time employment to about 1,016 persons comparable to the advertising sector (1,255), logging (1,173) and the manufacture of glass products (1,877) as shown in Figure 26. Employment data for the other sectors is sourced from the KNBS 2018 statistical abstract[62]. This does not include the casual and part-time labourers.

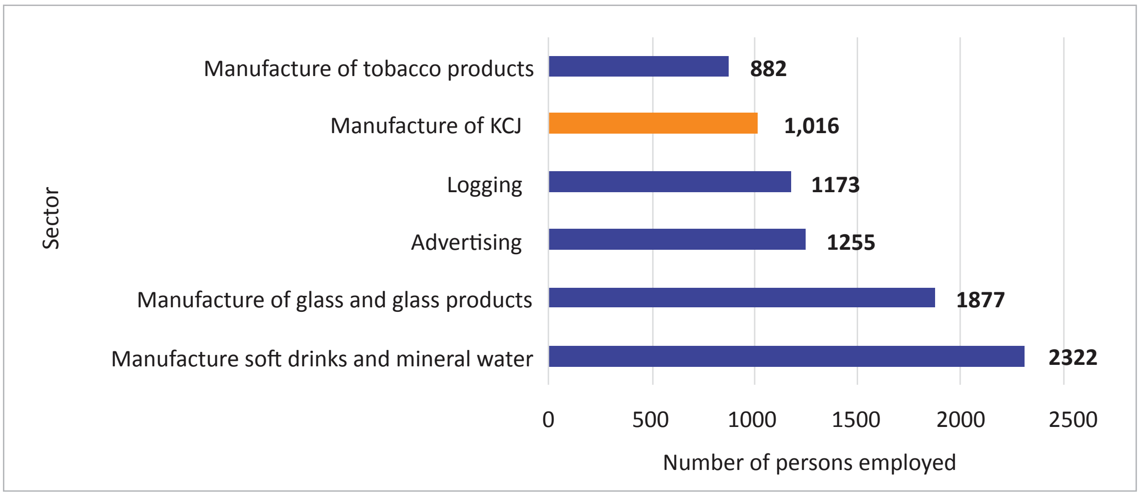


Figure 26: Number of persons employed in the KCJ value chain relative to other sectors

[61] Kenya National Bureau of Statistics. (2018). *Statistical Abstract 2018*. Nairobi: Kenya National Bureau of Statistics.
[62] ibid

This study also attempted to estimate the number of persons employed in the wood stoves informal sector but was limited by the scope of the assignment. Unlike the KCJ manufacturing, a lot of significant variability exists in the way the groups interviewed carried out their businesses. While some did this largely as groups, others did it through individual effort. Some groups did the production seasonally diverting efforts to other functions such as farming during certain times in the year while others carried this out consistently through the year. It was therefore difficult to determine a standard number of person-hours (or effort) needed to deliver a batch of stoves. Again, wood stoves vary greatly with some requiring installation at the user's kitchen, unlike KCJ that are sold as is. Creating reasonable models to estimate numbers of people employed was therefore limited.

The greatest cost in KCJ production is that of raw materials which accounts 30% to 50% of the total production cost. These costs include acquisition of clay, metal cladding, firewood for the kiln and water for soil mixing. The production cost varies from one manufacturer to another and from one hub to another. For instance, some manufacturers have acquired parcels of land where they source their clay hence eliminating the cost of clay and transportation while other groups work on the stoves themselves and do not require additional labour. Metal cladding is the most expensive input into the process, accounting for up to 80% of the total unit production cost. The second highest costs come from the acquisition of clay, fuel and the vermiculite. Other costs such as transport and distribution are also high and remain a major limiting factor for artisans aiming for markets that are further away from them – the further the product moves away from the manufacturing premises, the more expensive it becomes which in turn impacts sales.

Table 11: Estimated production cost of a standard KCJ

#	Item	Unit of Measure	Price per unit (KES)	Quantity	Est. number of Stove Produced	Unit Cost (KES)
1	Clay	Tractor	3000	1	500	6
2	Clay Transportation	Tractor	6000	1	500	12
3	Clay digging	Persons	500	2	500	2
4	Firewood	Headloads	200	8	150	11
5	Water	Litres	1000	1	500	2
6	Vermiculite	Bag (25 Kg)	800	1	70	11
7	Labour (Mixing clay)	Persons	500	4	500	5
8	Labour (moulding)	Persons	5	2	500	4
9	Cladding	Pieces	250	1	1	250
	TOTAL					303

*Estimated based on a group interview in western Kenya and may vary across producers

4.2.3 Case 2: Insights from the Kamukunji Production Hub

Kamkunji Jua Kali centre is one of the oldest and largest informal production hubs in the country. The centre was set up as an incubation centre for low-tech manufacturing. The Government, through the Ministry of Labour, built 47 sheds and waived the licensing requirements by the county council for the artisans. It was started in 1986 with a membership of 375. This number has increased rapidly over the years and currently stands at about 6,000 members. Being part of this association, which charges a membership fee of KES 300, increases members' access to finance through the different financial institutions (e.g. Equity

Bank) and enables members to voice their concerns. The hub is managed by an association led by a 16-person committee headed by a chairperson, vice chairman, secretary and a treasurer. The association is registered under the Micro and Small Enterprises Authority (MSEA), which falls under the Ministry of Industrialisation (formerly under the Ministry of Labour). Committee leaders are elected every three years through a process overseen by MSEA.

The hub is divided into sections based on the products manufactured. There are sections for those who produce storage boxes, wheelbarrows, cookstoves (household and institutional), kitchenware and other farm implements. Smaller groups based on the type of product are often to help regulate pricing, marketing and quality. The facility has, however, barely been expanded since the 47 sheds were set up though the number of members has been on the increase. This has led to overpopulation and congestion.

About 500 members of the association are involved in either wood or charcoal cookstoves production as cladding producers or stove fabricators. Most of them, however, are not specialists but deal in a variety of products.

Figure 27: A Jua Kali artisan working on parts the KCJ metal cladding at Kamukunji

Figure 28: A Jua Kali artisan working on parts the KCJ metal cladding at Kamukunji

These fabricators report various challenges and barriers that hinder their business expansion. One of the limitations is their technical capacity. Most of the fabricators have learnt their trade through apprenticeship with only a few having obtained formal training on stove production. There is therefore a need to learn new and modern design techniques in stove production if they are to remain competitive in the market. With the new campaigns on efficient cookstoves that aim to align with ISO IWA guidelines, the artisans will need new knowledge and skills on how to transform the existing designs of KCJ and the metallic charcoal stoves into more appropriate models. A key challenge to this transition is lack of automation as most production processes are currently manual. While there are machines available to optimize human input, increase productivity and lower costs, their adoption remains a debatable solution. Adoption of new machines and technologies poses a threat to the artisans' job security as these machines will not only require new sets of skills to operate but may displace some of the people currently engaged. Increasing competition from products manufactured in China poses a threat to local stove production and emphasizes the need for sector transformation. Imported products are already directly competing with those produced in the artisanal market (e.g. spades) and sold at lower costs due to the economies of scale gained from their mass production capacities. The concern is that this competition may soon be observed in the cookstoves sector if artisans do not transition to more modern productions processes.

Limitations in accessing new markets or expanding within the current ones were also reported as a challenge. Artisans were in the past offered opportunities to exhibit their products in the Central Business District of Nairobi. This is no longer an option due to new regulations. There are still opportunities to exhibit in other countries such as the *'Nguvu Kazi'* forum in Rwanda. There is therefore room for government and other sector stakeholders to promote artisanal activities.

4.3 Preference and Willingness to Pay

When the respondents were asked to select their most preferred stove, the 6 kg complete LPG cylinder emerged as the most preferred (26.5%) followed by the TSOF (20.9%). The most preferred stove among 9 out of 10 households are found within the 6 types of stoves in figure 29.

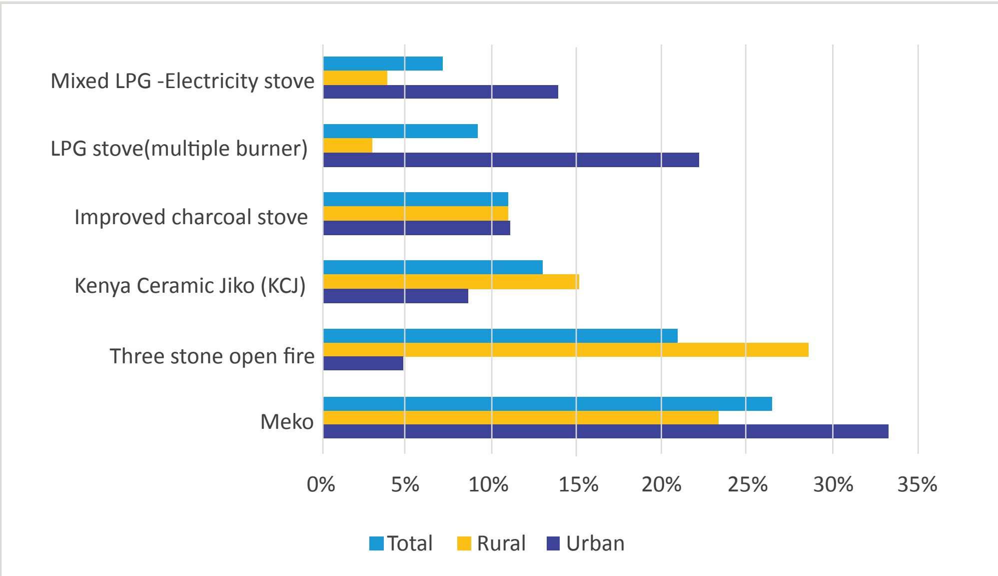


Figure 29: Top 6 most preferred stoves

Reasons for preferring the 6 kg complete LPG cylinder are evident but the preference of the TSOF – which is counter-intuitive, is discussed further below in Case 3. Although the preference for the TSOF is high, the response skewed toward rural households, of which 28.6% preferred it compared to only 4.8% in urban areas. The TSOF is the most preferred stove by rural users. The respondents identify LPG as the most preferred fuel. The 6 kg complete LPG cylinder is the most preferred stove and the LPG multi-burner stove is the fifth most preferred stove. Combining these two stoves, the overall national preference for LPG based solutions stands at 35.6% (55.5% urban and 26.2% rural). The KCJ is the third most preferred stove nationally at 13% but with a lower preference among urban households (8.6%) relative to rural households (15.1%).

From this data, we find that preference is distinct between urban and rural users. Among urban users, the most important factor affecting the choice of stove, after cost, is ease of use[63]. Ease of use is a compound factor that includes the following capabilities: direct ignition, systematic heat regulation, systematic fuel use, allowance for partial fuel refill, non-smoking clear flame/heat, and fuel level detection. When assessed against these six parameters, the liquid and gaseous stoves outcompete the solid biomass stove as shown in Table 12.

Table 12: Ease of use[57]

Stoves	Direct ignition	Systematic heat regulation	Systematic fuel use	Partial fuel refill	Clear flame/ heat	Fuel level detection	Total Score (/5)
6kg Complete LPG Cylinder	1	1	1	0	1	0	4
Kerosene Stove	1	1	1	1	0	0	4
Moto Sawa	1	1	1	0	1	0	4
Safi	1	1	1	0	1	0	4
Para Meko	0	1	1	1	1	0	4
Jiko Okoa	0	0	0	1	0	1	2
KCJ	0	0	0	1	0	1	2
EcoZoom	0	0	0	1	0	1	2
Envirofit	0	0	0	1	0	1	2
Wisdom	1	0	0	1	0	1	3

Respondents were further asked if they owned their most preferred stoves, and if not, what the main limiting factor for ownership was. As seen in Figure 30, almost all the respondents who preferred the TSOF are already using it. For the 4% who preferred the TSOF but weren't using it, the main limiting factors were unavailability of firewood in the market (45%) and safety concerns (30%). The main limiting factor for all other stoves was cost. This was especially significant for the LPG stoves - 87%, 85% and 76% of the respondents who preferred but did not own the LPG-multiple burner, the 6 kg complete LPG cylinder, and the mixed LPG/electricity stoves respectively identified cost of stove as a limiting factor. This highlights the cost of stoves as a major entry barrier in the transition to cleaner cooking solutions.

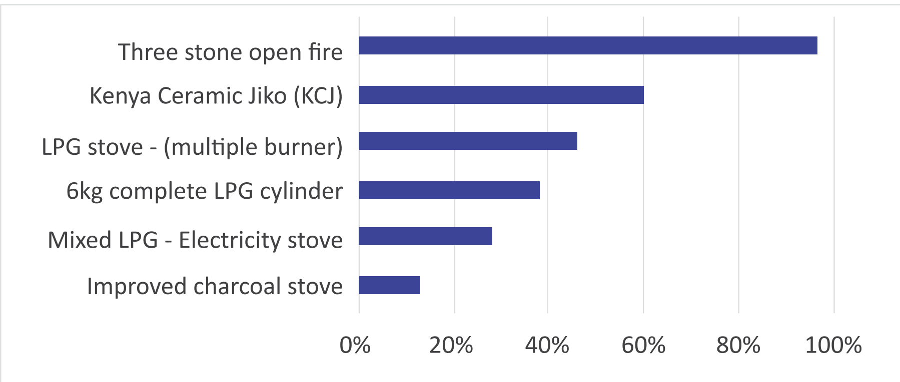


Figure 30: Proportion of respondents owning their most preferred stove

[63] EED Advisory. (2018). Feasibility study on improved cooking solutions in low income areas in Nairobi.

Table 13: Factors limiting stove ownership

Limiting Factor	Proportion (%)
Stove is unavailable in the market	7.3
Fuel is unavailable in the local market	3.4
The stove is expensive	70.1
Fuel for the stove is expensive	6.9
Safety concerns	5.4
Other	6.8

As an additional exercise, participants were asked about their willingness to pay for various cooking technologies. This approach resulted in a database of "stated-preferences" for different cookstoves. While not quite as valuable as actual purchase choices, or "revealed preferences", collecting stated preferences could clarify upper bounds of pricing and consumers' preferences for different types of technologies[64]. Our approach was similar to the approach used in the 2016/17 MTF survey commissioned by the World Bank. Respondents were assigned a stove at random from among 6 options: BURN - Jikokoa, KCJ, Kerosene wick stove, 6kg complete LPG cylinder (single burner), Electric single coil, and a Wisdom gasifier stove. Respondents were then asked if they would be willing to purchase the randomly selected stove for one of four randomly assigned prices: 100%, 75%, 50% or 25% of the full retail price, resulting in a hypothetical demand curve for each stove as shown in Figure 31.

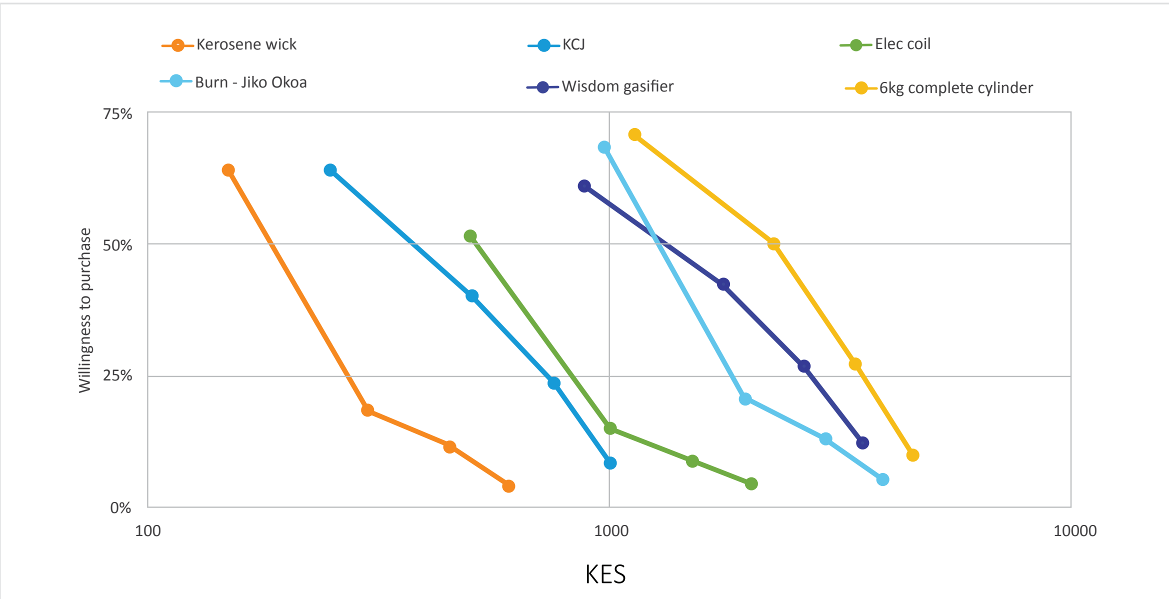


Figure 31: Respondents willing to purchase a stove at 25%, 50%, 75% and 100% of the price

Note the horizontal axis, which shows the stove prices, is on a logarithmic scale. This makes it easier to compare the angles of each curve. Steep curves indicate that willingness to pay decreases sharply moving from lower to higher prices (left to right along the x-axis). From the figure, we can see some

[64]Blumenschein, K., Blomquist, G., Johannesson, C., Horn, M., N. and Freeman P. (2007). Eliciting willingness to pay without bias: evidence from a field experiment. *The Economic Journal* 118(525): 114-137

stoves, such as the kerosene wick and electric coil stoves, experience a sharp drop in demand when the offer price changes from 25% to 50% of the retail price. Other stoves, like the Wisdom gasifier and the 6kg complete LPG stove, see much smaller changes when the offer price varies by the same relative quantity. Of note also, is the low willingness to pay (WTP) for KCJ at higher price points – 64% WTP for a KCJ at KES 250 compared to WTP of 24% at KES 750. This may be contrasted with the 6kg complete LPG cylinder which has a 71% WTP at KES 1,125. It may therefore be inferred that KCJ producers, who sell their stoves at a price range of KES 250 – 500, tend to respond to market demand in making and pricing their stoves. While the quality of stove may be improved using high-quality liners and cladding, this would make the stoves more expensive, yet the market does not respond to more expensive KCJs. Also, worth noting is the low WTP for improved charcoal stoves at current market prices – the WTP for a BURN stove at the market price (KES 3,890) was 6%. It may be inferred that with the current ownership rates of branded cookstoves being at 3%, pricing of these stoves or the revenue models needs reviewing if mass adoption is to be realized.

If respondents declined to purchase the stove at the initial asking price, they were asked if they would be willing to purchase the same stove under 6, 12, or 24-month payment schemes. Positive responses to the offers of staged payments indicate that families unable to afford the technology upfront would be willing to purchase it if some financing mechanism was in place. Figure 32 shows the effect of adding a 6-month payment plan to respondents' willingness to pay for the KCJ, the Jikokoa by BURN and 6kg complete LPG cylinder stoves. The boost in demand is larger for Jikokoa (2-12%) than the other two stoves: KCJ increases from 5-13% and the 6kg complete LPG cylinder at 0-7%. Except for one scenario, the increase in WTP decreases with increasing price. The exception is the observation that, at the current market prices for the 6kg complete LPG cylinder, provision of financing mechanisms has no impact on the willingness to pay.

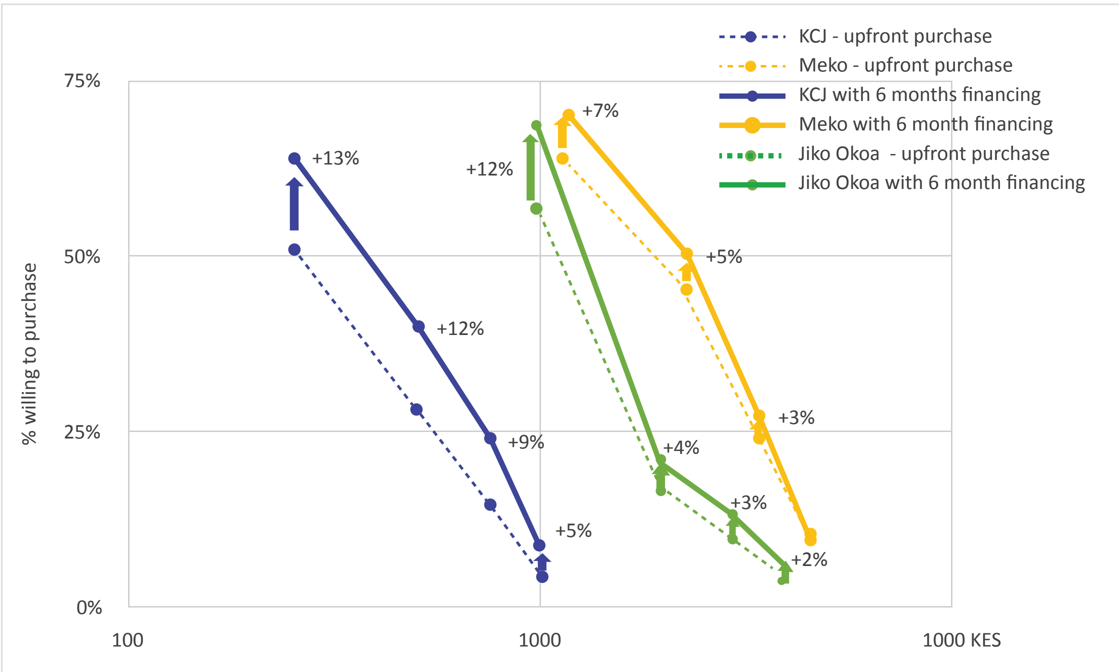


Figure 32: Change in willingness to purchase KCJ and 6kg complete LPG cylinder stoves at different price points between one-time cash payment and 6-months staged payment

The survey also asked people who declined offers of staged payments why they did not want to purchase their randomly assigned stove. The most common reason given was that respondents didn't need the stove offered (37% overall). Others thought that they could not afford the payment (29%) or fuel (19%), the stove would be unreliable (8%) or gave other reasons. For example, some households – such as those offered an electric stove but lacked access to electricity – indicated that they could not use the stove.

4.3.1 *Case 3*: Lessons from the Three-stone Open Fire Challenge

About 59% of households in Kenya use the TSOF compared to 76% twenty years ago[65]. Although the proportion of household users has dropped, the aggregate number has increased from 4.7 million households[66] to 7.4 million households due to the overall population growth. The TSOF, also known as the open-hearth, open-fire or three-stone hearth, has remained the most common form of cooking technology for decades and continues to defy efforts to displace it as the centre of cooking especially in rural areas. As mentioned above, it seems counter-intuitive that it is the most preferred stove among rural households with 28.6% of the respondents mentioning it as such. While acknowledging that stove selection is a complex multi-dimensional decision-making process, this study proposes five reasons why preference for the TSOF has remained the case.

a. Perceptions and attitudes towards the problem:

Cooking using the TSOF is considered traditional and promoters of alternatives expect households to see it as such and therefore be inclined to readily adopt other forms of cooking. It is also considered an inferior technology associated with very low-efficiency rates[67]. While the low-efficiency rates have been demonstrated, the idea that it is an inferior technology is a misconception as will be discussed in point number (b) below. Since it is considered inferior, efforts to displace the TSOF do not ask how the alternatives can mimic the appealing aspects of the existing setting. Drivers of choice favouring the TSOF go beyond the technology itself and, like with other technologies, include the type of housing and availability of appropriate fuels within reasonable distances. Like other past research, this study also finds that most of the TSOF users are rural households (76% use rate) with considerably greater access to fuelwood than the urban households and have cooking spaces that can accommodate this type of cooking. Therefore, while many initiatives seek to replace the technology, it is the rural setting that is a greater determinant of this choice.

b. Appropriate technology:

The TSOF is a widespread technology that has been refined over thousands of years[68]. Its appealing attributes are often misunderstood or overlooked. In addition to being durable and sturdy, the TSOF has an all-in-one design that can accommodate varying sizes and shapes of cooking appliances from large cooking pots, to medium sized pans to kettles. The ability to adjust according to the size of the cooking utensil distinguishes this option. Besides the stones themselves, there are no moving parts, bearings, rollers or springs reducing the risk of breakages or malfunction. No parts require replacement even after sustainable use. Users can use it for dual or triple purposes including roasting, drying and space heating while cooking (without extra consumption of a cooking fuel). Multiple solid fuel sources are compatible including firewood, maize cobs, maize stalks, and animal dung among others. In some instances, the smoke produced repels insects.

[65] Nyang, F. (1999). Household Energy Demand and Environmental Management in Kenya (Doctoral dissertation). University of Amsterdam

[66] Republic of Kenya. (1999). *Kenya 1999 Population and Housing Census*. Nairobi: Central Bureau of Statistics.

[67] Ekouevi, K., Kennedy, K. and Soni, R. (2014). *Understanding the difference between cookstoves.* Washington DC: World Bank, Energy Sector Management Assistance Programme

[68] Bailis, R. & Cutler, J., C. (ed). (2004). Encyclopedia of Energy Wood in Household Energy Use. Amsterdam; Boston: Elsevier Academic Press: 509-526.

Figure 33: Technological advantages of the TSOF

c. Inaccurate assumptions:

In promoting alternatives to the TSOF, the headlines messages are around fuel cost savings. It is estimated that the TSOF overall thermal efficiency is between 5 and 20%[69]. Although this is an important consideration, it will be most attractive in areas that are fuelwood constrained, which is not necessarily the case with a majority of households that use firewood - when respondents were asked how often they *could not* acquire firewood in the desired quantities, 45% and 56% of urban and rural firewood users said "never" as shown in Table 14. The attractiveness of this proposition is reduced in cases where fuelwood is available in enough quantities and at little to no cost. The same type of response was seen even when the respondents were disaggregated as male and female.

Table 14: How often respondents could not acquire firewood in desired quantities.

	Urban (%)	Rural (%)
Often (more than once a month)	11	11
Sometimes (4-12 times a year)	12	11
Rarely (less than 4 times a year)	28	20
Never	45	56
Not applicable	1	0
Don't know / Unsure	4	2
Total	**1**	**1**

Another inaccurate assumption is that most households do not appreciate using the TSOF but resort to using it due to a complete lack of alternatives. This study finds that more than 20% of households identify TSOF as the most preferred cooking option – second only to LPG based cooking. It is the most preferred stove in rural areas with a preference rating of 28.6%. The other inaccurate assumption is that the users of TSOF are not aware of the negative impacts of IAP. Only 6% of TSOF users do the cooking in the main living area, an indication that the inconvenience of cooking outside is overridden by the exposure to smoke. This demonstrates an understanding and awareness of the pollution attributed to TSOF. The rest of the

[69] Ekouevi, K., Kennedy, K. and Soni, R. (2014). *Understanding the difference between cookstoves.* Washington DC: World Bank, Energy Sector Management Assistance Programme

households either have the TSOF in a separate room in the main house (15%), in a separate room outside the main house (59%), open-air cooking (19%) or on a balcony (1%). Attributing deforestation to non-commercial fuelwood use is also inaccurate. Contrary to common perception, non-commercial traditional biomass energy use for coking does not drive deforestation but in a few instances may contribute only to degradation, which is an emerging consensus across several studies[70,71] .

d. Cost and distribution:

It only takes three similar sized, typically spherical stones to build a TSOF. Such stones are widely available and therefore there are no upfront costs of purchase or installation. There are no distributors or need for after-sales-support. No training is required on the use of the solution. This makes the TSOF very competitive relative to any other form of cooking technology in rural areas.

4.4 Cost and Payment Methods

Table 15 provides the average reported prices for stoves that were purchased, and where applicable, provides the reported prices by manufacturers. Where comparison is possible, consistency between survey averages and reported numbers is observed.

Table 15: Reported pricing of stoves

Stove	Survey Outcomes		KII with supply side players
	Urban (KES)	Rural (KES)	Unit costs (KES)
Biogas	-	73,500	>50,000
Fixed biomass stoves	8,000	18,307	
Improved charcoal stove	3,895	3,673	2,990 to 5,300
Kenya Ceramic Jiko (KCJ)	408	388	250 - 500
Kerosene wick stove	503	675	
Kuni mbili	473	694	
LPG Multiple burner	14,963	10,873	
LPG/Electric Stoves	28,920	39,250	
Meko	4,503	4,592	est. 4,500
Metallic charcoal stove	529	417	
Potable firewood stoves	3,500	1,000	2,800-3,600

In addition to the reported cost of stoves, the study also sought to understand the various options of payments for stoves adopted by households. At 99% and 97% in urban and rural areas respectively, most stoves are sold on an upfront cash purchase basis in Kenya. This is unsurprising given that at 82%, retail stores (small retail stores, supermarkets, wholesale retail shops and open markets) represent the largest proportion of last mile distribution channels for stoves. Among the few respondents who acquired their stoves on some form of credit, borrowing from family and friends was the most commonly observed form of credit followed by borrowing from self-help groups. Loans from financial institutions were rare. These observations

[70] Masera.,R.,O.,Bailis ,R.,Drigo,R., Ghilardi.,A. and Ruiz-Mercedo,I.(2015). Environmental Burden of Traditional Bioenergy Use. *Annual Review of Environment and Resources 40* (1),121–150. Retrieved from https://doi.org/10.1146/annurev-environ-102014-021318.

[71] Mahiri, I., & Howorth, C. (2001). Twenty years of resolving the irresolvable: approaches to the fuelwood problem in Kenya. Land Degradation & Development, 12(3), 205-215

reflect lessons from USAID's funded Jiko Safi Fund – the fund worked with the Kenya Union of Savings and Credit Cooperatives (KUSCCO) to disburse funds to KUSCCO members from whom end users could take loans to acquire improved cookstoves[72]. The Fund noted that, even with this facility, only 30% of their sales (estimated at 13,000 in 2017) were on credit. A key lesson was that the low loan amount of KES 2,000 – 5,000 discouraged applicants from engaging in the rather complicated loan application process, not to mention paying the associated fees.

Table 16: Mode of payment (type)

Mode of Payment	Primary Stove		Secondary Stove	
	Urban (%)	Rural (%)	Urban (%)	Rural (%)
Bought, full upfront payment (cash)	99	97	99	97
Bought, full upfront payment (loan)	0.2	0.3	0.2	0.8
Bought, under installment (hire purchase)	0.2	1.6	0.2	2.0
Other	0.1	1.1	0.2	0.0

Table 17: Mode of payment (source)

Mode of Payment	Primary Stove		Secondary Stove	
	Urban (%)	Rural (%)	Urban (%)	Rural (%)
MFIs	0.0	0.0	0.2	0.0
Family/friends/employer	1.2	1.9	1.1	2.0
Mobile loans	0.2	0.0	0.0	0.0
Self-help group (women / youth)	0.3	1.3	0.0	1.6
Other	0.6	0.5	0.9	1.2

[72] USAID. (2017). *KUSCCO's Jiko Safi Clean Cookstove Fund.* Retrieved from https://www.winrock.org/wp-content/uploads/2017/09/KUSCCOProfile.pdf

5. COOKING FUELS

This chapter further elaborates the discussion set out in Chapter 3 on cooking solutions by focusing on various aspects of cooking fuels. The study finds that about 64.7% (8.1 million) of households in Kenya still use wood as their primary cooking fuel, followed by LPG at 19.0% (2.4 million) and charcoal at 10% (1.3 million). Woodfuel (charcoal and firewood) is the most commonly used primary cooking fuel with 75% of households report using it as is seen in Figure 34.

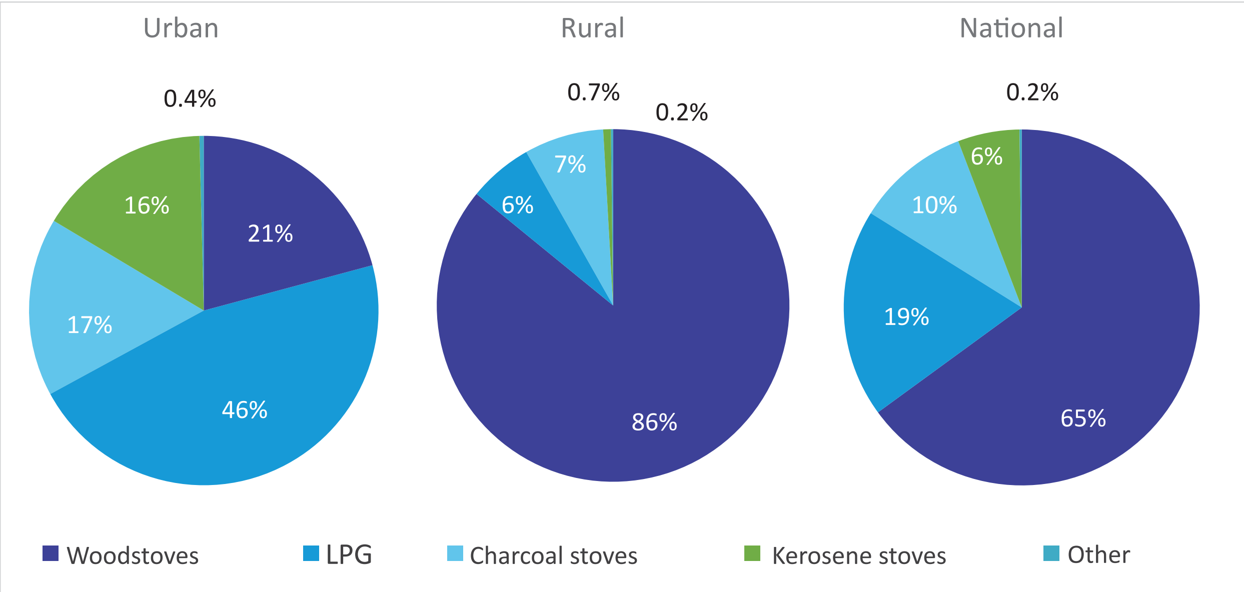


Figure 34: Primary fuels used by households in Kenya (urban, rural, national)

With data on primary and secondary cooking options (presented in Section 3.2), the survey provides information on the most common household fuel mixes. Table 18 is a matrix of primary (rows) and secondary (columns) cooking options nationally. The row totals give the percentage of households using the different cooking options as their primary fuels. For instance, 19% (cell H1) and 64.7% (cell H5) of Kenyan households use LPG and wood as their primary cooking fuels respectively. The column totals give the percentage of households using the different options as a secondary cooking option. For example, 4.1% (cell D7) and 31.6% (E7) use kerosene and charcoal as secondary fuels respectively. Values for both primary and secondary fuels, can be read within the table. For instance, 22.9% of households (cell D5) use wood as the primary fuel and charcoal as secondary while 4.9% who use charcoal as the primary fuel do not have secondary fuel (cell A4). At 34.5% (cell A5), a significant proportion of Kenyan households (4.3 million) rely solely on wood for cooking. Among those households that named a secondary option, the most common pairing is wood and charcoal (highlighted in yellow). In households using either LPG or kerosene as a primary option, charcoal is the most prevalent secondary stove. From this, we can conclude that charcoal still plays a major role in Kenya's household energy mix as a secondary fuel for a substantial fraction of the population in both rural and urban areas, among grid-connected and off-grid households.

Table 18: Percentages of pri. and sec. pairings of cooking options nationwide

		A	B	C	D	E	F	G	
	Secondary stove → Primary stove ↓	No 2nd stove (%)	LPG (%)	Electric (%)	Kerosene (%)	Charcoal (%)	Wood (%)	Other (%)	Total (%)
1	LPG	6.6	1.3	0.3	2.2	6.5	2.0	0.1	19.00
2	Electric	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.20
3	Kerosene	3.3	0.2	0.0	0.0	1.9	0.2	0.0	5.60
4	Charcoal	4.9	2.0	0.0	1.1	0.3	2.0	0.0	10.30
5	Wood	34.5	5.4	0.0	0.8	22.9	1.1	0.0	64.70
6	Other	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.10
7	Total	49.40	9.00	0.30	4.10	31.60	5.40	0.10	99.90

In addition to primary and secondary fuels, the study sought to establish the reported mix of fuels used per household by asking respondents to select all the fuels used for cooking within the household. As seen in Figure 35, 9 out of 10 rural households consider fuelwood (firewood) as one of their cooking fuels further indicating that the challenge of promoting access to modern energy is largely a rural one. In contrast, 1 of 2 urban households use LPG. Kerosene is mostly used in urban households while charcoal is no longer mostly an urban fuel with its prominence now comparable to rural areas – with the majority of Kenyan households being rural, charcoal is used by more rural households (3.2 million) than urban households (2.5 million).

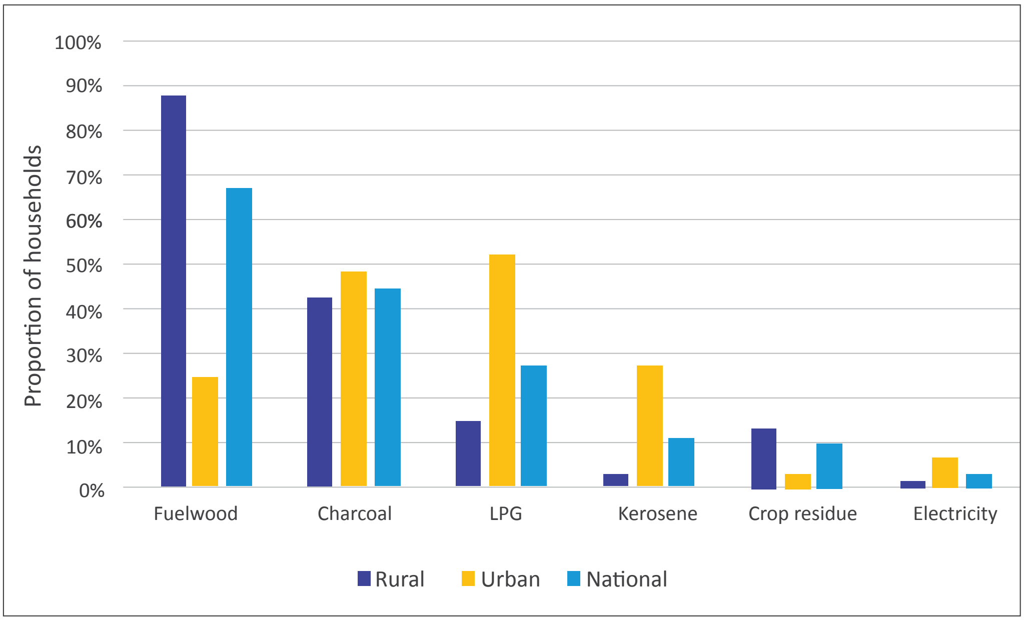


Figure 35: Household cooking fuels nationwide (without aggregating pri., sec., and tertiary use)

Stacking has implications for programmes that aim to reduce or displace the use of traditional forms of cooking with clean fuels like LPG. While access to a clean cooking solution is a positive step, this study finds that most Kenyan households using LPG as their primary cooking option also use one or more traditional fuels like charcoal (47%), wood (17%), and kerosene (18%). Researchers have demonstrated that even minimal use of polluting fuels in combination with clean fuels can confound efforts to improve health. To achieve World Health Organisation standards for $PM_{2.5}$[73], traditional wood or charcoal burning must be limited to just 1–3 hr/week.[74] Data from this survey shows that wood, charcoal, and kerosene consumption among households using LPG as their primary fuel is lower than households using polluting fuels as their primary fuel but is still substantial. Figure 36 compares fuel consumption among households using different primary stoves, with LPG users represented far left corner of the graph. Among households that have LPG as their primary fuel, those that also use fuelwood, charcoal or kerosene as their second option consume 144 ± 51 kg, 48 ± 9 kg and 14 ± 3 kg per household per month of the secondary fuel respectively[75]. The message here is clear that uptake of clean fuels although it typically results in the reduction of use of traditional fuels it does not necessarily translate into complete displacement.

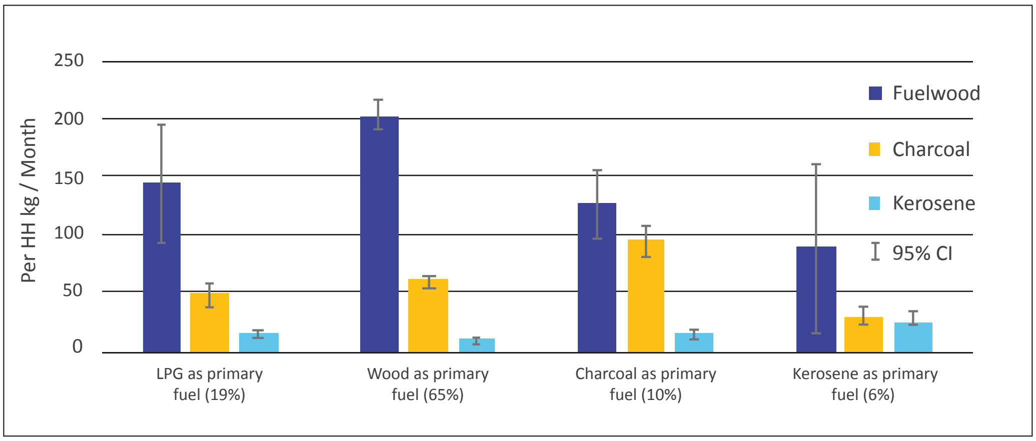


Figure 36: Monthly consumption of polluting fuels by HHs

5.1 Last Mile Distribution Channels

5.1.1 Modes of fuel acquisition

This study also sought to understand how households acquire the various fuels seen in the market looking at aspects of purchase versus collection, methods of delivery from source to household, types of fuel vendors and distances travelled to purchase fuels. As may be expected, incidences of fuelwood purchase in rural setting is less prevalent than in urban areas. 27% of urban households using firewood purchase it, compared to 12% of rural households. At 28%, a notable proportion of rural households that use charcoal report producing it themselves as opposed to purchasing. The rise of LPG last mile transporters is also notable - an aspect that has not been documented in the past at a national level. 34% and 21% of urban and rural LPG users respectively report having the fuel delivered to their households. With the advent of the *boda-boda* (motor cycle riding services), there has been innovation around transport and delivery services in Kenya. *Boda-bodas* now play a significant role in the delivery of LPG to both rural and urban households. This is a further elongation of the LPG value chain but a necessary addition that seems to address the last mile distribution challenge in some contexts.

[73]According to the WHO Air quality guidelines, 2006, the mean levels of $PM_{2.5}$ should be 10microgram/m^3. This is the lowest levels at which total cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence and response to long term exposure to $PM_{2.5}$

[74]Johnson, M.A. and Chiang, R.A. (2015). Quantitative guidance for stove usage and performance to achieve health and environmental targets. Environ Health Perspect 123:820–826. http://dx.doi.org/10.1289/ehp.1408681

[75] Data are given as mean ± 95% confidence interval.

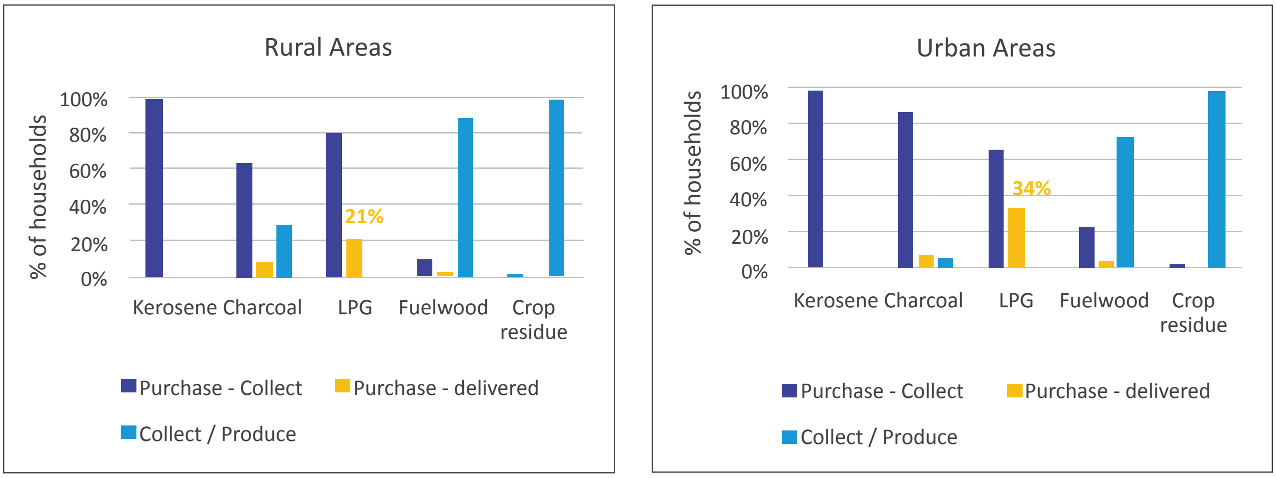


Figure 37: Modes of acquisition of the most commonly observed fuels for rural and urban household use

5.1.2 Fuel acquisition points

Last mile fuel distribution points vary with fuels as seen in Figure 38. For instance, kiosks play a significant role in the access of kerosene and charcoal both in the urban and the rural setting. Firewood is mostly purchased from open markets both in urban and rural areas. Of note is that only 40% of LPG is purchased from specialty stores (e.g. petrol stations) in urban areas with the largest distribution points being kiosks at 42%. In addition to the *boda-bodas*, the stocking of LPG cylinders at local kiosks is seen to significantly improve last mile distribution of LPG both in the urban and rural areas. The sale of LPG has evolved from restricted purchase by tank brand in speciality store (e.g. petrol stations) to purchase across any speciality store to a diversified suite of options including kiosks and home delivery. This provides valuable lessons on the last mile landscape to promoters of other fuels aiming to increase penetration and use.

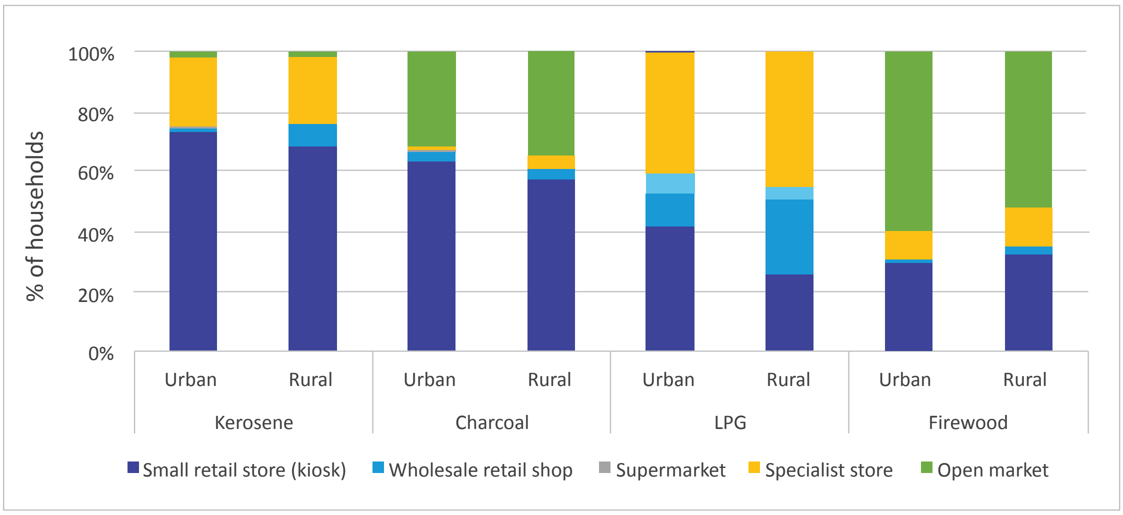


Figure 38: Last mile fuel distribution points

5.1.3 Distance to fuel purchase points

Poor populations generally have limited access to cleaner fuels[76] and data from this survey confirms this trend in Kenya. As a proxy for access, the study asked respondents what distances they travel to obtain the fuels they purchased. Rural consumers, who tend to have on average lesser disposable income, travelled further than urban consumers for all commercial fuels except purchased fuelwood (Figure 39).

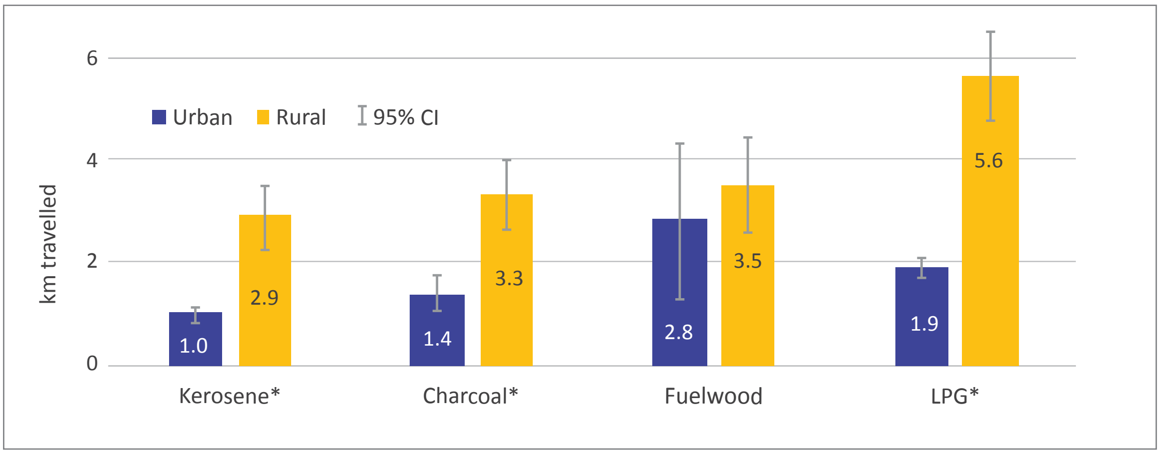


Figure 39: Average travel distance to access commercial fuels for urban and rural residential consumers (stars denote statistically significant differences between rural and urban areas with 95% confidence)

5.1.4 Fuel Availability

The study also sought to evaluate respondents' perceptions on availability of the various fuels used. This was based on the question, "In the past 12 months, how often was [fuel used] unavailable in the quantity you desired?" Figure 40 summarizes the observations.

At an average of 86% and 81% in urban and rural areas respectively, LPG users were more likely to note that they have not had concerns on availability of LPG in the quantities desired over the last 12 months compared to any other fuel. Charcoal users, on the other hand, had the highest incidence of people indicating that the fuel was either 'often' or 'sometimes' not available in quantities desired. Also, worth noting is the observation that while kerosene has relatively well-developed last mile distribution networks when assessed against distances travelled and purchase points, there are concerns over consistency of supply in rural areas with 37% of users noting that they 'often' or 'sometimes' unable to access the fuel in quantities desired. Disaggregating the information by gender does not highlight significant variances in opinion between female and male respondents. Like distances travelled to purchase a type of fuel in section 5.1.3, this data should not be equated to the fuel availability across the country but as reported by uses of the fuel.

[76] Sovacool, B. K., M. Bazilian and M. Toman. (2016). Paradigms and poverty in global energy policy: research needs for achieving universal energy access. *Environmental Research Letters* 11(6): Retrieved from https://iopscience.iop.org/article/10.1088/1748-9326/11/6/064014/pdf

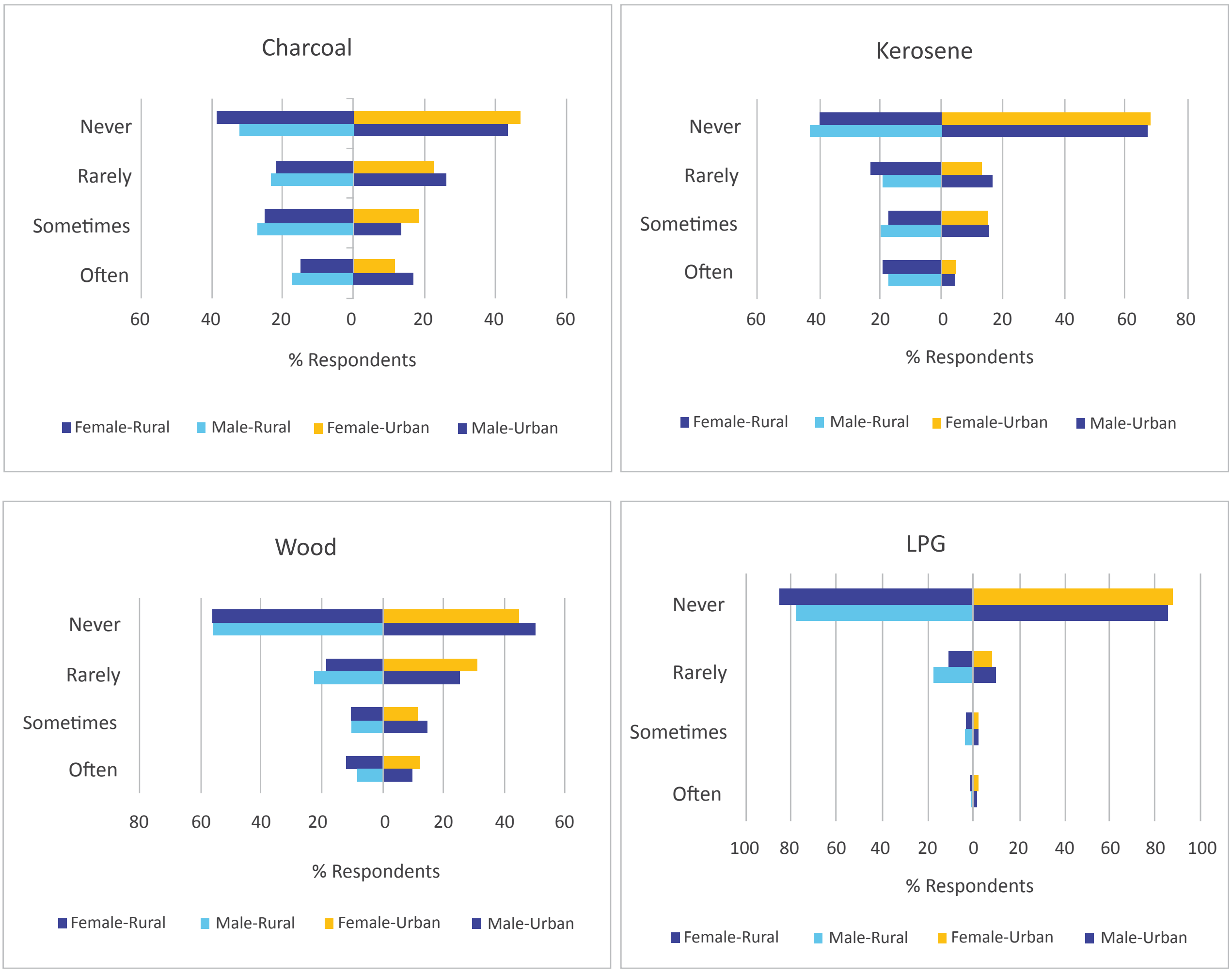


Figure 40: Unavailability of fuel in quantities desired disaggregated by gender and locality (often – more than once a month; rarely – 4-12 times a year)

5.2 Fuel consumption and prices

The survey studied weekly consumption trends for all fuels and expenditure data for all purchased fuels. This data has been used to estimate annual consumption and expenditure for household cooking energy in the country. This in part, make this comparable to past national surveys such as Nyang (1999) and KAMFOR (2001).

5.2.1 Consumption

Household-level consumption was estimated based on a respondent's recollection of the fuel(s) they had consumed in the past week leading up to the interview, or in the case of LPG, size of the cylinder typically purchased (3kg, 6kg, 13 kg or other), and roughly how many months the cylinder lasts. Enumerators were trained to first ask the size of the cylinder followed by the duration it lasts on average. This data was input on ODK and a backend calculator converted the data into usage per week. The questionnaire also included an option for 40kg cylinders, but no households indicated using this larger cylinder. This question did not factor in whether usage was at a primary, secondary or tertiary level, as long as it was part of the fuel mix. Table 19 provides a summary of the weekly per capita consumption of different fuels disaggregated as rural, urban and national.

Table 19: Weekly household consumption of fuels (Kgs but Ltrs for Kerosene)

Fuel	Urban		Rural		National	
	Mean	Median	Mean	Median	Mean	Median
Fuelwood (kg)	23.7	15.0	26.2	20.0	25.9	20.0
Charcoal (kg)	7.0	4.0	7.9	5.0	7.6	4.0
LPG (kg)	1.3	1.5	0.9	0.8	1.1	0.8
Kerosene (l)	2.5	2.0	1.5	1.0	2.2	2.0
Crop Residues (kg)	5.2	3.0	8.1	5.0	7.7	5.0

We used these data to estimate annual consumption by simply multiplying weekly or monthly consumption by 52 or 12. Table 20 shows average annual consumption per household with 95% confidence intervals for each fuel and the proportion of the Kenyan population using that fuel. Combining the results in Table 20 with estimates of the total urban and rural households in Kenya results in a rough estimate of nationwide residential fuel consumption. This is shown in Table 21[77].

Table 21 reinforces some of the long-understood differences between energy demands in urban and rural households, but challenges others. Fuelwood and crop residues, typically rural fuels, are used by far more households and have higher median consumption in rural areas. The same holds for LPG and kerosene in urban households. However, charcoal, which has traditionally been considered an urban fuel, is used by nearly the same proportion of urban and rural households. Moreover, as seen in Table 21, consumption per household is higher in rural areas (though per capita consumption is similar in the two regions) with a plausible reason being rural families are larger than urban families.

Table 20: Average annual consumption for common cooking fuels by households[78]

Fuel	Urban			Rural			Total		
	% HHs using	Average (kg/yr)	95% CI (kg/yr)	% HHs using	Average (kg/yr)	95% CI (kg/yr)	% HHs using	Average (kg/yr)	95% CI (kg/yr)
Fuelwood	24%	1232	224	86%	1362	60	67%	1349	59
Charcoal	46%	364	44	42%	411	29	44%	395	24
LPG	51%	68	3	15%	47	3	27%	57	2
Kerosene	29%	163	12	7%	78	10	14%	114	9
Crop Residues	3%	270	155	11%	421	61	9%	400	57

Table 21: Average annual residential consumption of common cooking fuels nationwide

	Urban (%)		Rural (%)		Total (%)	
	Average (kton/yr)	95% CI (kton /yr)	Average (kton/yr)	95% CI (kton /yr)	Average (kton/yr)	95% CI (kton /yr)
Fuelwood	1294	235	8296	394	9590	447
Charcoal	732	88	1271	98	1969	122
LPG	151	8	50	4	201	7
Kerosene	205	16	38	5	243	15
Crop Residues	39	23	333	48	372	56

Summing up the representative survey data results in estimates of 9.6 Mton of fuelwood (95% CI: 9.1-10.0), 2.0 Mton of charcoal (95% CI: 1.8-2.1), 201 kton of LPG (95% CI: 190-210), 243 kton of kerosene (95% CI: 230-260), and 372 kton of crop residues (95% CI: 320-430). Charcoal has been known as an urban fuel, but this is increasingly changing as more rural areas use it as a primary cooking fuel.

5.2.2 Prices

Most fuels, except for LPG, can be purchased in small quantities and consumed within a few days. For these, the survey asked respondents about their expenditure and quantity consumed in the past week. These quantities were divided to obtain a unit cost: KES per kg for fuels sold by mass or KES per litre for kerosene. For LPG, respondents were asked about the size of the cylinder that they own (3kg, 6kg or 13kg) and the cost of refilling. These quantities were computed to estimate monthly cost, which were converted to weekly values. Table 22 presents the median and average weekly spend on the main cooking fuels used in Kenya. The kerosene costs presented do not disaggregate the cost of kerosene for cooking from that of kerosene for lighting. Use of LPG has the lowest mean and median at the national scale as well as disaggregated between urban and rural respondents.

Table 22: Weekly average and median expenditure on cooking fuels (KES/Week)

Fuel	Urban		Rural		National	
	Median	Mean	Median	Mean	Median	Mean
Kerosene	200	245	105	142	200	211
Charcoal	200	270	200	229	200	246
Fuelwood	250	342	250	409	250	396
LPG	188	200	113	137	138	176

Fuels have different energy content values and stoves have different thermal efficiencies. A more balanced comparison of fuel prices accounts for these factors by considering the cost of energy delivered to the cooking pot. Figure 41 shows both KES per unit mass and USD per unit energy delivered[79]. Prices vary by fuel and differ slightly between urban and rural markets. Commercial fuels like LPG and kerosene are more expensive per unit mass. However, when converted to useful energy by accounting for the energy content of the fuel and efficiency of the stove, the pattern differs considerably. Due to its low energy content and poor energy conversion efficiency, purchased fuelwood, the cheapest fuel per kilo, is the most expensive in terms of energy delivered. LPG, the costliest fuel on a mass basis, is marginally more expensive than the remaining options. Kerosene is the cheapest fuel in terms of energy delivered. As explained, kerosene is also the most accessible fuel in terms of distance consumers must travel to acquire it. Despite these factors, kerosene is not a popular fuel among Kenyans using purchased fuels; far more people use charcoal or LPG either as primary and secondary cooking options (Section 3.2). Thus, factors other than ease of access and energy cost must be factored into household decisions.

Energy density[80] varies across and even within fuels making the comparison of the cost of various fuels per unit mass or volume incomplete. Figure 42

[77] Estimates of population, extrapolated from the last census, are from UNICEF, available at https://data.humdata.org/dataset/kenya-population-projection-by-county-2009-2018-and-subcounty-2015.
[78] The table omits fuels used by less than 1% of households: sawdust, dung, biogas, pellets, ethanol, and briquettes.
[79] Energy cost is estimated using fuel calorific value and stove conversion efficiency. See Annex A1.3 for details.
[80] *Specific energy* is the technical term used interchangeably with energy content

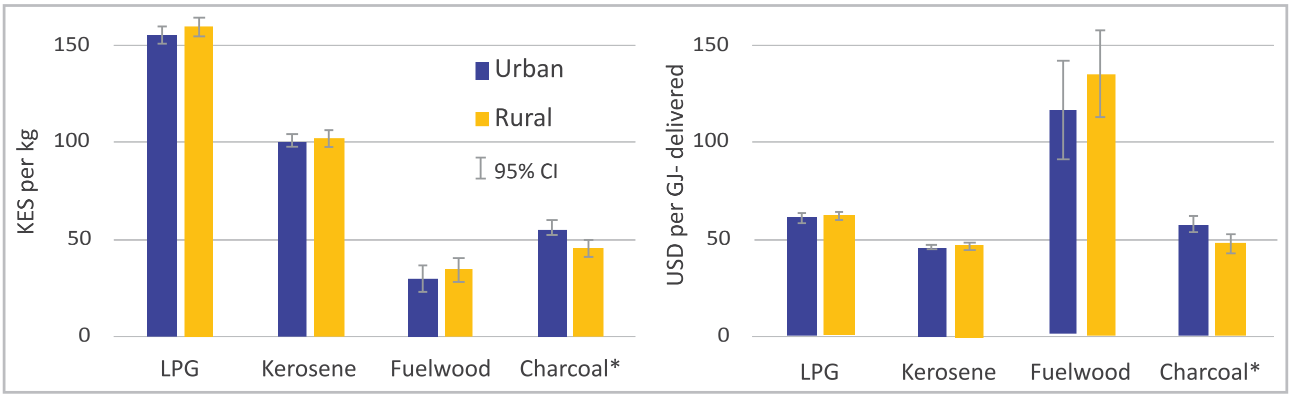
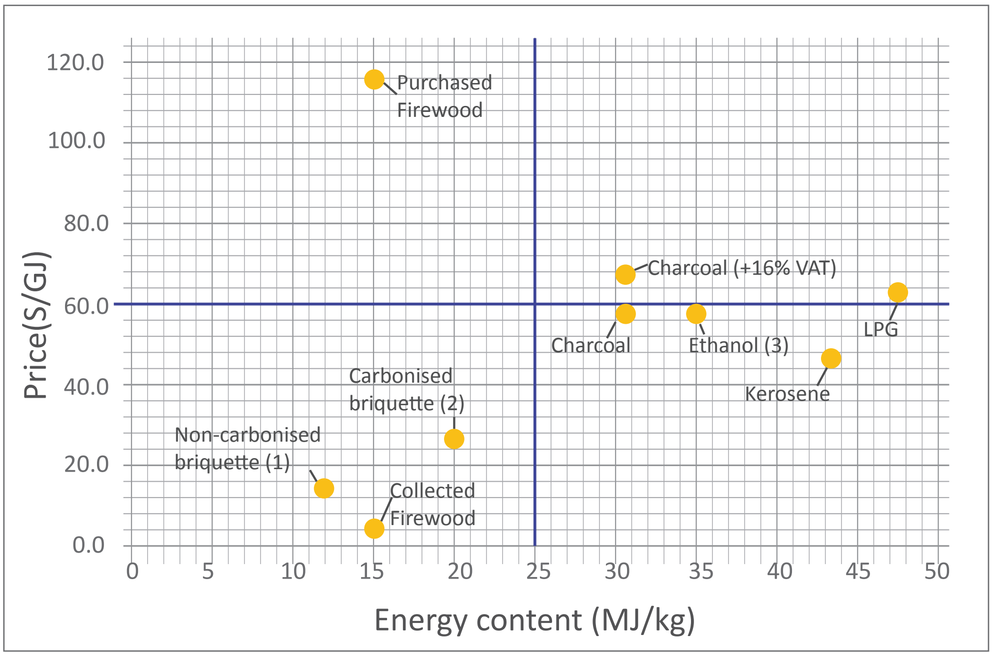


Figure 41: Fuel price per unit mass (left) and energy delivered (right) for major commercial fuels (star denotes statistically significant differences between rural and urban areas with 95% confidence)

compares various fuels based on price per unit of energy ($/GJ) and energy density (MJ/kg). Apart from the estimated prices of non-carbonized and carbonized briquettes, the rest of the statistics are average market prices reported by respondents covered in the household energy survey. The sample sizes across fuels are statistically robust apart from ethanol, which had less than 10 data points. Fuels are split into four quadrants: high price, low energy (quadrant 1), high price, high energy (quadrant 2), low price, low energy content (quadrant 3) and low price, high energy content (quadrant 3). This contributes to the market preference and demand for charcoal, kerosene and LPG for cooking as the three are in quadrant 4. It also explains why most forms of briquettes are not cost competitive as substitutes for charcoal at the household level. Other factors affecting demand discussed in this report include ease of access (extent of the distribution networks), ease of use, affordability of the cooking device and



[1] and [2] – from secondary data[81]; [3] – less than 10 data points

Figure 42: Cost of fuels based on price per unit of energy ($/GJ) and energy density (MJ/kg)

divisibility (for example, charcoal and kerosene are sold in very small units making them affordable to low income households). Although ethanol is price competitive (although the data points are limited to 10), the distribution network is still nascent and there are challenges with supply. Applying a 16% VAT on charcoal raises the fuel into quadrant 2 (high cost, high energy.) The impact of such a policy move needs to be evaluated further since it does not automatically result in higher demand for cleaner fuels. In some cases, it may result in an increase in demand for kerosene.

5.3 Case 4: Lessons from the Rise in use of LPG

The LPG market in Kenya has experienced tremendous growth over the past decade. Figure 43 highlights the growth in LPG sales as presented in two reports: the 2018 KNBS Statistical Abstract and PIEA's quarterly publication, Petroleum Insight, for March 2018. While there is a variance in the reported sales values between the reports, both clearly demonstrate a rise in uptake, with 2013 marking a clear point of inflection.

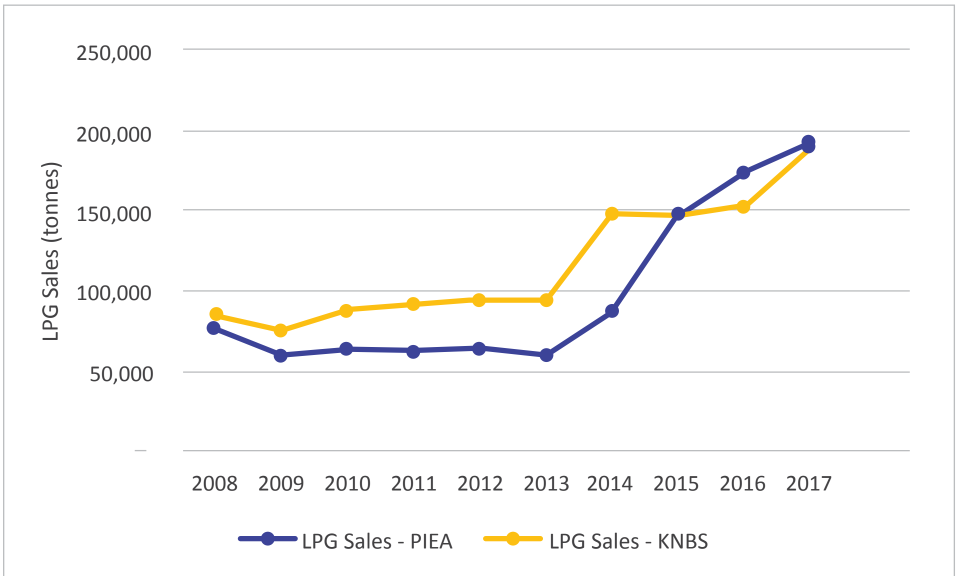


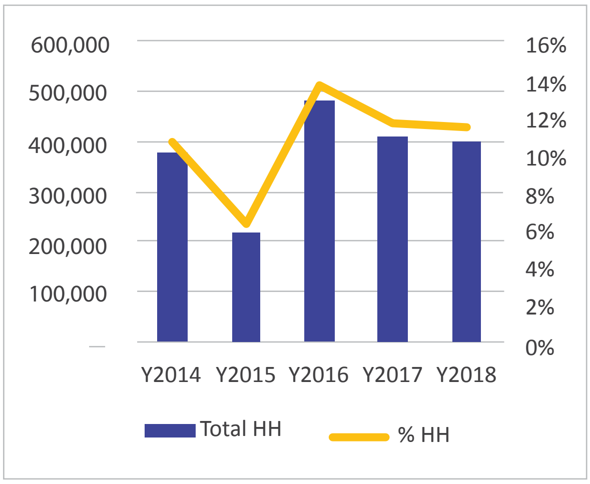
Figure 43: LPG Sales in Kenya (2008 – 2017)

According to Nyang (1999), only 9% (20% urban and 4% rural) of households in Kenya were using LPG as a cooking solution as of 1999[82]. The Kamfor study (2002) estimates this to be 8% (23% urban and 1.8% rural) about two years later[83]. Over the last two decades, the number of households using LPG has increased about six times from about 0.6 million to 3.7 million: The current use rate is estimated at 29.7% (54.2% urban and 18% rural) and an estimated 2.8 million households use LPG stoves as their primary stove. Beyond the overall national use rate, this study finds that more than half (53.4%) of the households using LPG started using it within the last five years - translating to an estimated 2 million households. Disaggregated by urban and rural households, 60.6% and 40.7% of current users respectively started using the LPG stove within this period. Notably the number of households using LPG

[81] Camco (2012) Analysing briquette markers in Tanzania, Kenya and Uganda, Energy and Environment Partnership (EEP), Gauteng, South Africa
[82] Nyang, F. (1999). Household Energy Demand and Environmental Management in Kenya (Doctoral dissertation). University of Amsterdam.
[83] Republic of Kenya. (2002). *Study in Kenya's Energy Demand, Supply and Policy Strategy for Household, Small Scale Industries and Service Establishment. Nairobi: Ministry of Energy*

is not equivalent to the number of stoves sold over the same as households could own more than one LPG based solution. The study asked the respondents how long they have been using LPG as a cooking option rather than when they purchased the stove. The most impressive growth has been realized in the last three years, with 42.4% urban users and 26.1% of rural users having started using LPG during this period as shown in Figure 44. The largest increase in number of new LPG users (about half a million) was in Y2016 and is a very likely reaction to the zero-rating of LPG in the Finance Act of 2016. Figure 44 compares the number of new users (households) with the tonnes of LPG sold in the market[84]. Note that the total LPG sales statistics are not exclusive to domestic users but includes others (commercial and institutional). Although not similar, the two graphs show a surge around Y2016.

Here we highlight four key reasons that have contributed to this impressive rise in the uptake of LPG as lessons to inform other market transformation initiatives.



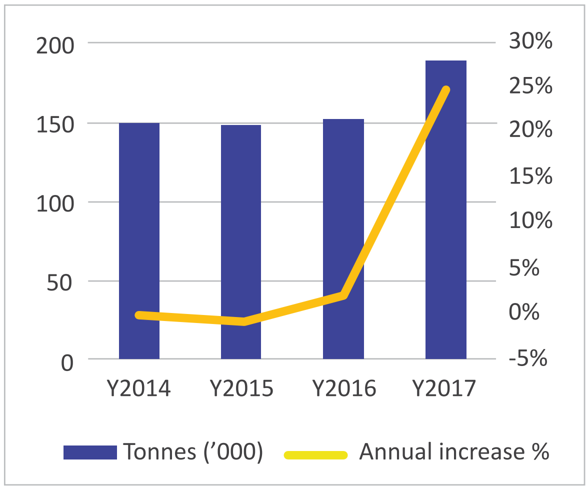


Figure 44: First-time users of LPG over the last 4 years (left) vs total LPG sales (KNBS, 2018)

a. Introduction of the smaller tanks (6kg complete LPG cylinders):

The introduction of smaller portable tanks, especially the 6 kg cylinders, and the easy-to-use low-cost cooking grills made LPG more accessible to lower income households. Total Kenya claims to have been the first distributor to introduce the 6 kg complete LPG cylinder – branded as Meko - into the market in the early 2000s[85]. However, just a reduction in size does not translate to more uptake as the introduction of the 3 kg complete LPG cylinder by the National Oil Corporation of Kenya (NOCK) in 2011 did not experience the same reception.

b. Standardisation and the LPG cylinder exchange pool:

Before the standardisation of the cylinder design, consumers would be restricted to using separate regulators and cylinders from individual dealers. Cylinders were not compatible across brands. In 2009,

[84] KNBS (2018). *Statistical Abstract 2018.*Nairobi: Kenya National Bureau of Statistics
[85] Total Kenya Limited. (2012). *Annual Report and Financial Statement.* Nairobi: Total Kenya
[86] Republic of Kenya (2018). *The Kenya Gazette Notice of 4th May 2018 (Publication No.4124).*Retrieved from http://kenyalaw.org/kenya_gazette/gazette/volume/MTcwMQ--/Vol.CXX-No.52
[87] ERC. (2018). *Wholesale LPG.* Retrieved from https://www.erc.go.ke/download/wholesale-register-lpg/

the Ministry of Energy through a subsidiary regulation – Energy (Liquefied Petroleum Gas) Regulations, 2009 instituted the LPG cylinder exchange pool, which among other things, standardized the 1kg, 3kg, 6kg and 13kg cylinders and valves and allowed LPG users to exchange their LPG cylinders with any dealers regardless of the brand. This immediately turned each LPG outlet to an exchange point accessible to all users regardless of the cylinder type they use. Gazette notice No. 4124 published on May 4th, 2018 proposed to amend this arrangement by changing the mandatory requirement to exchange with one that is done under a mutual agreement between dealers[86]. This has now come into effect. Part of this draft regulation reads, "LPG cylinder brand owners may enter into a mutual LPG Exchange Agreement to enhance their access to the LPG cylinder market". This may reduce the competitiveness of smaller distributors in favour of the larger ones if the larger distributors choose to collaborate. In such an occurrence, the larger distributors would control a significant market share making easing circulation of their cylinders. The broader goal of the regulation is to control the rising cases of illegal gas refilling points which compromise quality and safety.

c. *Innovation and expansion of last-mile distribution options:*

LPG has traditionally been sold exclusively by petrol stations and petroleum products dealers, limiting access to households that are within reasonable distance to such outlets. This, however, changed with the creation of the exchange pool and other outlets including supermarkets and local kiosks now stocking LPG. This further evolved to LPG delivery services (e.g. through motorcycles) improving downstream access. The Energy and Petroleum Regulatory Authority has licensed 89 firms to operate as wholesalers of LPG and 43 firms to provide storage and refilling services[87]. Building on this point-to-point delivery system, companies like PayGo and Envirofit are using technology to further optimize the supply of LPG by not only monitoring cylinder volumes remotely and delivering full cylinders directly to households based on need, but also to allowing users to pay for the gas as they use it, rather than having to pay for the whole cylinder's worth at once.

d. *Fiscal and tax incentives:*

The Minister of Finance through the Finance Act of 2016 zero-rated LPG sending a strong signal to the market on the Government's intention to promote the uptake of LPG. This has contributed greatly to the increase in use of this fuel option. Data from this study as well as annual statistics presented by the Kenya National Bureau of Statistics show a surge in the use of LPG around this time. As a measure to address incidences of adulteration of other petroleum products with kerosene, the Finance Act 2018 introduced a KES 18/litre levy on kerosene. Since this is a competing source of fuel for cooking, it is expected that some of the users of kerosene will now shift to LPG and other alternatives.

[86] Republic of Kenya (2018). *The Kenya Gazette Notice of 4th May 2018 (Publication No.4124).*Retrieved from http://kenyalaw.org/kenya_gazette/gazette/volume/MTcwMQ--/Vol.CXX-No.52

[87] ERC. (2018). *Wholesale LPG.* Retrieved from https://www.erc.go.ke/download/wholesale-register-lpg/

6. MARKET ENABLERS

The cooking sector in Kenya is composed of various stakeholders who play unique but interrelated roles in promoting access to both cooking technologies and fuels. It is regulated by standards, policy, legal and institutional frameworks established at global, regional, national and sub-national levels. Although access to finance remains a key barrier, various forms of finance and financial services are available to the sector players. This chapter provides a map of the key stakeholders while discussing the enabling environment supporting, influencing or stifling access to various forms of cooking solutions.

6.1 Institutional Structure

The cooking sector has several players as summarized in Figure 45. These range from the national and county governments that shape policies and regulations affecting the sector, to end users who are the consumers of both fuels and stoves.

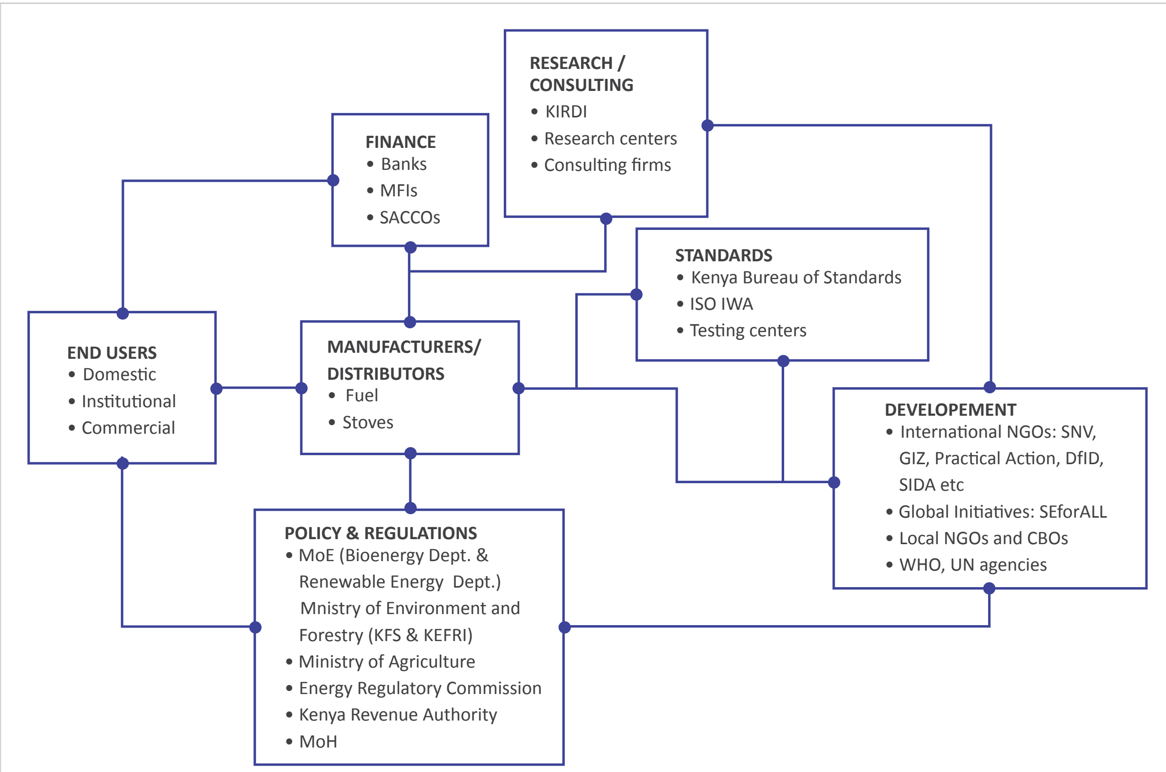


Figure 45: Map of Stakeholder in the Cooking Sector.

6.2 Legal, Regulatory and Policy Frameworks

6.2.1 Global Frameworks

The Sustainable Development Goals (SDG) of the United Nations, adopted in January 2016, are a set of 17 goals, each with its own set of targets, and are the "blueprint to achieve a better and more sustainable future for all"[88] globally. SDG 7 on affordable and clean energy seeks to ensure access to affordable, reliable, sustainable and modern energy. The Goal has 5 main objectives to be achieved by 2030 as listed below:

- Ensure universal access to affordable, reliable and modern energy services;
- Increase substantially the share of renewable energy in the global energy mix;
- Double the global rate of improvement in energy efficiency;
- Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology;
- Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support.

In addition to ensuring energy access for all, the targets have a focus on the use of cleaner energy sources and use of energy efficient technologies to reach this goal. This is especially critical in consideration of risks posed by climate change and the need to mitigate this risk through reduced emissions.

The Paris Agreement is a global effort to address climate change. The Agreement entered into force on 4th November 2016 and is currently ratified by 184 of the 197 Parties to the Convention[89]. Central to the agreement is the goal to limit the global temperature rise to below 2°C of the pre-industrial temperatures while strengthening countries to deal with the adverse effects of climate change. To this end, all Parties to the Agreement are required to detail their efforts for adaptation and mitigation (including reductions in emissions) in what is termed as the 'Nationally Determined Contributions', and to regularly report against these commitments. Kenya is among the Parties and its NDCs are highlighted in the section below.

Sustainable Energy for All *(SEforALL)* is an international initiative that was central in ensuring the inclusion of universal access to modern energy services in the SDGs and the Paris Agreement, and is working with various stakeholders to "drive further, faster action toward achievement of [SDG 7] … and Paris Climate Agreement"[90]. Aligned to the SDG 7 targets, this initiative has three main objectives: ensure universal access to modern energy services; double the global rate of improvement in energy efficiency; and double the share of renewable energy in the global energy mix. To achieve its mandate, SEforALL marshal's evidence of actions, benchmarks progress, and connects stakeholders to each other and to solutions. Kenya was among the first countries to sign a commitment to the SEforALL Initiative and has to date developed a SEforALL Investment Prospectus detailing actions that the Government will carry out to ensure access to energy for all. Universal access to clean cooking is among the priority actions identified within the Action Agenda. High Impact Initiatives relevant under the clean cooking sector are highlighted and include Regional, National

[88]United Nations. (n.d.). *Sustainable Development Goals*. Retrieved from https://www.un.org/sustainabledevelopment/energy/
[89]UNFCCC. (2018). *Paris Agreement – Status of Ratification*. Retrieved from https://unfccc.int/process/the-paris-agreement/status-of-ratification.
[90]Sustainable Energy for All. (n.d). *About SEforALL*. Retrieved from https://www.SEforALL.org/about-us

and Sub-national financing and development of business models. Elaboration of the stipulated actions follows in subsequent sections. Kenya has localized the SEforALL objectives under the ***SEforALL Action Agenda*** where Kenya's overall vision for SEforALL is to attain universal access to affordable and quality energy. This is further elaborated with the mission statement that Kenya seeks to "facilitate provision of clean, sustainable, affordable, competitive, reliable and secure energy services at least cost while protecting the environment".

The Alliance (former Global Alliance for Clean Cooking) works with a global network of partners to build an inclusive industry that makes clean cooking accessible to the three billion people who are unreached. The Alliance's work is in alignment with the Sustainable Development Goals and is geared towards achieving universal access to clean cooking by 2030. The Alliance works in collaboration with the ***Clean Cookstoves Association of Kenya (CCAK)*** whose mission is to facilitate the scale up of clean cookstoves and clean fuels markets in Kenya. CCAK aims to "facilitate the increase of adoption of clean cookstoves and fuels to 5 million households in Kenya by 2020" with a rallying call to have "over 10 million Kenyan households using clean cooking solutions by 2022"[91].

6.2.2 Regional frameworks

The East African Community (EAC) is a regional economic community whose membership is comprised of Burundi, Kenya, Rwanda, South Sudan, Tanzania and Uganda. Among the efforts of the EAC is regional integration in 4 key areas: Customs Union, Common Market, Monetary Union and Political Federation[92]. Customs Union and Common Market integration pillars are seen to have a direct impact on the Kenya clean cooking sector.

The Customs Union Integration Pillar establishes free trade on goods and services within the bloc and imposition of a common external tariff (CET) on imports from non-EAC countries when sold to EAC partner States. Under this integration pillar, the bloc amended custom duties and the CET with the new tariffs coming into effect from 1 July 2018[93]. Relevant to the cooking sector was the zero-rating (0% import duty) of inputs and raw materials for use in the manufacture of energy saving stoves imported by gazetted users in all EAC Parties except Tanzania. Additionally, the policy includes country specific CET duty rates effective for a one-year period starting from 1 July 2018 that have been approved to address country specific economic needs. Among these duty rates is the imposition of a 35% import duty on complete sets of non-electric cooking appliances including stoves for Kenya. This change in tax policies revised the government's 2016 decision to reduce import tax on complete stoves and parts from 25% to 10%. Tax on parts for manufacturing stoves was, however, maintained at 10%. It is argued that these tax policies are anchored under the *Big Four Agenda of the Government of Kenya,* where one of the pillars is enhancing manufacturing by zero rating of inputs for energy saving stoves and imposing a 35% tax on complete units is expected to promote local manufacture / assembly of energy saving stoves. While this is the case, this may also negatively impact distributors in Kenya who import complete products. From discussions with various stove distributors, it is observed that this tax regime will significantly increase the cost of imported products reducing affordability by the end-user. Additionally, some distributors indicated considerations to move to neighbouring markets with lower tax requirements, and therefore more conducive business environment. Overall, this may have a cascading negative effect on achieving the target number of improved cookstoves that should be

[91]Clean Cookstove Association of Kenya. (n.d). About CCAK. Retrieved from https://kenyacookstoves.org/about-us/

[92]East African Community. (n.d.). Pillars of EAC Regional Integration. Retrieved from https://www.eac.int/integration-pillars

[93]Ernst & Young. (2018). Indirect Tax Alert: *The East African Community amends custom duties and common external tariffs.* Retrieved from https://www.ey.com/gl/en/services/tax/international-tax/tax-alert-library

disseminated within the country- Kenya targets that the number of households using improved biomass cookstoves will increase by 4 million by 2022 as part of attaining its Nationally Determined Contribution under the Paris Agreement[94] and realizing universal access to clean cooking by 2030.

The Common Markets Integration pillar provides freedoms and rights that foster economic growth and development within the EAC. Energy is one of the sectors under the common market pillar where the EAC seeks to adopt "policies and mechanisms to promote the efficient exploitation, development, joint research and utilisation of various energy resources available within the region" as detailed in Article 101 of the Treaty of the Establishment of the East African Community. To this effect, the EAC has, among other things[95]:

1. Developed the *Regional Strategy on Scaling Up Access to Modern Energy Services.* The Strategy, which was adopted by EAC Council of Ministers in November 2016, promotes adoption of high impact, low cost scalable approaches and its targets include: Access to modern cooking practices for 50% of traditional biomass users; access to reliable electricity for all urban and peri-urban poor; access to modern energy services for all schools, clinics, hospitals and community centres; and access to mechanical power within the community for all productive services. While the strategy was a step in the right direction, it is observed to have had various weaknesses among them being[96]: It was developed at the EAC level but Partner States were responsible for implementation yet no effective power for enforcement was granted to the EAC; the Strategy set very ambitious targets that required significant resources to realize yet Partner States have limited funding available for executions; the strategy did not lay a roadmap for realisation of targets leaving Partner States to implement it as they saw fit. There are good lessons for Kenya from this strategy as the country looks to implement plans to achieve SEforALL and NDC targets.

2. Established the *East African Centre for Renewable Energy and Energy Efficiency (EACREEE*). The Centre, which was launched in June 2016 and legally registered in March 2018, develops and promotes adoption of policies, legal and incentive frameworks, capacity development, and mobilisation and implementation of infrastructure that promotes renewable energy and energy efficiency. EACREEE is currently housed at Makerere University College of Engineering, Design, Art and Technology.

6.2.3 National and Subnational Frameworks

Various frameworks are seen to affect the Kenyan cooking sector including the regulatory framework, economic development goals and global aspirations for human development and environmental protection. These are discussed under the sub-headings Policies and Regulations, Standards and Development Agenda below.

6.2.4 Policies and Regulations

Following the *Constitution of Kenya 2010*, which specifically provides that each county government is responsible for county planning and development in electricity and gas reticulation and energy regulation, there is a need to update some of the current regulations to reflect the requirements of the Constitution. Though the Constitution does not

[94] Republic of Kenya (2018). *Kenya National Climate Change Action Plan for 2018-2022 – Draft.* Retrieved from Kenya Climate Change Knowledge Portal

[95] East African Community. (n.d). *Projects and Programmes – Renewable Energy.* Retrieved from https://www.eac.int/energy/renewable-energy/projects-and-programmes

[96] Norwegian Agency for Development Cooperation. (2013). F*orward Looking Review of the Regional Strategy on Scaling up Access to Modern Energy Services in The East African Community.*

elaborate on these functions, the *Energy Act of 2019*, provides some clarity on what these responsibilities entail. Relevant to this cooking sector study is the county governments' responsibility in regulating and licensing of: i) biomass production, transport and distribution; ii) biogas systems; and iii) charcoal production, transportation and distribution. At the same time, the Bill, under Article 92, gives provisions for the Cabinet Secretary to make regulations for the licensing and management of renewable energy sources including but not limited to solar, wind, biogas and biomass among others, under the recommendation of the ERC. Licensing of biomass production, transport and distribution is especially key as it includes regulating the use of charcoal. Various issues for consideration arise with this devolved approach: What roles are to be achieved at the national level and what aspects target the counties? Will licensing be standardized? What are the conditions for cross-county biomass distribution? Who within the counties is responsible for regulation and licensing?

Very deliberate efforts will be needed to ensure that these mandates are adequately devolved while ensuring congruence at the national level, and environmental protection. As highlighted by Odongo and Ngige (unpublished research)[97], the Cabinet Secretary is also required to "develop, and publish the Integrated National Energy Plan and reviews energy plans under Section 5 (1); "Sub-section (4) requires the Cabinet Secretary to consolidate the plans contemplated in subsections (2) and (3) into an integrated national energy plan which shall be reviewed after every three years"; and Subsection 6, which deals with monitoring implementation of the integrated energy plan requires the Cabinet Secretary to prepare and publish a report on the implementation of the national integrated energy within three months after the end of each financial year". The bill also proposes the establishment of the Rural Electrification and Renewable Energy Corporation, which, among other things, will be mandated with developing and promoting the use of renewable energy and technologies including those of biogas, biomass, charcoal and fuelwood. It also mandates the Cabinet Secretary with promoting the development of renewable energy technologies. In the absence of updated regulations (to align with the constitution), current regulations prevail and are highlighted below.

The Energy Sessional Paper No. 4 (2004) is among the most influential policy interventions in Kenya addressing the demand and supply of energy for cooking in the country. The paper recognizes biomass fuels as the most important source of primary energy in Kenya, and specifically wood fuel, which was at 68% of the total primary energy consumption at the time of drafting. It further presents various challenges faced by the cooking sector, the main one being a household woodfuel demand that exceeded the sustainable supply by 20 million metric tonnes in 2004 and whose deficit was projected to rise to 33 million metric tonnes by 2020. To address this, the paper presents commitments that are directly targeted at the cooking sector and relevant to this cooking sector study. Among these are Government's commitments to:

i. "Licence charcoal production to encourage its commercial production in a sustainable manner;
ii. Promote private sector participation in energy production, distribution and marketing;
iii. Increase the adoption of efficient charcoal stoves from 47% [in 2004] to 80% by 2010 and to 100% by 2020 in urban areas; and to 40% by 2010 and 60% by 2020 in rural areas;

[97]Odongo, F., and Ngigi, A. (n.d). *Implications of the Energy Bill 2017* on the clean cooking sector

iv. Increase the rate of adoption of efficient fuelwood stoves from 4% [in 2004] to 30% by 2020;
v. Increase the efficiency of the improved charcoal stove from 30/35% [in 2004] to 45-50% by 2020 and;
vi. Offer training opportunities for Jua Kali artisans at the village level for the manufacture, ***installation*** and maintenance of renewable energy technologies including efficient cookstoves."

Additionally, the paper acknowledges the need for policies that influence a shift to use of cleaner fuels. Among these is a measure to promote "wider use of both kerosene and LPG in households, as an alternative fuel to improve the quality of household energy and mitigate demand on woodfuel" under the Petroleum Supply and Distribution Policy of this Sessional Paper. This is due to be replaced by a new Energy Policy at the final stages of approval.

The Energy Act 2019 replaces the Energy Act of 2006 and will guide the energy sector through 2030. Regarding the cooking sector, the draft regulations specify policies and strategies for biomass, biofuels, biogas and LPG among others. Among the strategies presented include, but are not limited to: taking the necessary steps to transition the country from use of kerosene, firewood and charcoal to environmentally friendly fuels such as LPG; promote efficient conversion and cleaner utilisation of biomass energy; promote use of briquettes as an alternative to wood fuels; provide incentives for biofuel production projects and consumption and implement a bioethanol pilot project; and promote the use of biogas an alternative to woodfuel and kerosene for both domestic and commercial use.

The Forest (Charcoal) Rules of 2009 and revised in 2012 by the ERC (now EPRA) act upon some of the articles of the Energy Act of 2006, specifically those regulating the sustainable production, transportation and marketing of charcoal. Key components of the regulations include: charcoal producers and transporters must be licensed by the Kenya Forest Service (KFS) and licensing requirements are laid out; commercial charcoal producers must organize themselves in Charcoal Producers Associations (CPAs) which in addition to facilitating sustainable charcoal production, must implement reforestation conservation plans; charcoal wholesalers or retailers should not trade with unlicensed producers and should keep records of their sources of charcoal; charcoal producers are prohibited from use of endangered or threatened plant species in charcoal production, among others.

The Forest Conservation and Management Act of 2016 retains the licensing role of KFS noting that the service is to "receive and consider applications for licenses or permits in relation to forest resources" and to "implement and enforce rules and regulations governing importation, exportation and trade in forest produce". Among the Regulations provided for by the Act concern production, transportation and marketing of charcoal. The Act continues to note that anyone who "makes or is found in possession of charcoal in a national, county or provisional forest; or in community forest, private forest or farmlands without a license or permit of the owner" commits an offence.

The Energy (Liquified Petroleum Gas) regulations of 2009 are subsidiary regulations anchored on the Energy Act, 2006. These regulations outline the licensing requirements for those involved in the LPG business including the importation, bulk storage, filling, transportation, wholesale and retail trade of LPG. It also includes safety measures and powers of inspection of business vehicles or facilities by the ERC, as well as requirements to adhere to KEBS standards for cylinder specifications and handling, storage and distribution of LPG. The Regulations standardized LPG cylinders of the capacities 1kg, 3kg, 6kg and 13kg and their respective valves used, and established an LPG cylinder exchange pool that "regulates the exchange of LPG cylinders among the LPG marketing companies". This exchange pool made it possible for variedly branded cylinders to be accepted at any refill station. This has now been modified and restricts this exchange to distributors who have a mutual agreement.

In reference to the Sessional Paper 4 of 2004 and the Energy act of 2006 are the ***Energy (Improved Biomass Cookstoves) Regulations of 2013***. The regulations are intended for manufacturers, importers, distributors, technicians, and contractors of improved Biomass Cookstoves, and institutions using biomass fuels for cooking and heating purposes. Institutions that rely on biomass for cooking are required to install improved biomass cookstoves and maintain records of the stoves installed in their premises. The regulations also set out the various classes and requirements for licensing for installation, maintenance, manufacture, importation and distribution of cookstoves for both household and institutional use.

6.2.5 Government Initiatives and Programs

Kenya's Vision 2030 is the country's development blue print for transformation to an industrialized middle-income county by 2030. The Vision recognizes the "development of new and renewable sources of energy" as a key enabler for this development. It also hopes to ensure sustainable energy for all by 2030.

With this regard, the government seeks to promote the use of alternative sources of energy including biogas, bio-energy (including bio-ethanol) and diesel value chains. The Vision also seeks to promote the adoption of improved cooking stoves and charcoal kilns. Designed to cover 5-year durations, Medium Term Plans (MTP) lay the road map for realisation of the vision. The first MTP covered 2008-12, the second 2013-17 and the current MTP covers 2018-2022. The current plan, MTP III is packaged as the government's Big Four initiatives that seek to prioritize manufacturing, affordable housing, food and nutrition security and universal health coverage. It is under the manufacturing pillar that the government is promoting local production of, and/or assembly of cooking solutions through the increment of the tax on non-electric cooking appliances from 10% to 35%[98, 99].

The efforts to promote the uptake of alternative fuels and improved cookstoves are already being seen through government programmeming, initiatives and legislation both at the national and sub-national level. Among national actions are:

i. ***The Gas Yetu – The Mwanachi Gas Project*** by National Oil Corporation of Kenya aims to distribute 6Kg complete LPG cylinders with the goal to increase LPG penetration to 70% by 2020. The project design includes distribution of complete LPG cylinders at a discounted price of KES 2000 enabled by a government subsidy on the initial cylinder stove, and development of last mile distribution channels where the distribution model involves working with at least one distributor per sub-county. At the time of this study, a pilot test had been conducted in Kajiado North Sub-county and Machakos County. The media, however, reported that the project had been suspended though reasons for suspension remain unclear. If implemented as currently envisioned, the project will have significant impact on LPG penetration and usage.

ii. ***Finance Act of 2018*** saw the introduction of an anti-adulteration levy of KES 18 per litre levied on kerosene. While this levy was mainly intended to discourage the adulteration of vehicle fuels, it is

[98] This tax increment is for the current financial year 2018/19.
[99] Ernst & Young. (2018). *Indirect Tax Alert: The East African Community amends custom duties and common external tariffs.* Retrieved from https://www.ey.com /gl/en/services/tax/international-tax/tax-alert-library

expected to have the secondary effect of reducing the use of kerosene for household cooking, especially among the urban poor, due to the increased unit costs of the fuel. Consequently, it is expected that households will turn to cheaper alternative fuels with LPG being a very likely alternative given stove preference among urban households.

iii. ***The Kenya Off-grid Solar Access Project***, a flagship project of the Ministry of Energy running from 2017 to 2023 and financed by the World Bank, seeks to "increase access to modern energy services in underserved counties of Kenya"[100]. According to the Project Appraisal Document, Subcomponent 2B of the Project, with an allocation of US$6 million, concerns clean cooking solutions for households. The project will promote "cleaner household cooking appliances and fuels" in efforts to help target counties (including West Pokot, Turkana, Isiolo, Samburu, Marsabit, Kilifi, Kwale and Taita Taveta) transition to cleaner, more efficient, improved stoves. Stove promoted under the project include woodstoves that are at least Tier 2 (roughly 30 percent efficient) and Tier 3 charcoal stoves (roughly 40 percent efficient).

County governments are also playing more active roles in ensuring energy access for all. A review of 39 publicly available County Integrated Development Plans (CIDPs) for 2018-22[101] showed that all but 5 of the CIDPs referred to the cooking sector either from a reporting angle, a planning perspective or both. Some of the counties had very specific cooking sector goals (see Table 23) with most of them targeting household use. Kitui and Mandera, however, have differentiated approaches with Kitui planning to train communities to make clean cookstoves while Mandera plans to lobby for legislature that will require adoption of improved clean energy saving cooking technologies in all institutions.

Table 23: Cooking sector related targets per CIDPs

County	Cooking sector related targets
Isiolo	Proportion of households accessing energy saving cooking fuels and facilities increased from 5% to 25% by 2022
Makueni	One of the objectives is to enhance access to reliable energy. Relevant to the cooking sector is the promotion of alternative sources of energy for cooking such as gas, fuel-efficient stoves and biogas with a goal of 20,000 households using biogas fuel for cooking.
Busia	Under the objective of optimized utilisation of renewable energy resources available within the county towards achieving sustainability, the county plans to install at least 100 biogas digesters per year for the next 5 years.
Garissa	With the objective to facilitate exploration and exploitation of energy resources, Garissa county plans to reduce the proportion of households using wood cooking fuel from 95% to 70% by 2022.
Kisii	Kisii County plans to have a biogas promotion programme to increase the number of households using the technology from 90 to 630 by 2022. Additionally, the county hopes to increase the percentage of households using energy saving jikos from 15% to 75% by 2022.

[100] World Bank Group. 2017. *Project Appraisal Document: Off-Gird Solar Access Project for Underserved Counties.* Retrieved from http://documents.worldbank.org/curated/en/212451501293669530/pdf/Kenya-off-grid-PAD-07072017.pdf

[101] The County CIDPs are published on RoGGKENYYA.org

County	Cooking sector related targets
Kitui	With an objective of enhancing the use of renewable energy, Kitui county plans to promote and train communities (at least 20 groups) to make clean cookstoves.
Machakos	With the objective to ensure access to affordable, reliable and clean energy, Machakos county plans to have the number of households using clean cooking technologies increased by 6000 households by 2022. The percentage of households using solid biofuels for cooking is to be reduced from 84.3% to 45%.
Mandera	To conserve the environment, use of organic wastes and ensure clean and healthy environment, Mandera county plans to install biogas plants in learning institutions and to lobby for legislation for all institutions to adopt improved clean energy saving cooking technologies.
Tana River	Tana River county plans to promote sustainable sources of energy with a view to reducing desertification caused by too much extraction of fuelwood. This is achieved through installation of 2000 energy saving jikos in selected villages across the county, piloting and operating 1 biogas plant by Sept. 2019.
Trans Nzoia County	The county plans to increase adoption and utilisation of green energy through establishment of 125 biogas demonstration projects
Wajir	The county plans to increase the proportion of households utilizing affordable, renewable clean cooking fuel (LPG gas, energy saving stoves, bio-char etc.) from 5% in 2018 to 40% in 2022.

Kenya's Ratification of the Paris Agreement was domesticated into the law of Kenya according to Article 2 Section 6 of the Constitution of Kenya 2010. Under the Nationally Determined Contribution, Kenya seeks "to abate GHG emissions by 30% by 2030 relative to the business as usual scenario of 143 CO_{2eq} According to the draft ***National Climate Change Action Plan for 2018-2022,*** the largest proportion of these reductions is expected from shifts in energy demand; adoption of alternative fuels including LPG and ethanol in urban areas and improved biomass cookstoves in rural areas is estimated to contribute to 7.3MtCO_{2eq} in reductions. Additionally, this shift is expected to have significant health benefits among them being the "reduction of deaths from household air pollution from 49% of the annual total deaths (21,560 in 2017) to 20%. To this effect, the Action Plan proposes goals and actions to promote the uptake of these technologies by 2022 among them being:

- "Number of households using improved biomass cookstoves increased by 4 million, through a programme that promotes:
  - o Loan programme through micro-finance institutions to assist with the up-front cost of cookstoves
  - o Local manufacture and servicing of clean cookstoves, e.g., tax-relief incentives for manufacturers; training and loans for local service
  - o Local businesses to stock improved cookstoves, with an emphasis on women-led businesses

- Biogas technology scaled up to increase access to clean energy through the construction of 6,500 digesters for domestic use and 600 biogas systems in various schools and public facilities".

In addition to the SEforALL Action Agenda is the ***SEforALL Investment Prospectus*** that details actions that the Kenyan government will take to ensure sustainable energy for all by 2030. These actions, most of which are seeking funding, are part of the Kenya Energy Modernisation Programme and those relevant to the cooking sector include:

- The development of the cookstove sector through a project that will establish a local cookstove manufacturing plant to produce improved, efficient and affordable cookstoves. The project targets production of about 300 improved cookstoves per day;

- Development of standard and labelling (S&L) for cookstoves in Kenya. Implemented by the Ministry of Energy, CCAK and The Alliance, the project aims to develop and implement an S&L strategy for clean cooking in the country. The strategy has already been developed and plans for implementation are underway;

- The Ministry of Energy plans to scale up the Kenya National Domestic Biogas (Biogas for Better Life) Programme which targets to construct 6,500 digesters every 5 years;

- The Ministry of Energy and has been collaborating and coordinating the sector towards strengthening the supply side, demand generation and advancing pro clean cooking policies. Working with the private sector, the initiative aims to help reach 5 million households with clean cooking.

- Entec Consultants are seeking to implement a clean cookstoves market acceleration project. The project involves awareness creation, market development, capacity building and linkages to Microfinance institutions as approached to increased uptake of improved stoves.

- International Research and Development Africa Limited is planning to set up Bioethanol supply infrastructure with a targeted capacity of 300,000 litres per day produced from second generation feedstock. Additionally, the Ministry of Energy, in conjunction with UNDP, has ran a pilot and looking to scale up the use of bioethanol as an alternative household fuel in Kenya.

- Restart Africa plans to establish a briquetting plant. The project entails awareness creation, market development, capacity building and capital investments for constructing a briquetting plant.

6.2.6 Standards

According to The Alliance, "standards provide rigorous definitions and goals for emissions (relevant for climate and health), efficiency, safety, durability, and quality". The Kenya Bureau of Standards (KEBS) has put various standards forward in guiding manufacturers of cookstoves both internationally and at a national level.

a. International Standards

The International Organisation for Standardisation (ISO) has developed some of the best available international guidelines with regard to the cooking sector. The current guiding standards are The ISO ***Harmonized Laboratory Test Protocols*** guided by ISO 19867-3: Voluntary performance targets for cookstoves based on laboratory testing, and ISO 19867-1: Standard test sequence for emissions and performance, safety and durability. The voluntary performance targets result in 6 tiers of performance for various categories as summarized in Table 24 and can be used to benchmark the performance of various stoves. It should be noted that the various tiers are not designed to be interpreted together as the different indicators are relevant for different impacts.

Table 24: Voluntary Performance Targets – Default Values

Tier	Thermal Efficiency (%)	CO Emissions (g/MJ delivered)	Fine Particulate Matter Emissions (mg/MJ delivered)	Safety (score)	Durability (score)
5	≥50	≤3.0	≤5	≥95	<10
4	≥40	≤4.4	≤62	≥86	<15
3	≥30	≤7.2	≤218	≥77	<20
2	≥20	≤11.5	≤481	≥68	<25
1	≥10	≤18.3	≤1031	≥60	<35
0	<10	>18.3	>1031	<60	>35

b. National Standards

KEBS has developed specific standards for improved cookstoves. Among these standards are: KS 1814-2018 Biomass stoves – Performance Requirements and KS 2759 – 2018 Ethanol fuelled cooking appliances – Specifications which are highlighted below; KS 2520 – 2014 Domestic biogas stoves – Specification; ISO 17225-3: 2014 Solid biofuels - Fuel specifications and classes Part 3: Graded wood briquettes; and ISO 17225-7:2014 Solid biofuels - Fuel specifications and classes Part 7: Graded non-woody briquettes, among others.

The Biomass Stoves – Performance requirements, which provides specifications to produce both domestic and institutional biomass stoves. The specifications speak to the various components of a biomass stove including the cladding, the ceramic liners, the size of the pots that can be supported, and the insulation material between the liner and the cladding among others. Below is a highlight of the cladding and liner requirements:

i. Cladding: the casing should be treated accordingly to ensure no rust and the stove-top gauges should have a nominal thickness of 22 Inches for both institutional and domestic stoves while the stove clad gauge should have a nominal thickness of 24 for institutional stoves and 26 for household stoves.

ii. Ceramic liner: these should be made from suitable potter clay and/or pottery sand that has been uniformly fired at 700°C – 900°C. Fired bricks should be used in the combustion chamber of institutional stoves.

The standards also specify thermal and emission performance requirements for stoves. When tested according to ISO 19867-1, the thermal efficiency requirement for domestic natural draft biomass stoves is at least 30% for charcoal ceramic stoves and 40% for other stoves. A minimum of 45% efficiency is expected from forced draft domestic biomass stoves and all types of institutional biomass stoves. Regarding emissions, the KEBS Standards provide performance requirements for $PM_{2.5}$ and CO.

Additionally, the standards require the branding of stoves including information on the manufacturer, product name, manufacture date, serial number, thermal efficiency and the KEBS standardisation mark. Stove delivery to the customer should include an instruction manual, packing list and warranty.

Discussions with sector stakeholders indicated that the Standards, as currently presented (KS 1814-2018), are very stringent and have rendered a large majority, if not all, of the biomass stoves within the market non-compliant. Consequently, business within the formal sector is on a go-slow due to concerns over performance emission levels. To correct this, the Standards are under discussion for review.

KS 2759 – 2018 Ethanol fuelled cooking appliances – Specifications provide requirements for the ethanol cookstoves including the materials they should be made of and their performance, as well as the various inspection tests that they should undergo. Among the various inspection and methods of testing specified in the standards include:

a. Combustion performance test where the appliance should heat 5 litres of water from 25°C to 90°C in less than 20 min and shall boil water within 30 min;
b. Determination of power output with a requirement of a heat output of at least 1.4kW at 45% thermal efficiency;
c. The emissions test where the CO_2 to CO ratio should not exceed a volumetric ratio of 1:0.03
d. The rigidity test with various requirement including that stoves should not become distorted or broken;
e. The stability test with the expectation that stoves should not topple over; and
f. The surface temperature test that requires that the temperature of any surface that may be touched during operation should not exceed 60°C .

6.3 Private Sector Engagement

6.3.1 Financing Options

Financing is key across the cooking solutions (stoves and fuels) value chain - manufacturers need working capital to produce the stoves, distributors needs financing to purchase stock while the target consumers require money to buy the stoves. Dividing the value chain financing needs into enterprise financing (manufacturers and distributors) and consumer financing, this section highlights financing approaches observed within the Kenyan cooking sector.

6.3.2 Enterprise Financing

While discussions on improved cookstoves have been at the fore for a while in Kenya, the ICS market is still quite young to attract commercial financing: formal manufacturers are either at start-up or early growth stages while informal manufacturers are too unstructured. Softer financing approaches have therefore been adopted and include:

1. Result Based Financing

As the name suggests, Result Based Financing (RBF) is a financing mechanism where payments are made after achievement of pre-agreed and verified results. RBFs are therefore focused on real impact (e.g. number of stoves reaching the end user) and are as a tool to finance social programmes that work; financing as a performance incentive. Figure 46 summarises the RBF approach:

With funding from DFID through the EnDev Kenya programme, The Netherlands Development Organisation (SNV) is implementing an RBF programme in Kenya known as the *Clean Cookstove Market Acceleration Project*. The project's goal is to accelerate the uptake of 100,000 higher tier stoves (Tier 2 and above by IWA Tiers) by mitigating entry and market development barriers. The programme beneficiaries are private sector actors distributing cookstoves on either credit or cash, and include cookstove manufacturers, retailers, SACCOs, MFIs, Banks, Community Based Organisations and Non-Governmental Organisations. Expected to come to a close in June 2019, the project has 1.3 million Euros available for utilisation, where draw down per stove is based on stove performance rating on the IWA Tiers: <Tier 2 in CO emissions receive 8 Euro; Tier 2 stoves receive 10 Euro; Tier 3 stoves receive 13 Euro and an incentive for alternative fuels (LPG, Pellets and Ethanol) is provided at 10 Euro. Stoves must be pre-approved to qualify for the incentives and the approval process includes testing at the Kenya Institute of Research and Development (KIRDI) using WBT testing protocols including safety with results evaluated against the ISO IWA Cookstove Performance Standards. A controlled cooking test (CCT) is also required to ascertain fuel savings of at least 40%. Stoves that were approved

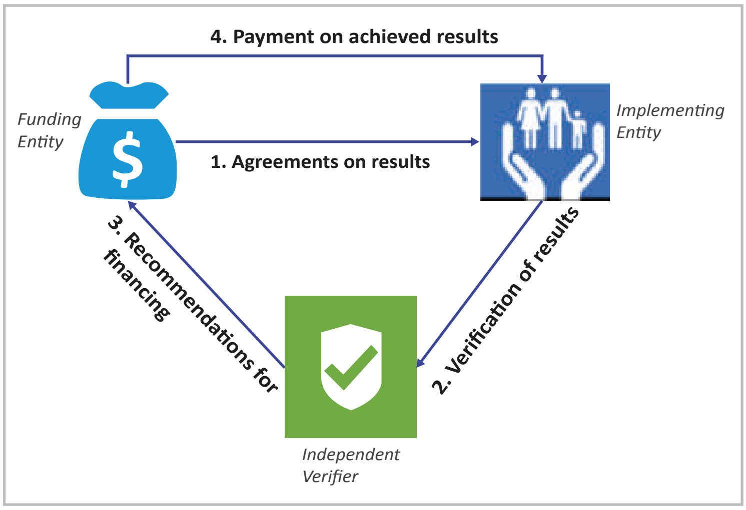


Figure 46: Description of RBF Structure

under the project as of 1 July 2018 included: BURN Jiko Poa charcoal stove, Envirofit super saver charcoal stove, EcoZoom Mama Yao charcoal stove, Biolite Fan wood stove, Wisdom gasifier stove, Safi Ethanol stove, Koko Networks Smart ethanol stove, Moto Safi ethanol gel stove, PayGo Energy LPG stove, and the Fusion Experience Kenya Ltd. LPG stove. Some of the challenges and lessons learnt in the implementation of the project include: the verification process is quite tedious which increases the costs for both the facility and the beneficiaries; Distributors don't necessarily have capacity to keep records which complicates the verification process; there needs to be a way to incorporate locally produced stoves such as the Scode charcoal stove which is left out in the approved list of stoves due to testing requirements.

2. *Grants / Concessional loans*

Development agencies have launched various funds targeted at helping entrepreneurs scale up their businesses. Among initiatives targeted at, or that include, cooking solution in Kenya are:

i. The Green Enterprise Challenge implemented by Micro Enterprises Support Programme Trust under the DANIDA Country Programme dubbed the Green Growth and Employment Programme 2016-2020. The fund targets start-ups that are less than 3years old and that have a green element in them.

ii. The Africa Enterprise Challenge Fund mobilizes funds and leverages marching capital to support businesses to innovate, create jobs and leverage investments and markets. AECF targets innovative, commercially viable and high impact projects. With Renewable energy being one of its target areas, AECF looks to fund the production and/or distribution of cleaner fuels and energy efficient cookstoves.

3. *Impact Investors*

Impact investors put money into companies with the intention of making measurable social, economic and/or environmental benefits in addition to their financial return. Among investments seen in Kenyan cooking sector include Acumen's investments in BURN Manufacturing and Biolite, Novastar Ventures and Energy Access Ventures investments in PayGo Energy, and AHL Venture Partners investment in BURN Manufacturing among others.

Crowdfunding is gaining momentum in Kenya as an avenue for raising finance. Crowdfunding is defined as "The practice of funding a project or venture by raising money from a large number of people who each contribute a relatively small amount, typically via the Internet"[102]. An Energy 4 Impact report identifies four aggregate types of crowdfunding where funding can be based on donations, rewards, debt or equity campaigns[103]. The report continues to note that funding campaigns generally fall within one of three categories: the partnership model, for recurring fundraisers, where the platform helps bring the crowd; one-off fundraiser, which tends to be a larger campaign for a specific purpose; or personal or community fundraiser, where individuals or communities raise funds for a cause". Various crowdfunding platforms exist including Global Giving and the Kenyan based platform, M-Changa, which are donation-based funding platforms; Kiva which provides micro-loan debt; Bettervest, Lendahand and TRINE providing SME loans; and Crowdcube that provides equity[104] .

4. Carbon Finance

Carbon finance, through the Clean Development Mechanism and voluntary markets presents an option for financing scale up of improved cookstoves. A study by the Stockholm Environment Institute on carbon financing in Kenya and India[105] recognizes that carbon financing can have a role in increased dissemination of ICS through attracting of international actors and technologies, establishment of standards for monitoring stoves and facilitating better follow-up and after sales services to consumers. However, the mechanism also presents risks, among them being the uncertainties in the future demand for carbon credits and the mismatch between the stove design needs to ensure efficiency and emissions reductions against the design needs for a culturally acceptable stove.

5. Self-financing

Self-financing involves an organisation or enterprise using its own resources to run its operations. This may be spent in either capital cost or on human resource.

6. Government financing

The Government may, depending on its development agenda, dedicate funding to enterprises to promote uptake of clean and improved cooking solutions. Among initiatives implemented is the *Gas Yetu project* and KOSAP. *Gas Yetu* is a subsidy programme on gas cylinders; among KOSAPs initiatives is an RBF programme to promote uptake of improved biomass stoves.

7. Consumer Financing

While the business models earlier presented illustrate some innovative market approaches to enable end users to purchase cookstoves, Table 25 highlights financial inclusion mechanisms aimed at enabling end users to access ICS.

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[102] Definition based on Oxford Dictionaries

[103] Energy 4 Impact. (2018). ***Crowd power success & failure: The key to a winning campaign.*** United Kingdom: Doughdawson Creative Design

[104] Energy 4 Impact. (2018). Crowd Power: ***Who is the Crowd? United Kingdom***: Doughdawson Creative Design

[105] Lambe, F., Jürisoo, M., Lee, C., & Johnson, O. (2014). ***Can carbon revenues help transform household energy markets? A scoping study with cookstove programmes in India and Kenya***. Sweden: Stockholm Environment Institute.

Table 25: Consumer financing options

#	Financing Approach	Description
1.	Loans from financial institutions	Some commercial banks have developed loan products that are directly targeted at energy solutions. Among these is Equity Bank with several loan products. The Ecomoto loan product through Equitel allows pre-qualified customers to access loans through their mobile phones to buy stoves. The stoves can be collected at designated Equity Agents. The Bank also has products that allow customers to purchase Pro Gas and Hashi Gas cylinders. External financing, e.g. by development agencies, is critical in such products to mitigate the risk of defaulting clients. The Ecomoto product, for instance, has received some guarantor funding from IFC.
2.	Micro-finance Institutions	Various microfinance organisations have loan products that enable their customer's access clean and renewable energy products. Among these are Kenya Women Microfinance Trust (KWFT) with products for stoves and biogas systems; Yehu Microfinance that distributes Jikos on Loan to their members in Mombasa, Kilifi, Voi, Kwale, Lamu and Malindi; and Musomoni Microfinance that has asset financing loans for clean energy products among others.
3.	Savings and Credit Cooperatives (SACCO) loans or savings	SACCOs are formally regulated savings groups, which hold money for members and disburse loans for goods and services. To promote ICS uptake, programmes such as the concluded Jiko Safi 'Clean Stove' Fund, funded by USAID and funds channelled through The Kenya Union of Savings and Credit Cooperatives (KUSCCO), have been set up to lend money to SACCOs, which then lend money to their members to purchase cookstoves. Launched in 2014, the Jiko Safi fund promotes sale of improved stoves such as BURN, EcoZoom and Envirofit, and reported sales of over 13,000 stoves to SACCO members as of 2017[106] .
4.	Informal savings (e.g. women and youth groups)	In addition to being potential distribution channels for cookstoves, community level saving groups (women or youth groups, *chamas)* also provide financing for cookstoves.
5.	Employer payroll deductions	Payroll deductions from an employee's pay check is an approach used to finance ICS by some employees.

6.4 Business Models

Evaluating business models involves an analysis of various operational aspects required for the success of a business. These may range from product selection, identifying a customer base, sources of revenue, financing details among others. Issues such as distribution channels and cookstove products within the Kenyan cooking sector have been discussed in earlier sections. This section focuses on payment models/options for acquisition of stoves.

[106] USAID. (2017). KUSCCO's Jiko Safi Clean Cookstove Fund. Retrieved from https://www.winrock.org/wp-content/uploads/2017/09/KUSCCOProfile.pdf

6.4.1 Cash-based models

As the name suggests, this model involves payment for stoves and fuels using cash. With 98% of the respondents who purchased their primary stoves, and 99% of those who purchased their secondary stoves having made full upfront cash payments for their stoves, this is the most commonly observed approach to the distribution of stoves in Kenya. This is unsurprising given that the last mile distribution channels most commonly accessed by consumers (see Figure 47) require upfront payments for their goods. As seen, retail stores represent the largest proportion and last mile distribution channels for stoves at 82% (small retail stores, supermarkets, wholesale retail shops and open markets). By virtue of their operational style, it is inevitable that upfront cash payments are the most commonly observed mode of payment for stoves.

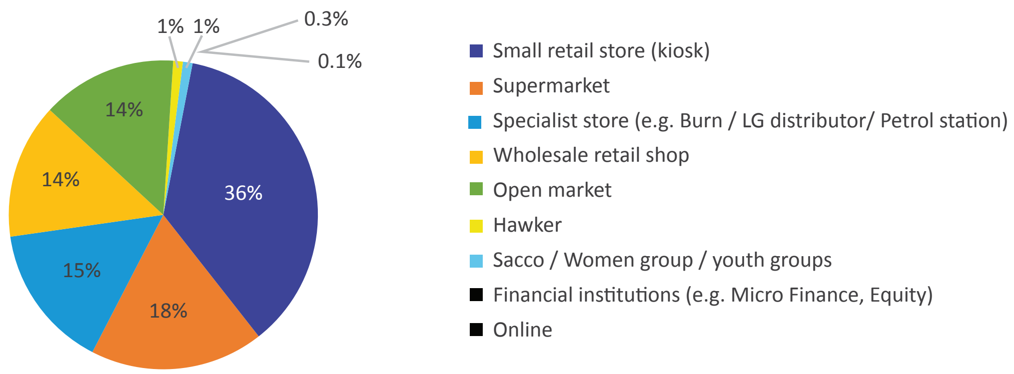

Figure 47: Last mile distribution channels for primary cookstoves

This observation may, however, speak to some of the limitations of access to improved cooking solutions in Kenya. Studies have identified cookstove price, which is directly linked to affordability, as a key factor influencing the uptake of improved cooking solutions. Some of these studies note that: "High costs are by far the most important reason households do not switch to LPG[107]" ; "Affordability is […] consistently rated as the top demand constraint by the manufacturers and distributors of industrially manufactured, high-quality intermediate ICS (rocket wood and charcoal stoves) in the US$15–50 range"[108], among others. There is therefore a need for innovative approaches to address this limitation. Some of these have been highlighted under the Financing section (e.g. innovative loan products by financial institutions) while others are highlighted below.

6.4.2 Pay-as-you-go business model

The requirement to make upfront payments in full is often seen as a barrier to adoption of improved cookstoves and cleaner fuels[109]. Divisibility of fuel – ability to buy fuel in small portions – therefore becomes a key factor for consideration in promoting cleaner fuels, and one that pay-as-you-go models attempt to address. The pay-as-you-go business model allows consumers the flexibility to pay for expenses as they arise, and to the extent that they can afford. While a commodity may be available in large quantities, the business model allows for small repayments, as one is able to make. This model has been adopted by various companies within the Kenyan cooking sector dealing with LPG as a cooking solution, where it is seen as an innovative approach to increase access to modern energy, especially among the urban poor.

[107] Kojima, M. (2011). The role of liquefied petroleum gas in reducing energy poverty. Extractive Industries for Development Series (25). Retrieved from http://siteresources.worldbank.org/INTOGMC/Resources/Unedited_LPG_report_Dec_2011.pdf

[108] World Bank Group (2014). Clean and Improved Cooking in Sub-Saharan Africa. Washington, DC: The World Bank Group.

[109] Debbi, S., Elisa, P., Nigel, B., Dan, P., and Eva, R. (2014). Factors influencing household uptake of improved solid fuel stoves in low-and middle-income countries: A qualitative systematic review. International journal of environmental research and public health 11 (8),8228-8250

Among companies implementing pay-as-you-go business models for LPG access are Envirofit with their product SmartGas™, PayGo Energy and Gulf Energy's Pima Gas. The operational structures of SmartGa™and PayGo Energy models are quite similar in that they both:

- Provide users with branded cylinders that are filled with LPG and are fitted with their respective valves and monitoring systems;
- Consumers pay an installation fee for the stove, cylinder and the monitoring unit which is less than the upfront cost of similar LPG solutions sold on cash basis;
- The valves allow for release of LPG on demand while the monitoring system, connected to the suppliers monitoring servers, detects the amount of gas remaining in the cylinder informing the need for cylinder replacement;
- Consumers make pre-payments for gas, as they are able and willing to using mobile money. Only as much gas as is paid for can be released as monitored through a smart gas monitoring system.

Pima Gas operates under a slightly different model where it allows its consumers partial refill of their LPG cylinders from authorized LPG vendors. This deviates from the standard operational model within the sector where one can only trade in an empty cylinder for a filled one.

These models therefore tap into benefits that have traditionally been associated with the use of charcoal and kerosene, especially among the poor households. One could acquire fuel for as low as KES 20 when using charcoal or kerosene while about KES 700 is needed to refill a 6kg LPG cylinder. While the longer-term economics of using LPG vs charcoal or kerosene has been shown to be in favour of LPG (cost and health benefits)[110], this indivisibility of LPG has in the past made the use of the fuel unattractive to poorer households, who may not afford the steep upfront cost of the fuel. The pay-as-you-go model addresses this barrier.

6.4.3 Lay-away business model

The premise of the lay-away business model is to work with consumers to save towards a certain goal, for instance, saving for an improved cookstove. It is seen as a tool for financial inclusion recognizing that the demands for utilisation of available resources makes it a challenge to save, especially among those with limited resources. With this model, the consumer saves directly and irrecoverable with the commodity supplier towards purchase of the commodity, and once they have saved enough to buy the said commodity, the supplier gives them the product. Unlike other micro-credit / micro-finance offerings that provide flexibility on how to use savings, any savings under this model must go towards the target product.

This model is being applied by KOKO Networks in Kenya in the distribution of their ethanol-based stoves. KOKO Networks has launched cloud connected KOKO point e-commerce kiosks for the distribution of ethanol fuel, customized fuel cannisters and customized ethanol stoves that are only compatible with their fuel canisters. Working with the kiosk attendants, and using mobile money, prospective stove customers can save towards the cost of purchasing a stove, and once enough money has been saved, collect the stoves from the kiosks.

6.4.4 Distribution through organized groups

Women and youth groups (*Chama*) provide a channel for last mile distribution of cookstoves. Most of these groups have adopted internal savings structures from

[110]Jeuland, M., A., & Pattanayak, S., K. (2012). *Benefits and costs of improved cookstoves: assessing the implications of variability in health, forest and climate impacts.* Retrieved from https://doi.org/10.1371/journal.pone.0030338

where members can borrow from (table banking) or wait their turn to collect funds (Merry-go-round). Wisdom Energy demonstrates how companies can tap into the group model as their main distribution approach: sales through groups account for about 65% of Wisdom Energy total sales. One of the benefits with working through groups is that stoves can be sold to individual members on credit with the group acting as a guarantor. In such instances, the individuals are allowed a window to make payments. Additionally, Wisdom Energy prefers to work with women groups – experience has shown that women groups are more effective in the dissemination of the stoves, an observation that echoes past studies . Specifically, Wisdom Energy observed that demonstrations to women groups ensured the women learnt how to use the stove which greatly increased the probability of

Figure 48: E-commerce kiosk

using the stoves post purchase; the operation of the stove can be a bit complex for those without training on how to light it.

6.4.5 Case 5: Women groups as distribution points

Wisdom Energy Hub Limited manufactures top lit up-draft gasification cookstoves (TLUDs). The cookstoves are designed to burn different biomass fuels including firewood, briquette, corn husks, cow dung and coffee husks. Wisdom primarily targets rural and peri-urban households with a special focus on areas adjacent to major forests and water catchment areas. So far, they have worked with a total of 124 groups across 6 counties including Nyandarua, Narok, Kiambu, Laikipia, Nakuru and Kajiado. In growing their business, they are faced with two main challenges including the lack of:

i. flexible financing scheme for their consumers - most of their customers are in low income areas and therefore unable to buy the stove on cash basis; and
ii. effective distribution channels for the rural end-users of the cookstoves -reaching the last mile consumer is costly and, in some instances, the last mile distributor may be lacking.

To curb these challenges, Wisdom designed a simple model that leverages existing women groups as points of distribution. Wisdom brand ambassadors identify these groups, bundle them per regions and then set out monthly meeting schedules. Open demonstrations are conducted within the groups after which purchases are made. To engage with Wisdom, the groups must have: (i) been in operation for at least one year; (ii) documented evidence of having held regular meetings at a designated venue prior to their engagement with Wisdom; (iii) a formal structure of leadership and; (iv) no affiliations to MFIs. Newly formed groups and groups affiliated to MFIs are perceived as having higher risk of not meeting their financial obligations toward stoves acquisition and are thus not preferred. Groups affiliated to MFIs usually have multiple loans already and may struggle to take on additional obligations, which impacts their ability to pay on time or fully.

The customers make monthly payments of KES 1,200 (US$ 12) over a period of three months. They

[111]Kojima, M. (2011). The role of liquefied petroleum gas in reducing energy poverty. *Extractive Industries for Development Series* (25). Retrieved from http://siteresources.worldbank.org/INTOGMC/Resources/Unedited_LPG_report_Dec_2011.pdf

fill loan forms, which among other things enables them to provide guarantees for each other. The group's savings also acts as a form of security for the members to acquire the stoves on credit. Users also get to share their experience with each other while using the stoves and raise awareness among similar groups. Wisdom also sell their cookstoves through SACCOs and direct sales and has sold over 4,000 stoves in total. Lack of financing that would enable them to rapidly scale up across the country has been the main barrier to increased sales.

7. SOCIAL, HEALTH AND ENVIRONMENTAL COSTS

7.1 Greenhouse Gas Emissions

All household fuel combustion releases CO_2 along with a mix of other pollutants including methane (CH4) and Nitrous Oxide (N_2O), which are both included in common GHG emission inventories, as well as other climate forcing pollutants like carbon monoxide (CO), black or elemental carbon aerosols (BC or EC), organic carbon aerosols (OC) and Nitrogen Oxides (NOx). The data collected in this survey provides enough information to derive an estimate of total GHG emissions from residential cooking. In this section, we briefly describe the steps necessary to make this estimation and compare our estimate to previous estimates of Kenya's annual GHG emissions.

Pollutant emissions are measured by *emission factors*, which indicate the quantity of pollution emitted for each unit of fuel burned and may be expressed in terms of mass or energy (e.g. grams of pollutant per kilogram or mega-joule of fuel consumed). Emission factors are specific to different stoves and fuels, but also dependent on factors like fuel moisture and user behaviour. For this estimate, we used mass-based emission factors derived from previous studies (Table 26). Where available, we used measurements that were made in field conditions. If field measurements were not available, then we used lab measurements.

Table 26: Emission factors and Global Warming Potentials for common stove-fuel combinations ($g_{pollutant}/kg_{fuel}$)

	CO_2	CO	CH_4	$PM_{2.5}$	BC	OC	NO_x	N_2O	Source
100-yr Global Warming Potential	1	2.65	28	0	460	-69	-11	265	112
LPG	3085	14.9	0.1	0.5					113
Traditional woodstoves	1540	48.8	1.6	4.0	0.525	0.615			114
Improved woodstoves	1672	26.4	1.9	1.5	1.3	0.3			108
Traditional charcoal stoves[115]	4140	425.3	53.0	2.8			0.063	0.15	108
Improved charcoal stoves[109]	4905	393.0	50.2	3.5			0.063	0.15	116
Kerosene wick stoves	3027	17.7	0.3	0.5					107
Crop Residues in a traditional stove	1447	86.0	1.0	4.1	2.6	1.3	1.6		108

[112] Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang. (2013). *Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[113] Smith, K., R, Uma, R., Kishore, V., Lata, K., Joshi, V., Zhang, J., Rasmussen, R., Khalil, M. (2000). Greenhouse gases from Small-scale combustion devices in developing countries phase IIa: Household Stoves in India. Washington, DC: Environmental Protection Agency, Office of Research and Development.

[114] Masera, O., Bailis, R., Drigo, R., Ghilardi, A. and Ruiz-Mercado, I. (2015). Environmental Burden of Traditional Bioenergy Use. *Annual Review of Environment and Resources 40*(1): 121–150.

[115] Pennise, D.M., Smith, K.R., Kithinji, J.P., Rezende, M.E., Raad, T.J., Zhang, J., Fan, C. (2001). Emissions of Greenhouse Gases and Other Airborne Pollutants *from Charcoal-Making in Kenya and Brazil. Journal of Geophysical Research-Atmosphere (106): 24143-24155.*

[116] Jetter, A., Zhao, Y., Smith, K. R., Khan, B., Yelverton, T., DeCarlo, P., and Hays, M.D. (2012). Pollutant Emissions and Energy Efficiency under Controlled Conditions for Household Biomass Cookstoves and Implications for Metrics Useful in Setting International Test Standards. *Environmental Science & Technology 46*(19), 10827-10834

With fossil fuels like kerosene and LPG, all the emissions contribute to climate change. With biomass fuels like crop residues, fuelwood and charcoal, some of the CO_2 that is emitted when the fuel is burned may be recovered when new biomass grows. The amount that does not recover is considered non-renewable biomass (NRB) and contributes to climate change. The ratio of NRB to total biomass consumption (fNRB) can be used to estimate the climate impact. fRNB varies from place to place depending on factors like biomass accessibility as well as harvest intensity and growth rates. This information is difficult and time consuming to obtain. For this report we relied on data from a 2015 study, which estimated county-level fNRB throughout Kenya based on the best available information at that time (included in Annex A1.2).[117]

There are several ways to account for climate impact of household fuels.[112] Here we present two estimates. The first includes only CO_2, CH_4, and N_2O, which are long-lived GHGs that were included in the original Kyoto Protocol and commonly used carbon offset schemes. The second includes other long-lived gases along with CO, BC, OC, and NOx. These other pollutants have both direct and indirect climate impacts, but the magnitude is more uncertain than it is for CO_2, CH_4, and N_2O.[118]

For both groups of pollutants, we calculated emissions for each household surveyed by multiplying annual consumption of each fuel (summarised in Table 20) by each fuel's emission factor, weighting each pollutant by its Global Warming Potential (GWP) (Table 26), and adding the weighted emissions. We then took an average for each common stove-fuel combination across all urban and rural households and scaled up by multiplying the rate of use for each stove and fuel derived from the survey and total number of urban and rural households nationwide. Table 27 shows the impact of CO_2, CH_4, and N_2O and Table 28 shows the impact of these long-lived pollutants together with CO, BC, OC, and NOx.

Table 27: Net annual GHG emissions from residential cooking fuels accounting for CO_2, CH_4, and N_2O

TOTAL EMISSIONS (CO_2, CH_4, N_2O)	Urban			Rural			Total		
	% sample	Millions of HHs	Total (MtCO2e)	% sample	Millions of HHs	Total (MtCO2e)	% sample	Millions of HHs	Total (MtCO2e)
Fuelwood	24	1.0	1.1	85	6.06	5.2	65	7.48	6.2
Charcoal	43	1.9	2.3	39	2.77	3.8	40	4.61	6.1
Crop residues	3	0.1	-	8	0.54	-	6	0.69	-
Kerosene	28	1.2	0.5	6	0.44	0.1	13	1.51	0.6
LPG	51	2.2	0.5	15	1.07	0.1	27	3.07	0.6
TOTAL			4.3			9.2			13.6

[117] Drigo, R., R. Bailis, A. Ghilardi and O. Masera (2015). WISDOM Kenya: *Analysis of woodfuel supply, demand and sustainability in Kenya.* Washington DC, Global Alliance for Clean Cookstoves

[118] Myhre, G, et al. (2013). Anthropogenic and Natural Radiative Forcing - Final Draft Underlying Scientific-Technical Assessment. In T. F. Stocker, D. Qin, G.-K. Plattner, M. M. B. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, & P. M. Midgley (Eds.), Working Group I Contribution to the IPCC Fifth Assessment Report (AR5), Climate Change 2013: The Physical Science Basis (pp. 8-1-8 to 139). New York: Cambridge University Press.

Table 28:Net annual GHG emissions from residential cooking fuels accounting for CO_2, CH_4, N_2O, CO, BC, OC, and NOx

TOTAL EMISSIONS (CO_2, CH_4, N_2O)	Urban			Rural			Total		
	% sample	Millions of HHs	Total (MtCO2e)	% sample	Millions of HHs	Total (MtCO2e)	% sample	Millions of HHs	Total (MtCO2e)
Fuelwood	24%	1.0	1.6	85%	6.1	8.3	65%	7.5	9.9
Charcoal	43%	1.9	3.3	39%	2.8	5.5	40%	4.6	8.8
Crop residues	3%	0.1	0.1	8%	0.5	0.4	6%	0.7	0.5
Kerosene	28%	1.2	0.5	6%	0.4	0.1	13%	1.5	0.6
LPG	51%	2.2	0.5	15%	1.1	0.1	27%	3.1	0.6
TOTAL			5.9			14.5			20.5

Summing up, we estimate that the combined emissions of CO2, CH4, and N2O from combustion of residential cooking fuels is roughly 13.6 MtCO2e split 2:1 between rural and urban populations. Adding CO, BC, OC, and NO_x increases the total impact to 20.5 $MtCO_2e$, with a similar division between rural and urban households. To get a sense of scale, we compare these results to several recent estimates of Kenya's total emissions in Table 29. Residential cooking fuels and associated land cover change caused by NRB represents 18-47% of Kenya's total emissions depending on the source of data.[119] Adding the additional pollutants to this comparison would be misleading because they are not included in the emissions estimates given in Table 29.

Table 29: Independent estimates of Kenya's GHG emissions from Industrial sources and Land Use Change

Source	Year of estimate	Emissions		
		Industrial and other Sources[120]	LULUCF	Total
Kenya's SNC[121]	2010	50.0	21.2	71.1
EDGAR[122]	2012	73.4	Not available	Not available
CAIT[125]	2014	60	-31	29
PIK[124]	2014	72	-31	41

In July of 2015, the Ministry of Environment and Natural Resources submitted to the UNFCCC Kenya's Nationally Determined Contribution (NDC). This document sets the 2010 total greenhouse gas emissions at 73 $MtCO_2e$ as a baseline. Energy demand and land use, land-use change and forestry (LULUCF) being estimated at 6.9 $MtCO_2e$ and 26 $MtCO_2e$ respectively.

[119] Two data sources included in Table 29 have large negative emissions from LULUCF. These seem unlikely given what satellite data show about the country's land cover and that it is not included in Kenya's own NDC.

[120] Includes fossil-fuel burning, cement production, and gas flaring.

[121] United Nations. Framework Convention on Climate Change. (n.d). Retrieved from http://di.unfccc.int/ghg_profiles/nonAnnexOne/KEN/KEN_ghg_profile.pdf

[122] Janssens-Maenhout, G., Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Dentener, F., Bergamaschi, F., Pagliari, V., Olivier, J., Peters., Aardenne, J., Monni, S., Doering, U., Petrescu, A. (2017). Global Atlas of the three major Greenhouse Gas Emissions for the period 1970-2012. Earth System Science Data. Retrieved from https://doi.org/10.5194/essd-2018-164

[123] Climate Watch. Greenhouse Gas Emissions and Emissions Targets. (n.d.) Retrieved from https://www.climatewatchdata.org/countries/KEN?source=31

[124] Ibid

The National Climate Change Action Plan (2013-17) notes that uptake of improved cookstoves with higher conversion efficiency have the largest potential for GHG emission reductions. The 2018-2022 National Climate Change Action Plan targets GHG emissions reduction of an estimated 7.1 $MtCO_{2}e$ by 2022 through the uptake of alternative fuels and efficient stoves.

7.2 Indoor Air Pollution

7.2.1 IAP vs HAP: An introduction

According to the OECD Glossary of Statistical Terms, "Indoor air pollution (IAP) refers to chemical, biological and physical contamination of indoor air."[125]. One of the leading sources of IAP is the use of solid fuels and kerosene in traditional and inefficient/simple stoves such as open fires, which lead to emission of large amounts of pollutants such as particulate matter (PM), carbon monoxide (CO), hydrocarbons, and oxygenated and chlorinated organic compounds. Exposure to these pollutants contributes to deaths from respiratory and cardiovascular illnesses including pneumonia, stroke, ischaemic heart disease, chronic obstructive pulmonary disease and lung cancer.[126] IAP continues to pose a global health risk with annual deaths of 1.6 million - revised down from 3.8 million[127] - which is 30% higher than the number of traffic related deaths in the world. Globally, close to 3 billion people still use solid biomass as a cooking fuel. Sub-Saharan Africa contributes to over 20% of this population with about 646 million people using solid fuel with the majority residing in rural areas[128] .

In 2018 alone, research has shown that the leading cause of death among children under 5 years in low-income countries was Pneumonia (45% of the deaths in children under 5 years); it accounted for 28% of adults' deaths globally. Children under the age of 5 years remain susceptible to respiratory diseases because of exposures with their mothers and caregivers during cooking, and the damage is higher given their underdeveloped respiratory defence mechanisms and airways. In addition to the respiratory illnesses, a study in India has shown that the use of biomass fuel is also associated with prevalence of anaemia and stunting in these children[129] .

Though used interchangeably IAP and HAP may not mean the same thing. Over the years, the term IAP was used mostly to refer to pollution emanating from cooking within houses. However, in the recent past there has been a shift to the term Household Air Pollution. The redefinition was by Lim et.al who conducted the Comparative Risk Assessment of the Global Burden of Disease in 2012. The reasons for the redefinition were as follows[130]:

- Health-damaging air pollution from cooking fuels affects the environment around households, not just indoors.
- Emissions from burning household fuels can be transported well beyond the household and contribute to ambient (outdoor) pollution, creating health risks at a population scale.
- Labelling the risk as *"indoor"* implies that some form of ventilation like chimneys could solve the

[125] OECD. (n.d). Glossary of Statistical Terms. Retrieved from https://stats.oecd.org/glossary/detail.asp?ID=1336

[126] World Health Organisation. (2018). Household Air Pollution and Health. Retrieved from http://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

[127] World Health Organisation. (2018). Household Air Pollution and Health. Retrieved from http://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

[128] Ibid

[129] Das, P., Pedit, Hand & Jagger. (2018). Household air pollution (HAP), microenvironment and child health: Strategies for mitigating HAP exposure in urban Rwanda. *Environment Research Letter* (13). Retrieved from https://doi.org/10.1088/1748-9326/aab047

[130] Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., ... & Aryee, M. (2012). *A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010.*

problem, but as the previous points imply, shifting the pollution outside impacts neighbours nearby as well as people much further afield.

- In some places, solid fuels are used for space heating or lighting, as well as for cooking thus confusing the attribution of risk and assessment of appropriate interventions unless the household uses being considered are specified.
- *Indoor air pollution* overlaps with studies of pollution from other sources like second-hand tobacco smoke, household furnishings and consumer products. Specifying Household Air Pollution focuses the issue on solid fuel combustion for cooking, lighting, and space heating.

7.2.2 Measuring HAP impacts

A key consideration in estimating the impact of HAP is the process of arriving at an attribution factor (this derives the attributable fraction). The Institute of Metric Health and Evaluation in consultation with other experts on Global Burden of disease came up with the following method (illustrated in Figure 49) of estimating the burden of disease.

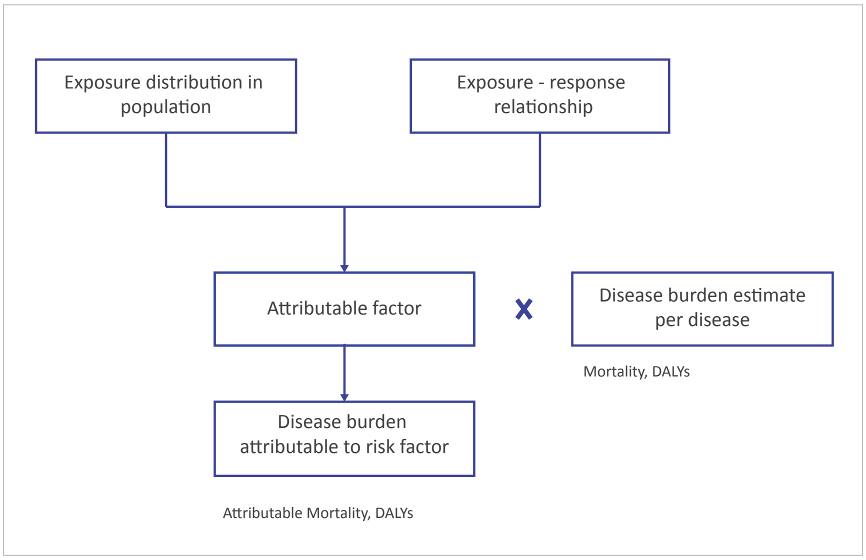

Figure 49: Estimation of burden of disease

The process begins by determining the fraction of the population exposed to household air pollution. The fraction of the population using dirty fuels and technologies is used as the proxy indicators in estimating this. This is then translated to individual exposure levels using epidemiological data obtained through exposure studies. These studies often involve the assessment of the concentration levels of the different pollutants (e.g. PM, CO) and the length of time in which the individual is exposed to the same. External concentrations are determined using air monitoring tools while the concentrations within the individuals can be determined by use of biomarkers such as urine and serum samples[131]. Although some studies have used technology to measure indoor air pollution, few have focused on determining the level of exposure per household member and isolating exposure attributed solely to indoor air pollution (as opposed to ambient air) leaving major informational gaps. The cost of deploying such technologies has

[131]Northcross, A. L., Hwang, N., Balakrishnan, K., & Mehta, S. (2014). Assessing exposures to household air pollution in public health research and programme evaluation. *EcoHealth, 12*(1), 57-67. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4416115/

also been quite prohibitive. In an attempt to provide this empirical data on this difficult and under-researched subject, a pilot on low-cost IoT enabled indoor air quality monitoring system was set up in low-income urban and rural households using traditional fuel sources. The results of this pilot are discussed in Annex A1.8.

The second step involves estimating the relative risk of disease caused by HAP. The Institute of Health Metric and Evaluation uses an integrated exposure response function (IER) to determine the relative risk. IER combines the epidemiological evidence for household air pollution to estimate the level of disease risk (e.g. stroke) at different levels of pollutant concentrations (in this case $PM_{2.5}$)[132]. The IER methodology also allows for the indirect quantification of cardiovascular effects of HAP[133]. Using the relative risk value from the IER output and the total number of deaths recorded for a disease (from the health data of a country), one can obtain the fraction of deaths that are caused by household air pollution or a specific pollutant.

7.2.3 HAP in Kenya

The Ministry of Health estimates that HAP in Kenya claims 21,560[134] lives annually. Other estimates are between 14,000 and 17,000[135] lives annually which is more than five times the number of lives lost to traffic accidents annually[136]. Lower Respiratory infections such as pneumonia and acute bronchitis have been the greatest contributor to the HAP related deaths in Kenya. In fact, acute lower respiratory infections are considered the second largest cause of death and are linked to 26% of all deaths reported in hospitals in Kenya[137]. Other diseases include ischemic heart disease (IHD), chronic obstructive pulmonary diseases (COPD) and stroke.

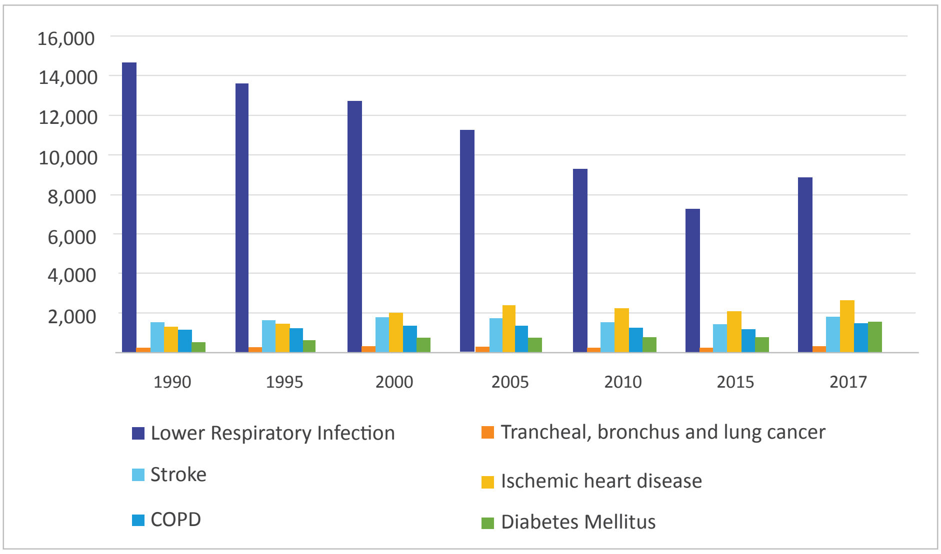

Figure 50: Number of Premature deaths from Household Air Pollution in Kenya[138]

[132] World Health Organisation. (2018). *Burden of disease from household air pollution for 2016 Description of method*. Retrieved from http://www.who.int/airpollution/data/HAP_BoD_methods_May2018.pdf

[133] Clean Cooking Alliance. (2017). *Global burden of disease from household air pollution: how and why are the estimates changing*? Retrieved from http://cleancookstoves.org/about/news/11-17-2017-global-burden-of-disease-from-household-air-pollution-how-and-why-are-the-estimates-changing.html

[134] Interview with Ministry of Health official done on the 28th January 2019

[135] Estimated based on data from Institute of Health Metrics and Evaluation, Global Burden of Disease Compare Seattle, WA: Institute for Health Metrics and Evaluation; 2018 [cited August 2018]. Available from: http://vizhub.healthdata.org/gbd-compare/.

[136] National Transport and Safety Authority. Accident Statistics as of 21st November 2018, 2750 people had lost their lives from road accidents. Retrieved from http://www.ntsa.go.ke/index.php?option=com_content&view=article&id=213&Itemid=706

[137] Stockholm Environment Institute. (2016). *Bringing clean, safe, affordable cooking energy to Kenyan households: an agenda for action*. Retrieved from https://mediamanager.sei.org/documents/Publications/SEI-NCE-DB-2016-Kenya-Clean-Cooking.pdf

[138] Institute of Health Metrics and Evaluation. (2018). *Global Burden of Disease Compare Seattle, WA: Institute for Health Metrics and Evaluation*. Retrieved from: http://vizhub.healthdata.org/gbd-compare/

The annual economic loss sustained by the country due to premature deaths related to HAP remains quite high. Considering just premature deaths in 2017, it is estimated that Kenya lost about 9,498 million USD[139] (95 billion Kenya Shillings) equivalent of 13% of the country's Gross Domestic Product (GDP). Other costs include the disability adjusted years (DALYs) and the amount spent by households in the treatment of HAP related diseases. A considerable percentage (about 11%[140]) of these deaths can be attributed to the technologies and fuels used by households for cooking. This study finds that 74.8% of households in Kenya (93.2% of rural households) are using solid fuels as their primary cooking fuel. Further, about 59% of households in Kenya still use TSOF as the main cooking solution with the majority being in the rural areas. 60% of those who use TSOF have children under 5 years. These numbers indicate that most households are still prone to household air pollution. However, the bulk of the households that use wood fuel (firewood or charcoal), cook outside of the main house in a separate room (see Figure 51). Though cited as one of the reasons for continued deaths and diseases from HAP, households tend to be aware of the immediate effects of indoor pollution such as coughing from the smoke and itchy eyes and this to an extent has influenced where cooking takes place and the design of the kitchens.

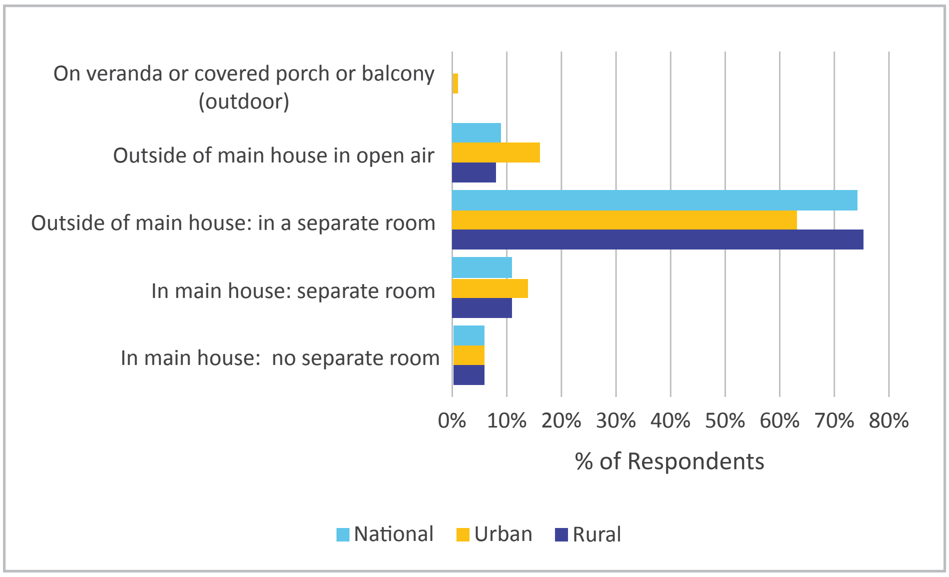

Figure 51: Proportion of households using wood fuel disaggregated by cooking areas

Several initiatives are underway to try and address the household air pollution concern among households in Kenya. Some of these include the SEforALL Action Agenda that aims to promote clean cooking and ensuring universal access to modern cooking services by 2030[141]. In line with this, the LPG strategy and action plan were launched to promote the uptake of LPG and the *Clean Cookstove Market Acceleration Project*, which is a Result Based Funding for manufactures and distributors of cookstoves in Kenya, was launched to increase uptake of clean cooking solutions in the country. These programmes however, are technology focused with only the number of stoves as the metric of success without taking into consideration other factors such as stove stacking which remains key when looking at

[139] Calculated based on VSL of USD 568,000 based on the report by Roy (2016), The cost of Pollution in Africa

[140] Estimated based on the 21,560 annual deaths attributed to HAP against total deaths at 189,087 as reported by the KNBS Economic Survey, 2018

[141] Republic of Kenya. (2016). Kenya SEforALL Action Agenda. Nairobi: Ministry of Energy and Petroleum

household air pollution. While a household may have an LPG cylinder, they may only use it sparingly and use charcoal more often, for example. This means that their exposure levels remain high.

Lack of affordable technologies that enable accurate monitoring of HAP and conducting exposure studies is a great challenge in addressing HAP in Kenya. Conducting these studies remains quite expensive and often limits the number of households that can be observed within a given period. Advanced monitoring techniques such as Direct Sense, MicroPEM remain out of reach for continuous monitoring because of their costs. In addition to the high cost, some of these technologies are intrusive. For instance, the MicroPEM must be worn around the neck the whole day during the data collection process. Such conditions compromise the quality of data that can be obtained and reduces the willingness of households to participate in the studies. Also, though the number of health assessments are generally increasing, they remain narrow in scope and do not allow for conclusive evidence on the impact of interventions such as clean cookstoves and the reductions in exposure to HAP and associated health outcomes. Exposure assessment studies should clearly show relations in personal exposure levels due to interventions or lack of it thereof. Most studies also tend to focus on household air pollution without taking into consideration ambient air conditions. There is a growing recognition that households may suffer more from external sources of pollution rather than from their own kitchens.

7.2.4 HAP Interventions

The use of cleaner cooking technologies has been prioritized as one of the ways through which households can reduce their exposure to air pollution. This strategy is believed to provide triple benefits of improved health, protecting the local environment and minimizing greenhouse gas emissions. The Alliance has been at the forefront of raising awareness and developing remedial interventions. Over $29 million dollars was raised and leveraged $120 million between 2011 and 2012 towards achieving this agenda[142]. Since 2010, about 116 million cookstoves and fuels had been distributed of which 80.9 million are considered clean and or/efficient. In 2016 alone, 37 million stoves and fuels were distributed with 30.8 million considered clean and efficient[143]. A larger share, 68% of these were liquid gas. Other ongoing initiatives include the Global LPG Partnership working to accelerate the transition to liquid petroleum gas for 50 million people by end of 2018; the World LPG Association through their 'Cooking for Life' Programme is encouraging decision makers to recognize the need to ensure that LPG markets develop in a safe way[144]. In addition to these global initiatives there are other related regional and national programmes such as the World Bank's Energy Sector Management Assistance Programme (ESMAP) and SEforALL aimed at dissemination and adoption of clean cookstoves.

Despite the global push towards the adoption of clean cookstoves, there has been limited success in the reduction of HAP exposure in developing countries. This can be partly attributed to the technical and social complexities associated with the stove design and end user preferences[145]. These factors include household size, ease of use, affordability, accessibility, cooking times, the type of meal to be prepared and social and cultural considerations such as eating around the fire[146]. In some instances, households

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142 Global Alliance for Clean Cookstove. (2012). Global Alliance for Clean Cookstoves Kenya Market Assessment Intervention Options. Retrieved from http://cleancookingalliance.org/binary-data/RESOURCE/file/000/000/165-1.pdf

143 Global Alliance for Clean Cookstoves. (2017). *2017 Progress report driving demand delivering impact.* GACC

144 *Sustainable Energy for All. (n.d). Universal Adoption of Clean Cooking Solutions.* Retrieved from https://www.seforall.org/hio_universal-adoption-of-clean-cooking-solutions

145 Lewis, J. and Pattanayak, S. (2012) Who Adopts Improved Fuels and Cookstoves? A Systematic Review available. *Environ Health Perspect* 120(5): 637–645: doi: 10.1289/ehp.110419

completely stopped using improved cookstoves, as was the case in Orissa India. In this case study, households were given improved cookstoves and taught how to maintain them. However, at the end of three years, most of the households were not using the stoves and their smoke exposure levels had not changed[147]. According to Lewis and Pattanayak (2013), one of the reasons for the failure of most ICS programmes in Africa and South Asia is the fact that these programmes have often concentrated on new stove designs, mass production and marketing, and provision of subsidies/incentives for wider dissemination without giving much attention to socio-cultural adaptability[148].

7.3 Environmental and Social Costs

Demand for fuelwood and charcoal has long been associated with increased deforestation and forest degradation. However, recent research has shown that the actual impact is probably not as large as has been portrayed historically.[149] Nevertheless, there are negative impacts, particularly in certain "hotspots", including Kenya and neighbouring countries[150].The contribution of fuelwood and charcoal to land cover change depends on the rate of extraction and productivity of woody biomass in the affected regions[151]. While the focus is often on "natural forests", affected areas include woodlands, shrubland, plantations, woodlots and other communally managed resources, as well as roadsides and riparian zones. The rate of extraction needs to be weighed against the rate of natural or managed regeneration to truly understand the level of sustainable use of these resources.

Prior work on woodfuel sustainability in Kenya estimated the country's residential fuelwood and charcoal consumption using data from the 2009 census and 2006 KIHBS survey.[152] It was estimated that Kenyan households consumed 10.5 Mton of fuelwood and 2.4 Mton of charcoal in 2009. Adding residential demand to commercial and industrial woodfuel consumption resulted in a total wood harvest between 25 and 33 Mton of wood. The range resulted from uncertainty introduced by several unknown factors including charcoal conversion efficiencies. The analysis concludes that this consumption exceeded sustainable supply by 31-42%, leading to a net loss of 8-11 Mton of woody biomass per year, largely in the form of forest degradation.

To make this estimation, the researchers needed spatially explicit information about the quantity of fuelwood and charcoal consumed each year as well as woody biomass growth rates across all land cover categories. This survey provides updated data, which will allow researchers to develop more accurate characterisation of the impacts associated with fuelwood and charcoal consumption. As was outlined in Section 5.2, data from this survey shows that Kenyan households currently consume roughly 10.3 Mton of fuelwood and 2.2 Mton of charcoal,

146 Bielecki, C. & Wingenbach, G. (2013). Rethinking improved cookstove diffusion programmes: A case study of social perceptions and cooking choices in rural Guatemala. *Energy Policy* (66) ,350-358. Retrieved from https://www.researchgate.net

147 Duflo, E., Greenstone, M. & Hanna, R. (2010). *Cooking stoves, indoor air pollution, and respiratory health in India.* Retrieved from https://www.povertyactionlab.org/evaluation/cooking-stoves-indoor-air-pollution-and-respiratory-health-india

148 Palit, D., and Bhattacharyya, S. (2014). *Adoption of cleaner cookstoves: barriers and way forward*. Retrieved from http://www.academia.edu/9763367/Adoption_of_cleaner_cookstoves_barriers_and_way_forward

149 Bailis, R., Y. Wang, R. Drigo, A. Ghilardi & Masera, O. (2017). Getting the numbers right: revisiting woodfuel sustainability in the developing world. Environmental Research Letters 12(11): 115002.Retrieved from https://iopscience.iop.org/article/10.1088/1748-9326/aa83ed/pd

150 Bailis, R., R. Drigo, A. Ghilardi and Masera, O. (2015). The Carbon Footprint of Traditional Woodfuels. *Nature Climate Change* (5), 266–272, doi:10.1038/nclimate2491

151 Masera, O. R., R. Bailis, R. Drigo, A. Ghilardi and Ruiz-Mercado, I. (2015). Environmental burden of traditional bioenergy use. *Annual Review of Environment and Resources 40*(1): 121–150

152 Drigo, R., R. Bailis, A. Ghilardi and O. Masera (2015). *WISDOM Kenya: Analysis of woodfuel supply, demand and sustainability in Kenya.* Washington DC, Global Alliance for Clean Cookstove.

comparable to the 2009 estimates, even though the population has increased substantially. Some of the reasons could be a decrease in charcoal consumption due to the uptake of alternative sources including LPG and the observed rise in use of charcoal in rural areas which may be displacing the use of fuelwood. Introduction of improved charcoal and fuelwood stoves could be another reason for the reduction in per capita consumption of both fuels.

In many traditional societies, the role of sourcing for these fuels has been led by women and children especially girls. According to a study carried out in India, women in surveyed households that use traditional cookstoves spent an average of 374 hours annually collecting firewood. The men, on the other hand, were spending 286 hours on the same activity[153]. Energy access in the home has complex gender dynamics[154]. Since men and women use energy for different activities, their appreciation for new energy interventions is different. In the introduction of new cooking technologies or policy interventions, the preferences could vary across genders, education levels, income levels and age groups.

Figure 52 outlines the average distances covered by respondents to get to the nearest purchase points for the four most common fuel types. Kerosene is the most accessible commercial fuel source for both rural and urban households. This demonstrate the mature and elaborate distribution network which makes kerosene one of the most used form of commercial fuel. Although the average distance to an LPG purchase point is almost double the average distance to a kerosene outlet, it is important to note that the frequency of purchase between the two fuels varies significantly between the two fuels. While kerosene may be purchased several times a week, LPG purchase is more infrequent as it is commonly sold in bulk quantities. This means that users could have a higher tolerance for longer distances for LPG relative to kerosene or charcoal which are not,

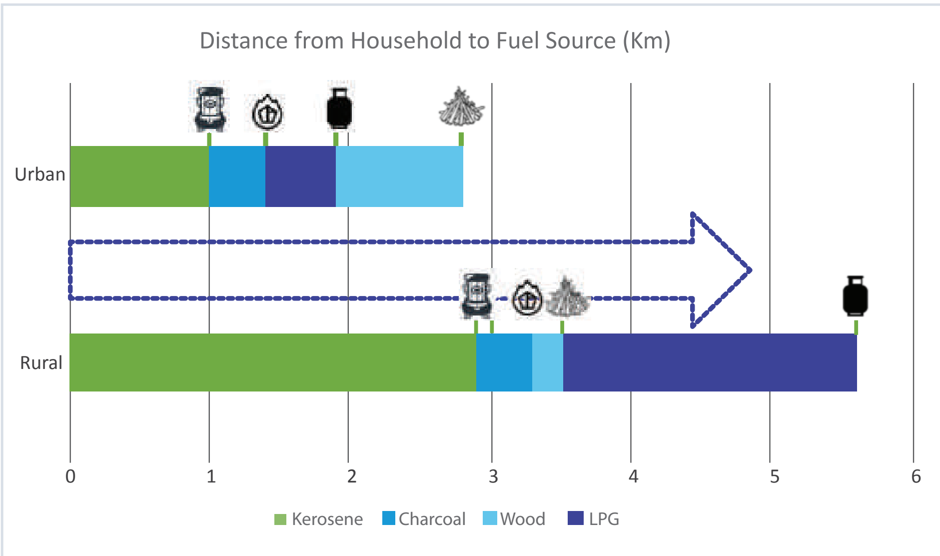

Figure 52: Distance in km from household to fuel purchase point

[153] Global Alliance on Clean Cooking. (2015). *Gender and Livelihoods Impacts of Clean Cookstoves in South Asia. Retrieved from http://cleancookingalliance.org/binary-data/RESOURCE/file/000/000/363-1.pdf*

[154] ENERGIA. (2013). *Mainstreaming gender in Energy sector practice and policy lessons from the energia international network.* Retrieved from https://www.energia.org/cm2/wp-content/uploads/2016/12/Mainstreaming-gender-in-energy-sector-policy-and-practice_FULL-REPORT.pdf

typically, purchased in bulk. The proliferation of affordable and in some cases free delivery services primarily through *boda-bodas*[155] has reduced the inconvenience of distance to a phone call for many LPG users. Between the years 2007 and 2015, the number of *boda-bodas* increased from 16,000 to approximately 500,000, according to the Motorcycle Assemblers Association of Kenya (MAAK). As at October 2017, 159,100 motorcycles had been sold for the year, an 87% increase in sales compared to the similar period in 2016[156] .

In the case of refugee camps, collection of fuels outside the camp poses the risk of direct harm to the women involved[157]. The protracted presence of an unnaturally high population within these areas places a strain on the surrounding environment. This amplifies the potential for inter-community conflict and may increase distances needed to be travelled to obtain the fuel. In addressing the energy needs within humanitarian contexts, the implication of this on the host communities needs to be considered.

7.4 Case 6: Cooking in Humanitarian Context

As of July 2018, Dadaab, which is the largest refugee camp in Kenya had a population of about 209,606 while Kakuma and the newly set up camp Kalobeyei had a combined total population of 185,615 refugees[158]. In both camps, firewood remains the main source of cooking fuel with 90% of households in Kakuma and 98% in Dadaab relying on it[159]. A percentage of the fuel is provided by UNHCR, 10% in the case of Dadaab (supplied to the most vulnerable groups) and 20% for Kakuma[160]. The distribution is usually through a tender process to local organisations such as LOKADO in Kakuma. The remaining proportion is met either through purchase by the households, mainly through barter trade with the host communities or by collection. It is estimated that the daily firewood consumption rate per person in Dadaab camp is about 1 Kg while that of Kakuma is 1.3 kg[161]. Besides firewood, households also use charcoal and kerosene to meet their cooking needs. The charcoal market in Kakuma is quite established and is estimated to be worth KES 200 million ($ 2 million)[162]annually. This is run mostly by the host community and is the main source of their livelihood. UNHCR distributes most of the firewood in Kakuma providing about 935 tonnes per month which translates to about KES 100 million ($ 1 million) per year. Households in Kakuma spend about KES 500 on average per month on energy for cooking [163]and research by Corbyn and Vianello (2018)[164] on Kakuma found that households that cooked using charcoal as primary fuel spent five times as much as those who were using woodstoves and twice as much as the TSOF users. This is because the price of charcoal is almost four times that of firewood by weight. According to the 2014 estimates, households in Dadaab spent an estimated KES 630 million (US$ 6.3 million) a year on wood fuel exerting extensive pressure on the adjacent social and natural environment. This may however vary with the per

[155] Boda-boda in this case refers to the motorbikes and not the earlier definition referring to non-motorised bicycles

[156] Kenya National Bureau of Statistics. (2017). *Leading Economic Indicator.* Retrieved from https://www.knbs.or.ke/inflation/

[157] Bizzarri, M. (2010). *Safe Access to firewood and alternative energy in Kenya: An appraisal Report.* World Food Programme

[158] UNHCR Factsheet 2018 retrieved from https://reliefweb.int/sites/reliefweb.int/files/resources/Kenya%20Operation%20Factsheet%20-%20July%202018.pdf

[159] United Nations High Commission for Refugees. (2015). *Safe Access to Fuels and Energy Strategy and Plan of Action for Refugee Operations in Kenya, 2015-2018.* Retrieved from http://www.safefuelandenergy.org/files/Kenya%20SAFE%20Strategy%20-%202015-18.pdf

[160] Ibid

[161] Ibid

[162] Corbyn, D. & Vianello, M. (2018). *Prices, Products, and Priorities: Meeting Refugees Needs in Burkina Faso and Kenya.* Retrieved from https://www.chathamhouse.org/sites/default/files/publications/research/2018-01-30-meeting-refugees-energy-needs-burkina-faso-kenya-mei-corbyn-vianello-final.pdf

[163] Corbyn, D. & Vianello, M. (2018). *Prices, Products, and Priorities: Meeting Refugees Needs in Burkina Faso and Kenya.* Retrieved from https://www.chathamhouse.org/sites/default/files/publications/research/2018-01-30-meeting-refugees-energy-needs-burkina-faso-kenya-mei-corbyn-vianello-final.pdf

[164] Ibid

capita consumption, which in return is affected by the availability of wood. In 2014, the households in Dadaab were spending up to KES 1,620 per month on firewood and KES 1,615 on charcoal[165] .

As is common in other households, refugee households also practice both fuel and stove stacking. 80% of households use a wood burning fuel-efficient stove, 39 % a regular charcoal stove and a further 10 % a charcoal fuel-efficient stove; Only 1 % use kerosene and less than 1 % use both biogas and electricity[166]. Other stoves in use are the ethanol stoves and LPG, though their use is restricted by the high costs of purchase. The most common improved stoves in both camps are the maendeleo stoves. In Kakuma, these stoves are distributed to arriving refugees. In Dadaab, close to 60% of households used the maendeleo stove, followed by TSOF at 37% while 11% use rocket stoves. There seems to be a marked difference in the consumption of firewood based on the cooking technology used in the camp. Households with open fire use an average of 1.6 Kg/day as compared to those that have maendeleo and rocket stoves at 1.1 kg/day and 1.2 kg/day respectively indicating that the more the efficient stove, the greater the energy saving.

Past and ongoing interventions to mitigate the high demand for firewood in the camps include use of solar cookers by solar international that was piloted between 1995 and 2004 in Kakuma[167]; ethanol stoves distributed under the Project Gaia; briquettes being made by Sanivation from charcoal dust and faecal matter from the camps[168] and the SNV market-based energy project (in Kakuma) to promote cookstoves and fuel supply chains to the camps and surrounding communities[169]. The UNHCR Safe Access to Energy and Fuel Strategy 2015-2018, built upon the UNHCR Global Strategy for Safe Access to Fuel and Energy (SAFE) and launched in 2014, also provides a roadmap on how energy needs in refugee camps can be addressed. The goal of this strategy was to ensure that by 2018, at least 60 % of refugee energy needs in Kenya are met in a sustainable manner. Some of the stated actions include integrating energy access issues into the UNHCR's country level emergency and response planning; and establishing and managing woodlots and other biofuels for fuel provision and environmental protection.

[165] Ibid

[166] United Nations High Commission for Refugees. (2015). Safe access to fuel and energy: A UNHCR strategy and plan of action for refugee operations in Kenya 2015-2018. United Nations High Commission for Refugees

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8. ANALYSIS OF BARRIERS TO CLEANER COOKING

8.1 Characterizing the core problem

The choice of cooking technologies and fuels is a composite process with several secondary and tertiary contributing factors. At the heart of the problem is the use of traditional cooking technologies and fuels. Drivers of the prevalent use of traditional cooking include high cost of alternatives, limited or non-existence supply and distribution channels, lack of awareness, socio-cultural preferences and ill-suited technological design. The impact of this situation is negative health consequences, rising GHG emissions, environmental degradation and environmental destruction. As demonstrated by the information collected in this study, other attributes including location (rural vs urban), size of household, access to fuels, socio-cultural practices, cost of technologies and fuels, choice of meals, past dependency, size and location of cooking areas which all contribute to the current and future use rates of various technologies and fuels.

Class of Barrier	Specific Barrier	Metallic & KCJ charcoal stoves	Branded charcoal stoves	Improved woodfuel stoves	LPG stoves	Biogas stoves	Pressurized kerosene stoves	Ethanol stoves	Electric stoves	Solar cookers
Cost and Acquisition	High cost of technology		■		■	■	■	■	■	■
	High cost of fuel				■				■	
	Limited market intelligence					■	■	■	■	■
	Lack of suitable business models					■				■
Appropriateness	High emissions / smoke	■	■	■						
	Size limitation						■	■		
	Lack of systematic fuel regulation	■	■	■						■
	Restricted to day-time use									■
Availability	Limited supply options									■
	Limited distribution options		■	■	■	■	■	■	■	■
	Limited or lack of awareness					■	■	■		■
Policy and Standards	(Low quality products (spoilage	■		■		■				
	Restrictive policy / standards						■			
	Unclear policy / standards					■				
	Non-existent policy / standards	■		■			■			■
■	Applicable Barrier									

Figure 53: Matrix of core and types of barriers

In trying to understand what would hinder the universal access to modern technologies and fuels, we isolate the barriers to growth in the sector with the aim of identifying high potential barrier removal options.

8.2 Overarching sectoral barriers

8.2.1 Finance Barriers

From the supply side, production/importation of cookstoves and fuels remains capital intensive. This is especially so when a new technology/fuel is introduced to the market. Production/importation of cookstoves and fuels, stove testing, creation of consumer awareness and last mile distribution are activities within the supply chain that are expensive. Access to finance is a major barrier to new products in the whose demand has not yet been proven. In such instances, investors have a low appetite for investing in such businesses, as they are unable to price the risk and estimate the probability of success due to lack of precedence. Start-ups are forced to rely on their own resources, which may not be enough to scale up. Also, financiers such as banks do not understand the market and the risks involved in the ICS businesses and therefore are reluctant to lend to such businesses. This was a common challenge among the respondents who were starting out. These start-ups include briquette, pellets, ethanol gel producers/ importers and gasifier cookstove manufacturers.

From the demand side, the barrier is structured in two forms. The initial cost of acquiring the ICS and the subsequent cost of the fuel. The initial cost of acquiring an ICS is higher when compared to the traditional cooking technologies. For example, a three stone has no initial cost when acquiring it compared to an improved branded biomass stove which would cost between KES 2,800-5,200 (USD 28-52). This is contrasted with the Kenya Ceramic Jiko (KCJ), which retails between KES 300-700 (USD 3-7) and the kerosene wick stove that retails between KES 300-1,500 (USD 3-15). The willingness to pay data shows that as expected, when the price increases, less people are willing to purchase an ICS. For example, when asked if they would be willing to pay for a 6 kg complete LPG cylinder gas at KES 4,500 (USD 45), the current market price, only about 30% of the respondents were willing to pay for it. The cost of fuel can be a barrier if it is being introduced for the first time (for example, an end-user who has been collecting firewood at no cost) or if the fuel is only available in large quantities that require lumpsum payments. The cost of refuelling a 6kg complete LPG cylinder is KES 900 (USD 9) and lasts for 4 weeks for an average household that uses it as a primary fuel. This survey finds that the reported average cost of 1 kg of gas for the urban household is KES 155 (USD 1.55) and KES 160 (USD 1.6) for rural households and this lasts for approximately one week depending on the rate of use. The average cost of one litre of kerosene is KES 100 (USD 1) for both rural and urban areas. The average kerosene consumption per week is 2.5 litres for urban and 1.5 for rural areas, though this is not disaggregated between kerosene for lighting and for cooking. This means that urban households using kerosene spend more than those using LPG. The cost of using kerosene in rural areas is comparable to the use of LPG. 60% of the respondents stated that the cost of fuel for the cookstove they preferred most was high.

8.2.2 Policy and Regulatory Barriers

Creating an enabling environment for the production and importation of ICS and fuels is key in ensuring that the products are available in the market at an affordable cost. Some policies, such as waivers for import duty on raw materials used for the manufacture of cookstoves, have promoted the development of the clean cooking sector but have also negatively affected some players within the supply chain. For instance, import of raw materials for the manufacture or assembling of cookstoves is zero-rated. This is a right step in promoting local manufacturing but a disadvantage to the importers who share the same market with the local manufacturers/assemblers. Importers of stoves must pay the import duty which puts them at a disadvantage compared to those who do local manufacturing. The intricate balance between promoting local manufacturing and ensuring high quality affordable cooking technologies are made widely available complicates the policy formulation process.

In August of 2016, the Banking (Amendment) Bill 2015 which set a cap on the lending rate at no more than 4% above the Central Bank base rate was signed into law. The amendment came into effect a month later. Banks in Kenya eventually scaled down the provision of unsecured loans and micro loans, choosing to direct most of their lending to government debt instruments. This has negatively affected access to finance among the sector players. Another barrier in the policy environment is the challenge in inclusion of stakeholder views in policy formulation. One example is the formulation of the KEBS biomass performance requirement standard. The standard has requirements on safety, durability, emissions, marking, packaging, storage and usage that the manufacturers/importers must adhere to. From discussions with ICS market players, the standards are too stringent and will restrict local production of biomass cookstoves. Leading manufacturers consulted during this study expressed concerns that their views on the standards had not been included in the final documents. The document is, however, currently under review. As discussed above, the role of policy can cause a transformational impact on access rates as demonstrated by the successes in the LPG sector. The standardisation of the hardware, ability to exchange LPG tanks across distributors and fiscal incentives coupled with innovations among the private sector can lead to positive results.

8.2.3 Market Intelligence and Awareness

Manufacturers, importers and distributors of various cooking technologies and fuels lack market information for rural, remote and underserved areas that need their solutions most. Information on the market size, existing and competing alternatives, supply and distribution channels, willingness and ability to pay, current and projected demand are all needed to inform business and investment decisions. Only a few have the resources to carry out the needed market assessment to advice or improve their service offering. In this study for example, we find changing the payment plan from upfront cash to a 6-month payment plan increases the willingness to pay for 6 kg complete LPG cylinder by up to 7%. This could be a key guide in pricing products. On the demand side, knowledge and awareness of the existing cooking technologies in the market and the effects of traditional cooking technologies is key in determining the kind of technology that a household will purchase. Although people are aware of the immediate effects of household air pollution resulting from the use of traditional cooking technologies such as irritation in the eyes and coughs, they may not be aware of the long-term effects of the same such as pneumonia, stroke, ischemic heart disease, chronic obstructive pulmonary disease and lung cancer. These long-term effects of household air pollution have a greater social-economic impact on households and should be considered when deciding on which cooking technology to use.

8.2.4 Technological Barriers

Some of the ICS are limited in terms of their design, specifically stability and diameter of the cooking space. For the ICS considered for this study, diameters ranged between 24-29 cm. This makes it hard to use for very large families who need to use larger cooking pots. It is for this reason that some manufacturers have introduced new stove models to address these concerns. For example, wisdom innovation developed Model 2 (M2) to address the issue of stability and durability, which were concerns in the first model of their stove. BURN manufacturers also introduced the Jikokoa extra, which is bigger in size as compared to the Jikokoa. This is also the case with EcoZoom who introduced a wood stove of 28 cm, 4cm wider than the previous model of 24 cm.

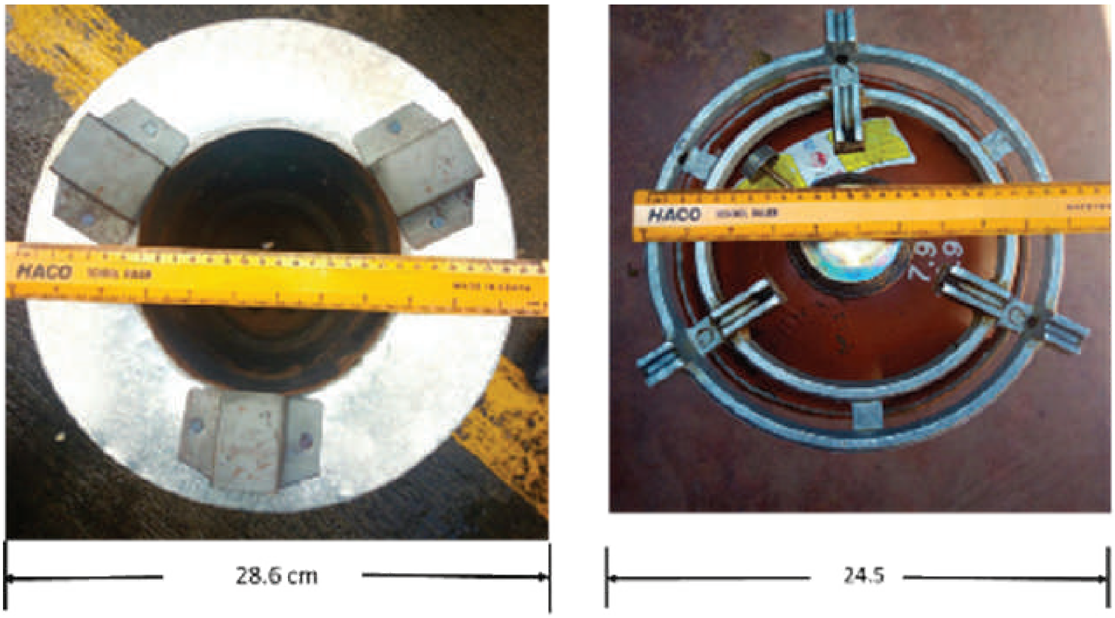

Figure 54: Minimal difference between the widest (wisdom) and narrowest stove (6kg complete LPG cylinder)

Ease of stove operation is another technological barrier. These includes factors such as ease of lighting the stove, ability to systematically regulate heat and fuel use, partial fuel refill and ability to detect fuel level. Cookstoves that address these factors are highly desired by the end-users. The charcoal cookstoves do not address most of these factors and this may explain why approximately 10 % of the population uses charcoal stoves as their primary stove. This may also explain why kerosene is still prevalent among households and LPG is the most desired cooking fuel.

8.2.5 Supply-chain Barriers

Limited options for dissemination of cookstoves and fuels in rural, remote and underserved areas of the country hinder the uptake. Unreliable or unavailable physical infrastructure is a key factor. Apart from kerosene and charcoal that have fully developed supply chains in the country, the other commercial fuels lack well defined supply chains that penetrate to such areas. Even in urban areas, the distribution channels for ethanol, biodiesel, briquettes and pellets are limited – more so in the low-income areas using traditional fuels that are to be displaced. Due to this limitation, preferences are set towards technologies that can be served by fuels that are readily and consistently available. This is, perhaps, one of the key hindrances in households purchasing stoves for new and novel forms of fuel even if these are better matched to their needs. With LPG, which requires specialized facilities for refill, the limited and sparse demand in rural areas makes the installation of distribution points financially unattractive which then restricts access in rural areas which continues to limit demand and thus completing the cycle.

8.3 Fuel specific barriers

In this section, this report provides a summary of the key barriers along specific fuels across the supply chain (upstream, mid-stream and downstream) and considering the impact of policy and regulations. Through a qualitative matrix the current state is marked by a red, amber, green (RAG) symbolizing an undesirable state that needs drastic change (restrictive), a transitional state that has both positive and negative issues (transitional) and an improved state that supports the uptake of the fuel (supportive) respectively. For example, charcoal has regulations to guide production and use (green) but lacks measures to promote sustainable use of the raw materials (red). Midstream distribution is well established with various options available for transporting charcoal from the production points to points of sale (green). Downstream networks are extensive and supported by the high uptake of improved charcoal stoves (green). The aim of this illustration is to provide a comparative summary of the fuel specific barriers. Ethanol, on the other hand, requires interventions from the upstream to downstream level.

Table 30: RAG rating of fuels

	Fuel	Policy/ Regulations	Upstream	Midstream	Downstream
SOLID	Charcoal	Charcoal regulations (2009)	Significant unsustainable production; low technology pyrolysis	Well established distribution channels	High adoption of improved stoves
	Woodfuel	Forest Act (2009)	Unsustainable production; informal production systems	Well established distribution channels	Low adoption of improved stoves;
	Briquettes	Unclear policy and regulations	Limited feedstock sources; charcoal is a leading source of feedstock	Incomplete distribution channels	Low adoption of improved stoves;
GAS	LPG	Zero-rated LPG (Finance Act 2016 +)	Well established distribution channels	Well established distribution channels	Incomplete distribution channels
	Biogas	Unclear policy and regulations	Nascent ecosystem of manufacturers	Incomplete distribution channels	Incomplete distribution channels; low technology adoption
LIQUID	Kerosene	Restrictive policy and regulations	Well established distribution channels	Well established distribution channels	Low adoption of improved stoves;
	Ethanol	Ethanol standards	Nascent ecosystem of manufacturers	Incomplete distribution channels	Incomplete distribution channels; low technology adoption
	Biodiesel	Unclear policy and regulations	Limited sources of fuels	Incomplete distribution channels	Incomplete distribution channels; low technology adoption

Mild barriers   Moderate barriers   Critical barriers

8.4 Monitoring and Evaluation Metrics

The basic components of Monitoring and Evaluation Frameworks include; baseline indicators, theory of change, monitoring plan, evaluation plan and a reporting plan. Preselected indicators and sources of data/information for the monitoring, evaluation and reporting plans form part of this. The monitoring and evaluation process is applied across five groups of indicators: inputs, processes, outputs, outcomes and impacts. Although not all are structured under this basic monitoring and evaluation framework, there are various documents that set targets on adoption of clean and improved cooking solutions in Kenya as summarized in Table 31. This – setting of targets, forms the first step in developing a monitoring and evaluation framework. This section of the report highlights key targets and makes recommendations on how to strengthen them.

Table 31: Kenya targets for cooking solutions

#	Document	Year	Objectives, Actions and Targets
1.	Kenya National Climate Change Action Plan (Draft) 2018 – 2022	2018	***Objective*** under the Energy and Transport priority: increase uptake in clean cooking solutions ***Actions*** - Number of households using LPG, ethanol or other cleaner fuels for cooking increased to 2 million; - Number of households using improved biomass cookstoves increased by 4 million - Biogas technology scaled up to increase access to clean energy through the construction of 6,500 digesters for domestic use and 600 biogas systems in various schools and public facilities
2.	Ministry of Energy (Kenya SEforALL) Secretariat)	2017	***Objective:*** Aims to align Kenya's goal with the Global Tracking Framework (GTF) ***Targets:*** TBC. Proposed indicators for the cooking sector include; (i) national access rate to modern cooking solutions, (ii) share of people using traditional fuels for cooking.
3.	Sustainable Energy for All: Kenya Action Agenda	2016	***Target:*** 100% of the population with access to modern cooking solutions by 2030: - LPG – 35.5% - Biogas – 0.8% - Bioethanol – 4.5% - Electricity – 2.3% - Improved cookstoves (solid fuels) – 57.7%
4.	GACC and CCAK: Kenya Country Action Platform - Pre-final CAP, amended 2016	2013	***Target:*** 5 million Kenyan households using clean cookstoves and fuels for cooking and heating applications by 2020.
5.	Clean Cookstoves Association of Kenya[170]	-	***Target:*** facilitate the increase of adoption of clean cookstoves and fuels to 5 million households in Kenya by 2020.

[170] Target as presented on their website. Accessed 22nd Jan 2019

To improve on the framing and monitoring of these targets and to strengthen the target setting processes, there is need to define the key terms (working definition), select the unit of observation (e.g. persons, households, communities), establish the baseline and provide details on how the progress and results will be monitored and evaluated. The common terms used in these documents include improved stoves, clean cookstoves, clean cookstoves and fuels, modern cooking solutions and clean cooking solutions. The unit of observation is also mentioned as households, institutions, populations, schools and public facilities. Most of the targets are to be achieved by 2020, apart from the Kenya Climate Change Action Plan, which sets the targets at 2022 and SEforALL Action Agenda which sets its target at 2030. This study finds that some of these targets have already been met and therefore need to be revised or reported as having been achieved. For draft documents such as the Kenya Climate Change Action Plan and the Ministry of Energy and Petroleum (Kenya SEforALL) Secretariat) tracking framework, new targets need to be set guided by the baseline status established in this study. An attempt to compare the results of this study with the SE4ALL targets is made and represented in the Table 32. Highlighted under the year 2018 are the outcomes of this study showing both primary usage and stove ownership.

Table 32: Comparision of the study data with SEfor ALL targets

Year	2013	2017	2018 (Primary Use)	2020	2022	2027	2030
LPG (%)	8.6	13.6	19	15	18.6	25.6	35.3
Biogas (%)	0.1	0.2	0	0.3	0.4	0.6	0.8
Bioethanol (%)	0	0	0	1	1.5	3	4.5
Electricity (%)	0.6	1	0.1	1.2	1.5	2	2.3
HHs access to clean fuels non-solid (%)	9.3	14.8	19.1	17.5	22	31.2	42.9
Improved cookstoves-solid fuels (%)	37.2	42.9	20.5	47.7	52.7	57.6	57.7
Total access to modern cooking services (%)	46.5	57.7	39.6	65.2	74.7	88.8	100
Access to unclean cooking services (%)	53.5	42.3	60.4	34.8	25.3	11.2	0
Total access to cooking (%)	**100**	**100**	**100**	**100**	**100**	**100**	**100**

From the comparison in Table 32 the following definitional issues are noted;

- The definition of 'Access' under the Kenya SEforALL document is unclear. For instance, does it refer to ownership or usage? If usage, is it as primary or secondary use? It is critical that definitions are specified in setting targets.
- Assuming the Kenya SEforALL projections are for primary usage, this study finds the total number of households using unclean cooking services as their primary cooking solution is at 60.4% which is higher than the baseline (2013) value of 53.5%.
- Assuming that the targets were on ownership, this study finds that national LPG ownership rates are at 29.8% which has surpassed the 2027 SEforALL targets.
- Further, what does access to unclean cooking services mean? If a household had a TSOF as their primary cookstove and an improved charcoal stove as their secondary stove, under which category would it fall?

For draft documents such as the Kenya Climate Change Action Plan and the Ministry of Energy

(Kenya SEforALL) Secretariat) tracking framework, new targets need to be set guided by these new findings. This study finds that at least 3.7 million households (30.2%) use clean cooking solutions (LPG, electricity, biogas or biofuels) – much higher than the Kenya National Climate Change Action Plan, which sets a target of 2 million households by 2022. Of these 3.7 million households, 1.3 million (10% of all households) use clean cooking solutions exclusively. The SEforALL Prospectus (2016) cites the Kenya Country Action Plan (2013) as marking a baseline of 3.2 million households using improved cooking solution although the Country Action Plan does not explicitly mention this figure. Factoring in improved cooking solutions (KCJ, branded charcoal stoves and branded wood stoves) in addition to the clean cooking solutions, this study finds that at least 5.2 million households (41%) use either clean or improved cooking solutions.

9. CALL TO ACTION

9.1 Conclusions

9.1.1 State of the transformation

Sustained efforts to transform the cooking sector from one that is highly dependent on traditional cooking solutions to one where a majority have access to improved solutions has yielded mixed results. There are positive outcomes that can be attributed to concerted effort at the sectoral and policy level while others have been realized as part of societal changes that come with demographic and developmental change.

On uptake of technologies and fuels, the increase in use of LPG solutions is one example that can be associated with policy and legislative interventions. Key actions include the standardisation of regulators, formations of the LPG common pool and tax incentives leading to improved distribution channels. Although the proportion of households using TSOF has reduced, the aggregate number of households using the technology has increased significantly. On the mix of sector players, there is an increase in private sector investments in bioenergy-based cooking solutions – a sub sector that was almost solely occupied by various development agencies. Initiatives led by development agencies still dominate this sub sector but there is a distinctive rise in private sector investments in improving the technology options, distribution channels and testing innovative business models. On global attitudes and prioritisation, cooking which historically was secondary to other energy development efforts including rural electrification, has increasingly been given prominence in global initiatives including the SEforALL. The burden of environmental and health costs associated with traditional cooking has contributed to this. Coalitions including The Alliance now lead efforts to raise awareness and resources to address the cooking challenges, which has contributed to formation of national coordinating agencies like the Clean Cooking Association of Kenya (CCAK). This study is one result of such efforts.

On policy standardisation and legislation, several measures are now in place and others in draft to improve access to better cooking solutions. Specific legislation, for example the Charcoal Regulations of 2009, tax incentives for LPG anchored in various Finance Acts and efforts to promote local stoves manufacturing at the East Africa Community level, demonstrate the changing prominence of cooking as a development agenda. Comparing the state of the sector in the early 1980s to the current scene, one observes several similarities; development agencies still play a central role, most households still use traditional forms of cooking, low penetration rates of novel fuels (e.g. briquettes and ethanol) and electricity still plays a marginal role as a cooking solution. However, there are changes that indicate progress including; increase in investments from the private sector, raised profile of the cooking sector in national and global development planning, increased use of policy and legislative action and a better understanding of the constraints in the cooking sector.

9.1.2 Inconsistencies in approaches

Charcoal is one of the most important fuels yet remains one of the least understood. The fuel balances livelihood sustenance of many communities in rural areas on one hand (especially in ASAL regions with limited options), and provision of an easily accessible cooking solution for urban households on the other. This study finds, however, that more household in rural areas are now increasingly using charcoal. Although the body of knowledge on charcoal has expanded, attitudes towards charcoal are still informed by prevailing historical narratives and current perceptions which associate the fuel with environmental degradation. As charcoal moves down the value chain from upstream supply to downstream use, a distinct mismatch in attitude towards this fuel is observed. While charcoal production is constantly restricted with little to no support offered to improve the production regimes, there are no reservations with the sale of charcoal and significant support is provided to improve the use of charcoal. Support for production of charcoal stoves, improving distribution and uptake through various initiatives including Results Based Financing (RBF), is provided by sector players. The same paradox has been observed at the policy level historically, where laws, policy, and declarations have been issued banning charcoal production, but the same restrictions are not applied downstream. Up until the 2009 Charcoal Regulations anchored under the Forest Act 2005, there was no overarching legislation guiding the sector. Further, promotion of briquettes is done mainly with an aim of displacing the use of charcoal yet, as mentioned above, many of the briquette manufacturers targeting households use charcoal dust as the primary raw material. Without the charcoal, many of these briquette manufacturers would be adversely impacted.

Attitudes towards kerosene suffer from similar inconsistencies. While kerosene is still used in Europe and North America for domestic heating, use in developing countries is systematically being discouraged. Other applications are found in the aviation sector. Therefore, kerosene can be used in modern ways just like other fossil fuels including LPG and petroleum in transportation. In developing countries, the use is distorted due to dependence of traditional and dangerous technological options. Although it is an important source of fuel for cooking, especially in urban households, hardly any attention or resources has been directed to improving stoves design and safety, unlike charcoal. The prevailing reason being that kerosene is a dangerous and non-renewable fuel while the same can be said of LPG which is even more flammable and equally non-renewable but receives significant support. Ethanol also suffers from similar safety risks, but it remains an accepted fuel option and receives sectoral and policy level support. The extent to which kerosene is dangerous relative to other fuels is not based on any empirical evidence but is largely anecdotal. However, kerosene, like LPG, has the potential to provide a cleaner cooking solution through pressurized use as opposed to the prevalent wick-based technologies.

Such inconsistencies create imbalances and missed opportunities that have the potential of creating diversified solutions to meet the complex household cooking needs. These inconsistencies and paradoxes can largely be attributed to the varied interests across sector players.

9.1.3 Low uptake of novel fuels and technologies persists

Fuels and technologies such as electricity, briquettes, pellets, liquid ethanol, gel ethanol, biogas, solar cookers and fireless cookers have been promoted over several decades. Their prevalence and use at the household level remain marginal. These fuels and technologies all present unique value propositions and have historically failed to transition into the mainstream due to specific reasons ranging from technological design, socio-cultural preferences, price and supply-distribution challenges. There are renewed efforts to promote some of these fuels and technologies, which could be the start of revolutionary changes. Some market transformation lessons, for example from the rise in LPG use, are relevant here as the sector considers actions that can increase the use of these fuels and technologies. Advances in the use of technologies such as the mobile phones and payment platforms such as mobile money present possible opportunities towards such transformations. The prevalence of motorbike transportation *(boda boda)* is a technological and societal evolution that also present last-mile distribution opportunities.

9.1.4 Major gaps in understanding HAP and the environmental burden

By all estimations, cooking fuels exert a significant burden on health and the environment. Several studies and literature contribute to this body of knowledge. Biomass based fuels are associated with forest deforestation and degradation; non-renewable fuels with GHG emissions; commercial cultivation of bioenergy crops with land-use change; among other environmental impacts. Measuring the impact of HAP is primarily a function of estimating cases of health complications that can be attributed to exposure and applying an attribution factor since not all the complications are due to HAP. It is the process of attributing a factor that requires a wider and more robust evidence base. This study finds that many of the sources available on the impacts on health and the environment could benefit from local context research and examples. Studies on the health impacts of HAP, for example, could benefit from longer-term field-based household level monitoring of exposure. Efforts to develop low-cost monitoring approaches are needed to build up the data sources that can be used to improve the estimation of impact.

This study through a pilot project sought to provide empirical data on this difficult and under-researched subject to inform and guide the policy formulation processes, but more importantly, support the targeting of efforts toward those that are most exposed. The pilot which involved the deployment of low-cost monitoring devices was done in two households; one in Gikambura in Kiambu County representing a rural household setting using fuelwood as their main cooking solution and another in Kibera slum, Nairobi County representing urban low-income households that depend on kerosene for cooking. Such initiatives need to be scaled up to generate a body of evidence sufficient to guide decision making.

9.1.5 Penetration rate is not a complete indicator of progress

Most surveys are designed to calculate or estimate the penetration rates. The investigations focus on identifying technologies and fuels in use. Although this is a critical first step in understanding the state of the market, this information needs to be supplemented by data on the usage of fuels. This study demonstrates that, for example, many households that use LPG – which is a cleaner fuel, still use significant amounts of charcoal. Focusing solely or mainly on penetration rates, or number of units sold, leaves larges gaps in understanding the state of cooking. All initiatives should have the twin purpose of increasing access and use. Understanding the use of cooking solutions across gender and age groups at the household level is also important in understanding the impacts of introduced technologies and fuels.

9.2 Call to Action

9.2.1 Develop a cooking sector market transformation program

The key recommendation from this study is a call for the development of a cooking sector market transformation programme. The purpose of this programme would be to fundamentally change the cooking sector – beyond the aim of increasing the number of stoves sold, into a clean, sustainable and profitable enterprise. This study establishes a baseline elaborating the status of access to fuels and cooking appliances but also provides information that explains the reasons informing the current situation. Moving the sector from this baseline to a desired end within a stated period and through clearly defined strategic

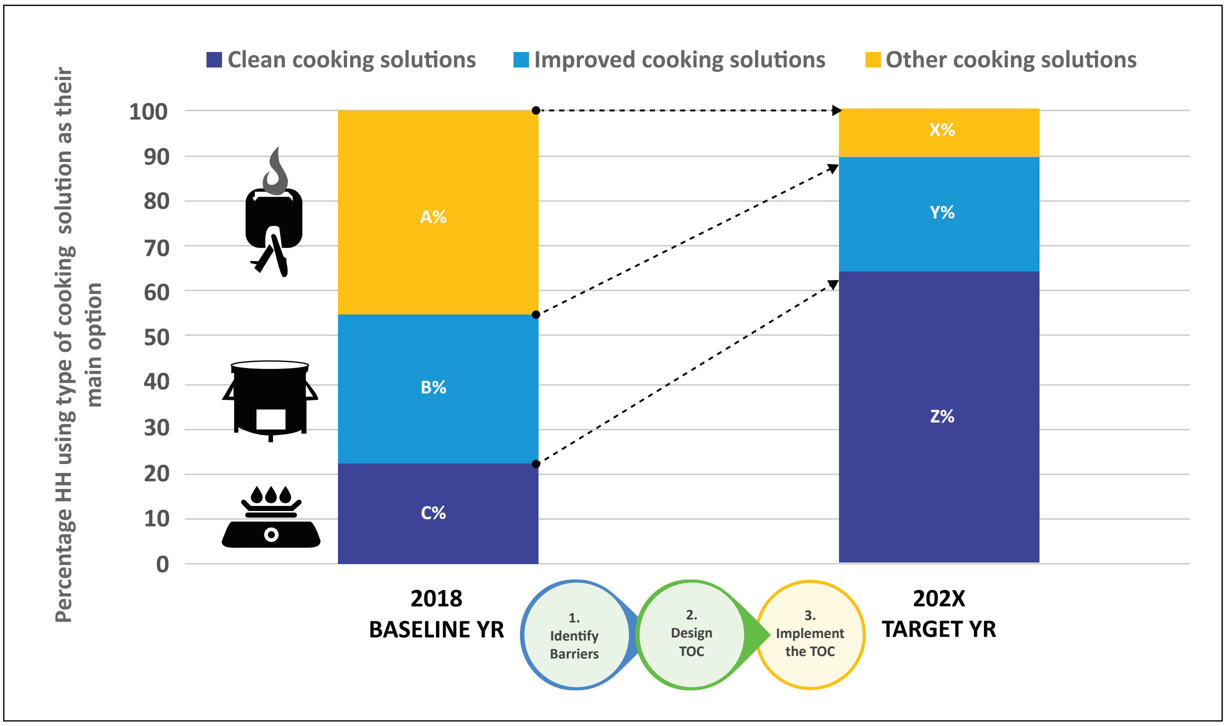

Figure 55: Moving from A, B and C% to X, Y and Z%

interventions as shown in Figure 55 should be the aim of this programme. Identification of specific barriers should be followed by the design of a theory of change (TOC) and implementation of the TOC.

Market transformation programmes aim to address barriers to entry and growth through essential and lasting changes to the characteristics of targeted markets. Although there is no universally acceptable definition of market transformation, common elements include targeted and strategic policy or regulatory interventions, introduction of actions to increase the number of goods or service providers, emergence of new and innovative business models, reduction in market barriers, technical and business capacity development and increased awareness of desired product or types of products. As opposed to interventions that seek to increase the availability or spread of products or services through direct promotion, market transformation programmes aim to affect the fundamental structure and characteristics of the market. Lighting Africa – whose aim is to enable "more than 250 million people across sub-Saharan Africa currently living without electricity to gain access to clean, affordable, quality-verified off-grid lighting and energy products by 2030" is an example of a market transformation programme. Figure 56 is a simplified depiction adapted for cooking fuels and appliances products characterizing a market. Market transformation interventions would generally focus on shifting the primary aspects of a market (yellow section), which in turn will change the secondary and tertiary market characteristics.

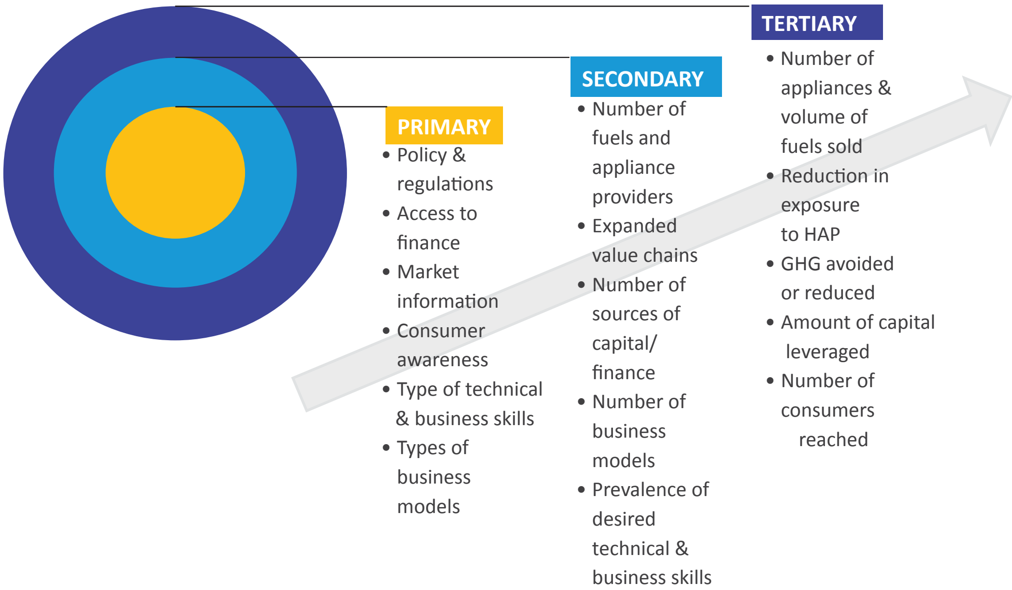

Figure 56:Illustration on the types of market characteristics

9.2.2 Approaches to market transformation

9.2.2.1 Sustain market intelligence efforts

This study finds that many of the objectives and goals towards promoting improved and cleaner cooking under various initiatives have already been achieved and surpassed. This could be interpreted as diligent effort to achieve these objectives and goals, or an understating of aims due to limited knowledge of the market at the onset, or both. This study is the first truly national undertaking that solely focuses on cooking. Although others have highlighted various aspects of cooking, this study delves deeper in understanding stove preferences, willingness to pay, cost of fuels and last mile distribution challenges. The Ministry of Energy, together with CCAK should institutionalize regular cooking sector surveys to track progress systematically and periodically. Like the interdecadal census, cooking studies that are designed and implemented using comparable statistical approached could be done every four or five years to inform the sector on the state of the market. Key sector performance metrics can then be tracked, and outcomes linked or associated with actions taken. Not only will this improve knowledge of the sector, but it will also provide lessons on effective planning and consequences of various policy and market actions

9.2.2.2 Design problem driven approaches

Various initiatives and documents including the Kenya National Climate Change Action Plan, SEforALL Action Agenda, GACC Kenya Country Action Plan (2013) and the CCAK set national targets for clean cooking. The common approach to all these targets is to state the number of households using clean cooking technologies or number of clean cooking technologies in the market. The core problem as stated above is the use of traditional technologies and fuels especially the TSOF. Since the prevalence of clean technologies is not synonymous with a reduction in use of traditional fuels, the focus should be reducing the prevalent use of traditional fuels. Whereas focusing on promoting the uptake of millions of improved cooking solutions contributes to addressing this problem, the two are not the same.

Focusing on the solution or technology rewards dissemination efforts, which may not occur in the most critical areas needed and based on the findings of this report, are the rural areas. Uptake could be skewed towards certain user groups, yet the focus should be on reducing the use of the TSOF and other traditional cooking options. A focus on the problem could state, for example, reduce the number of households using TSOF to n% (or an aggregate number like 2 million) by 2020. This helps to target efforts to those areas where TSOF is prevalent. Focusing on the solution, as demonstrated by this data could result in very high use rates of modern technologies, especially with the understanding that the households stack fuels and technologies – yet it may not address the core problem. Further, all approaches to promote clean cooking should be designed with the purpose of increasing both access and use.

9.2.2.3 Prioritize solutions and interventions

The uptake of LPG demonstrates how government policy when matched with private sector interests can result in positive market transformation. These efforts should be accelerated and expanded to rural and remote areas. Initiatives should include (i) promoting the uptake of LPG cylinders, (ii) providing financial incentives to promote use of the fuel, (iii) supporting the testing of innovative models like the pay as you go business model and (iv) improving distribution channels especially in low-income areas. This study also recommends the promoting of complementary fuels including pressurized kerosene, ethanol gel and ethanol liquid. Kerosene is considered a polluting cooking fuel when used with the wick stove. There are however, opportunities for innovation on the use of pressurized kerosene stoves, which are much cleaner solutions. This will be achieved through (i) further research on the current use dynamics, (ii) research and development on appropriate technology design, (iii) financial incentives to disseminate appropriate technologies and (iv) raising awareness, especially among the public sector, on the importance of using cleaner fuels for cooking. The process of promoting specific cooking solutions should be based on policy briefs developed from the data collected during this study and further dialogue with the sub-sector players. For example, the discussions can be fashioned along working groups on LPG, ethanol, and solid biomass, electric appliance, among others.

The terms of reference of these working groups would be to develop actionable policy briefs that outline measures that advance access and use of the specified cooking solutions. The working groups should also include crosscutting issues including HAP, GHG abatement and finance.

9.2.2.4 Support technology advancement and business development

The KCJ has been fabricated in largely the same way over the last three decades. Although the stove has been widely distributed and is one of the most popular cooking device, very little innovation and changes have been incorporated since. Collaboration between universities, research institutions, and the jua kali artisans needs to be strengthened and lessons from the numerous past projects need to be considered and factored into such an effort. This should be anchored in national programmes such as the Big Four Agenda. Local manufacturers have the capability to improve and standardize stove designs but lack the incentive. Figure 56 is an example of a locally produced (jua kali) improved charcoal stove. Several RBF schemes have been implemented in Kenya but very few, if any, of local artisanal manufacturers have benefitted from such programmes. The lack of standard designs that have undergone testing contributes to this. However, local artisanal manufacturers lack enough incentives to standardize, label and test their stoves – which then makes this a cyclic problem. This can be summarized as; local artisanal manufacturers do not have incentives like the RBF, and therefore are not inclined to standardize, label and test their products. Since they do not standardize, label or test their products, they are not eligible for the various RBF schemes.

In addition to the KCJ types of stoves, local innovation in designing the TSOF alternative and affordable pressurized kerosene stoves should be supported. A challenge fund to improve and introduce the KCJ version 2, alternatives or modifications to the TSOF along with the kuni mbili group of stoves and appropriate pressurized kerosene stoves should be established. The Ministry of Energy demonstration centres can be used as centres of innovation and even sale of these solutions. Untested business models should be supported or at the very least, allowed to be implemented. Innovation in technologies should be matched with innovation in products and service delivery.

Figure 57: Improved jua kali charcoal stove

9.2.2.5 Strengthen sectoral coordination

CCAK, being the cooking sector coordinating body, needs to be further strengthened in its role of *"facilitating the scaling up of clean cookstoves and clean fuels market in Kenya through convening and coordinating the sector, advocating for enabling government policies, creating public awareness and capacity building"*. Some of the practical approaches are to expand its resourcefulness within the sector. For example, CCAK should position itself as the source of up-to-date reliable market intelligence and a repository of knowledge. As stated above, CCAK should consider institutionalizing the cooking sector studies and have them carried out every four or five years. There is also a need to expand the membership base to include the players in oil and gas. Leading distributors of LPG, for example, should be members of CCAK. Access to robust market data is an obvious incentive to such players. CCAK should also seek to diversify its sources of funding to include private sector sources which will strengthen its autonomy. National cooking surveys can be supported by such entities with the understanding that detailed information will be provided to them while the general summaries will be provided to the larger public. In its current structure, CCAK is highly dependent on development agencies. This is understandable since the promotion of improved and clean cooking has traditionally been led by development agencies and civil society organisations. This however is changing with more private companies making substantial investments in building manufacturing and distribution infrastructure. A diversified source of funding further gives CCAK actual and perceived independence thereby positioning the association as an objective player in the sector.

9.2.2.6 Facilitate access to finance and fiscal incentives

With clear financing gaps along the cooking sector value chain, it is expected that facilitating access to finance will address a critical barrier to promoting improved and clean cooking solutions. Assistance should target upstream players including manufacturers and importers of fuels and appliances; midstream players including the distributors with working capital support; downstream players including last mile distributors; and consumer finance. Formal and informal financial institutions that are ecosystem enablers should also be provided with suitable funding sources that they can channel to this sector. The informal fuels and technology sector is particularly in critical need of financing options tailored to their realities and needs. As mentioned above, most of the programmes that provide financial incentives to target interventions, for example the RBF, have remained inaccessible to the informal cooking sector entrepreneurs for various reasons. While they need to strengthen their capacity to access such funds, the funds should also be designed to accommodate the limitations inherent in the informal cooking sector. Setting achievable requirements without diluting the purposes and aims of these programmes will start to bridge the gap between the funds and the informal entrepreneurs. Fiscal incentives should be designed to promote appropriate design, standardisation of products and local manufacturing with the aim of creating meaningful employment opportunities for local technicians and entrepreneurs. This is in line with the Government's Big Four agenda.

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A1 Annexes

A1.1 Images of cooking solutions

Clean Fuels Stoves · Improved stoves · Traditional Stoves · TSOF


TSOF


Metallic Charcoal stove


Fixed Biomass Stove


KCJ


Kuni Mbili


Gasifier


Branded Charcoal Stove


Branded Charcoal Stove


Kerosene Wick Stove


Multiple Burner LPG Cooker


Ethanol Liquid Stove


Biogas System


6 Kg LPG Cooker


Pressurized Kerosene stove


Ethanol Gel Stove


Electric Coil Cooker

Electric Coil Cooker

Mixed LPG and Electricity

Solar Retainers

Tubular biogas system

A1.2 Estimated County-level ratio of NRB to total biomass consumption (fNRB)

	Scenario A (Md) FM				Scenario B (Md) PM			
	"Total demand - Full market"				"Conventional demand - Partial market"			
	NRB Total		NRBdh Direct harvesting only (less LCC byprod.)		NRB Total		NRBdh Direct harvesting only (less LCC byprod.)	
	Direct harv. + LCC byprod.				Direct harv. + LCC byprod.			
County	kt od	fNRB %	kt od	fNRB %	kt od	fNRB %	kt od	fNRB %
Nairobi	0	0	0	0	22	38.3	20	35.9
Nyandarua	125	33.3	121	32.1	193	43.7	189	42.7
Nyeri	220	40.5	219	40.4	243	43	243	42.9
Kirinyaga	60	32.9	60	32.8	140	53.3	140	53.3
Murang'a	32	13.5	32	13.5	177	46.6	176	46.6
Kiambu	206	35.4	205	35.2	430	53.4	429	53.3
Mombasa	0	0	0	0	138	88.7	130	83.4
Kwale	311	38.3	156	19.2	171	26.9	15	2.4
Kilifi	693	43.1	528	32.8	312	25.4	146	12
Tana River	363	38.2	341	35.9	67	10.4	45	7
Lamu	20	18.8	0	0	3	2.9	0	0
Taita Taveta	577	61.3	575	61.1	276	43.2	274	42.9
Marsabit	58	22	58	22	35	16.3	35	16.3
Isiolo	78	38.9	78	38.9	40	25.9	40	25.9
Meru	129	21.6	128	21.5	199	30	199	29.9
Tharaka	81	28	7	2.4	72	25.8	0	0
Embu	250	51.4	189	38.8	180	43.3	119	28.6
Kitui	1,372	53	1,275	49.2	610	33.4	513	28.1
Machakos	98	24.7	91	22.7	170	36.2	162	34.5
Makueni	577	50.2	544	47.3	346	37.7	313	34.1
Garissa	46	12.5	41	11.1	37	11.2	31	9.5
Wajir	52	10	52	10	26	6.2	26	6.2
Mandera	3	0.5	3	0.5	34	7	34	7
Siaya	4	2.2	0	0	106	38	96	34.3
Kisumu	2	1.8	0	0	156	62.8	135	54.6
Homa Bay	3	1.1	0	0	125	31.3	119	29.8
Migori	2	0.8	0	0	189	44.8	185	43.9
Kisii	0	0	0	0	218	56.2	217	55.9
Nyamira	0	0	0	0	111	51.1	110	50.4
Turkana	118	20.3	117	20.1	88	17.3	86	17.1
West Pokot	509	53	414	43.1	220	32.9	125	18.6
Samburu	141	41.3	141	41.3	58	23	57	22.9
Trans Nzoia	45	23	8	4.1	179	54.3	142	43
Baringo	819	59	783	56.4	408	41.8	372	38.1
Uasin Gishu	113	41.9	64	23.7	218	58.1	169	45

	Scenario A (Md) FM				**Scenario B (Md) PM**			
	“Total demand - Full market”				**“Conventional demand - Partial market”**			
	NRB Total Direct harv. + LCC byprod.		**NRBdh Direct harvesting only (less LCC byprod.)**		**NRB Total Direct harv. + LCC byprod.**		**NRBdh Direct harvesting only (less LCC byprod.)**	
County	kt od	fNRB %	kt od	fNRB %	kt od	fNRB %	kt od	fNRB %
Keiyo-Marakwet	349	51.4	248	36.6	169	33.9	68	13.7
Nandi	183	31.8	154	26.8	153	28.1	124	22.8
Laikipia	277	47.1	233	39.6	180	37	136	28
Nakuru	320	39.8	135	16.8	529	52.4	344	34.1
Narok	1,013	54.3	614	33	501	37.2	102	7.6
Kajiado	1,473	69.5	1,470	69.3	841	57	837	56.7
Kericho	210	42.9	175	35.8	204	42.2	169	35
Bomet	103	22.3	103	22.2	142	28.3	141	28.1
Kakamega	99	28	94	26.4	309	54.8	304	53.8
Vihiga	0	0	0	0	102	60.3	102	60.3
Bungoma	43	17.5	13	5.5	258	56.1	229	49.7
Busia	0	0	0	0	136	62.7	121	55.7
Kenya	11,179	41.3	9,470	35	9,516	38.3	7,770	31.2

A1.3 The Calorific values and conversion efficiency for the fuels

Fuel	**Calorific values GJ/ton**	**Conversion Efficiency**
Wood	15	0.17
Charcoal	31	0.31
Kerosene	43.8	0.5
LPG	47.3	0.54

A1.4 Summary of Terms of Reference (TOR)

Cookstoves Technologies and Products

No	Task		Study approach capability & limitation
1.	The supply and distribution chain for each household cookstove technologies/ products in the Kenyan market identified.	□ X □	Identify last mile distributors Map the entire formal and informal supply chain for the formal sector. Get a snapshot of the supply chain of each cookstove category, with a focus on the informal supply side
2.	The manufacturing, production and installation processes including specific information on local manufacturing/ production and importation.	X □	Identify all the manufacturing, production, importation, installation processes for the formal and informal sector. Get a snapshot of the manufacturing, production, importation, installation process with a focus on the informal sector
3.	Existing business models for supplying and distributing identified cookstove products in Kenya.	□ X □	Last mile distribution business models All producer, supplier and distributor business models Landscape of existing business models among various producers, suppliers and distributors.
4.	Estimate and map the number of players in the cookstove supply chain	X	Estimate of the number of key players in the supply chain of cookstove and fuels
5.	Estimate the market share of cookstove products	□	Covered
6.	Estimate, quantify and map the penetration and adoption of cookstove products per stove type	□	Covered
7.	Assess and estimate the number and pEPRAentage of households still using three stones or open fire for cooking and why they are doing so at county level.	□	Covered
8.	Assess and describe the market development level (e.g. pre-commEPRAial, pioneering, expansion, and maturity) for different segments of cookstoves products Identify and describe the key success factors and barriers for the Kenyan cookstove market with focus on each cookstove technology segment.	□ □ □ X □	Market development based on cookstove penetration and potential market Historical context of market and outlook End user stove uptake barriers & enablers All stove supply barriers & enablers faced by enterprises Common supply barriers & enablers

No	Task		Study approach capability & limitation
9.	Identify and assess the effectiveness of the different options for cookstove financing solutions at the cookstove enterprise level and consumer level.	☐	Identify the effectiveness of financing solutions at the customer level.
		X	Identify the effectiveness of financing solutions at the enterprise level
		☐	Get a perspective of available and successful enterprise financing models
10.	Document comprehensive catalogue cookstove technologies in the Kenyan market.	X	Provide details of each cookstove technology in the market
		☐	Provide a perspective of supply dynamics of each type of cookstove technology category and Leverage available catalogues such as GACCs

Cooking Fuels

No	Task	Demand side data collection approach capability & limitation	
1.	Provide an elaborate description and analysis of the different cooking fuels in the Kenyan market.	☐	Identify and describe available fuel type
		☐	
2.	Estimate and map the number of players in the cookstove fuel supply chain (including listing by fuel type names of enterprises/ individuals, their contacts).	☐	Identify last mile fuel distributor.
		X	Map out the entire formal and informal sector fuel supply chain.
		☐	Get a snapshot of the supply chain of each fuel category
3.	Estimate, quantify and map the penetration, use and adoption of the different types of cooking fuels	☐	Covered
4.	Estimate the average annual expenditures for cooking fuels for households.	☐	Covered
5.	Assess and describe the extent of using multiple fuel/stove stacking for the different consumers	☐	Covered

No	Task	Demand side data collection approach capability & limitation	
6.	Assess and describe the market development level (e.g. pre-commEPRAial, pioneering, expansion, maturity and pricing) for different cooking fuels in the Kenyan market focusing on all types of existing cooking fuels and gauging their extent of reliance. Identify and describe the key success factors and barriers for the cooking fuels market focusing on all types of existing cooking fuels in Kenya.	□	Describe market development based on penetration of fuels and potential unreached market.
		□	Describe historical context of fuel market and outlook
		□	End user fuel uptake barriers & enablers
7.	Assess and estimate the number and pEPRAentage of households still using three stones or open fire for cooking and why they are doing so at county level.	X □	All fuel supply barriers & enablers faced by enterprises Common fuel supply barriers & enablers
8.	Identify and describe successful and sustainable business models for cooking fuels targeting all types of cooking fuels in the Kenyan market.	□	Identify successful distribution and pricing business models
		X □	Identify and detail all successful supplier business models Provide a perspective of available and successful supplier business models
9.	Document a comprehensive catalogue of cooking fuels.	X □	Provide details of each fuel and their supply Provide a perspective of the supply dynamics of each type of fuel category.

A1.5 List of KIIs & Survey Participants

Cookstove and Fuel Manufacturers and Importers	
1	Burn Manufacturing
2	Wisdom Innovations Limited
3	EcoZoom
4	Envirofit
5	KOKO Networks
6	Flexi Biogas International
7	Consumer Choice
8	Eco Brick
9	Chardust Limited
10	PayGo Energy
11	SCODE
Cookstoves Program Developers and Financing	
12	SNV-RBF
13	Equity Group Foundation
Promoters of Clean Cooking	
14	Energising Development, Kenya Country Programme (ENDEV)
15	Energy4Impact
16	Clean Cooking Association
Policies and Regulations	
17	Ministry of Energy and Petroleum
18	Petroleum Institute of East Africa
19	Kenya Bureau of Standards
Other Stakeholders	
20	ISAK
21	Isaiah Maobe- Briquette Experts

A1.6 Household Survey Questionnaire

A. Household Cookstove Use

Interview and Respondent Details			
1.	County		
2.	Sub-location Name		
3.	EA ID		
4.	Locality	Rural… 1	Urban… 2
5.	Enumerator's Name		
6.	Start Time	|__|__| : |__|__| Use 24 hour clock	
7.	End Time	|__|__| : |__|__| Use 24 hour clock	
RESPONDENT DETAILS			
8.	Household ID		
9.	Name of Respondent		
10.	Gender of the respondent	Male…1 Female…2	
11.	What is the relationship of the respondent to the household head?	Head…………………….…1 Wife/Spouse……………..2 Child/adopted child……...3 Grandchild………………..4 Niece/Nephew……………..5 Father/Mother……………..6 Sister/Brother……………..7 Son/Daughter-in-law..........8 Brother/Sister-in-law………9 Father/Mother-in-law…….10 Grandfather/mother………11 Other relative…………….12 Workers/workers's relative...13 Other non-relative………..14	
12.	Gender of head of HH	Male…1 Female…2	
13.	Respondent's Phone Num.		
14.	How many members of this household are children below 5 years	(Household members are people in your immediate family, related to you or members of your household, who normally (for the past six months).	
15.	How many members of this household are persons between the age 6 -17 years		
16.	How many members of this household are adults above 18 years		
17.	GPS Coordinates of the Dwelling	a. Latitude (S)	b. Longitude (E)
18.	Is the HH connected to KPLC	Yes….1 No…..2	

A.1	Which of the following cooking appliances does the household currently own? **(Select multiple; select from pictures)**	Kenya Ceramic Jiko (KCJ)….1 Improved charcoal stove…2 Metallic charcoal stove……3 Three stone open fire……..4 Kuni mbili stove (juakali)…5 Potable firewood stove (manufactured)….6 Fixed biomass stove…7 Gasifier stoves……… …8 LPG stove (multiple burner) …9 Meko……………………10 Mixed LPG-Electricity stove……….11 Kerosene wick stove………………...12 Pressurized kerosene stove……...13 Electric coil stove……………………..14 Electric induction stove……………15 Biogas stove…………………………...16 Retained heat cookers……………..17 Solar cooker……………………………..18 Liquid biofuel stove…………………19 Gel biofuel stove………………………20 Nyama Choma Grill………………...21 Microwave……………………………22
A1.i	What does this household use for cooking **most of the time**, including cooking food, making tea/coffee, boiling drinking water? Please tell me the cookstove or device that is used for the most time *(Ask only for HH using more than 1 stove in A.1)* *(This is the main stove)*	Kenya Ceramic Jiko (KCJ)…………………………….1 Improved charcoal stove…2 Metallic charcoal stove……3 Three stone open fire……..4 Kuni mbili stove (juakali)…5 Potable firewood stove (manufactured)….6 Fixed biomass stove…7 Gasifier stoves……… …8 LPG stove (multiple burner) …9 Meko……………………10 Mixed LPG-Electricity stove……….11 Kerosene wick stove………………...12 Pressurized kerosene stove……...13 Electric coil stove……………………..14 Electric induction stove……………15 Biogas stove…………………………...16 Retained heat cookers……………..17 Solar cooker……………………………..18 Liquid biofuel stove…………………19 Gel biofuel stove………………………20 Nyama Choma Grill………………...21 Microwave……………………………22

	Besides [A.2], what other stove does this household use for cooking most frequently, including cooking food, making tea/coffee, boiling drinking water? (Ask only for HH using more than 1 stove in A.1)	Kenya Ceramic Jiko (KCJ)…………1 Improved charcoal stove...........2 Metallic charcoal stove…………….3 Three stone open fire……………...4 Kuni mbili stove (juakali)…………5 Potable firewood stove (manufactured)….6 Fixed biomass stove…7 Gasifier stoves……… …8 LPG stove (multiple burner) ...9 Meko……………………10 Mixed LPG-Electricity stove……….11 Kerosene wick stove………………...12 Pressurized kerosene stove……... 13 Electric coil stove……………………. 14 Electric induction stove………….. 15 Biogas stove………………………….... 16 Retained heat cookers……………. .17 Solar cooker……………………………. 18 Liquid biofuel stove…………………. 19 Gel biofuel stove……………………… 20 Nyama Choma Grill………………... 21 Microwave……………………………… 22
	Do you currently use this stove?	Yes… 1 No… 2 A.3
	Why do you not use this stove?	Too small for some cooking pots … 1 Produces a lot of smoke (can't be comfortably used indoors) … 2 Low fuel efficiency … 3 Takes a lot of effort to light it … 4 Difficult to re-fill… 5 Fuel is expensive…6 Other (Specify) … 555
Ask the following questions first for the most commonly used stove and then repeat for second most commonly used stove		

A.6	What is the brand of this cook-stove?	Burn - Jiko Okoa.......1 Envirofit - Supersaver.......2 Envirofit - GoGrill saver.......3 Envirofit - Smart saver.......4 EcoZoom - Jiko bora.......5 EcoZoom - Jiko bora mama yao.......6 EcoZoom - Jiko fresh.......7 Scode - KCJ.......8 Scode - Metallic.......9 Scode - push and pull stove.......10 Maendeleo Stove.......11 Jiko poa.......12 Jiko Kisasa.......13 Scode - gasifier.......14 Scode - kuni mbili.......15 Scode - Jiko Smart.......16 Wisdom gasifier.......17 Upesi portable.......18 Smart saver wood (econofire).......19 Mimi Moto.......20 EcoZoom - Jiko dura.......21 Burn - Kuni okoa.......22 Envirofit – Supersaver.......23 LG.......24 Samsung.......25 Ramtons.......26 Hotpoint.......27 Beko.......28 Ariston.......29 Mika.......30 Bruhms.......31 Armco.......32

A.7	How many working burners does this stove have? (This question does not ask for cookstoves that obviously have a one burner)	
A.8	Is the stove fixed in one place or moveable?	Fixed…….1 Moveable…… 2
A.9	How long have you been using this **TYPE** stove for? (If less than a year, divide number of months by 12)	Years:
A.10	Which year did you acquire the cookstove (this question should be asked for all stoves apart from the three stone) The question is relevant for also self-built. **(write in full e.g. 1992 and not 92)**	
A.11	What do you use this cookstove for? (Select multiple)	Making breakfast (tea/coffee/eggs) … 1 Heating / Boiling water…2 Cooking light foods (e.g. boil rice, making eggs) …3 Cooking heavy meals (e.g. boil beans and maize) …4 Space heating … 5 All cooking needs… 6 Other (specify) … 555
A.12	How many times do you use the cookstove or cooking device for these activities in a typical week?	Several times each day…1 About once per day………2 A few days each week…..3 About once each week….4 Less than once per week..5
A.13	Where is the cooking with this cookstove or device usually done? (If in main house, probe to determine if cooking is done in a separate room. If outdoors, probe to determine if cooking is done on veranda, covered porch, or open air.)	In main house: no separate room… 1 In main house: separate room… 2 Outside of main house: in a separate room… 3 Outside of main house in open air… 4 On veranda or covered porch… 5 Other 555

A.14	How many working burners does this stove have? (This question does not ask for cookstoves that obviously have a one burner)	Purchased …1⟶**A.15** Receive for free/ gift/ donation….2 Self-built / self-installed stove… 3⟶**B**
A.15	Who gave it to you?	Local private organizations (NGO)…...1 Chief of village……2 Local govt……...3 Friend/ relative….4 Constructed it… 5 Other, specify…555 ***All*** ⟶ **A.24**
A.16	If you were to buy this today, where is the nearest place you would buy it from? (KMs)	
A.17	Which of the following best describes the point of purchase of the cookstove?	Small retail store (kiosk)… 1 Wholesale retail shop… 2 Supermarket…. 3 Specialist store (e.g. Burn / LG distributor) …4 MFIs…………………………………………………5 Hawker….6 Open market…….7 Online……………….8 Sacco / Women groups / youth groups…….9
A.18	Did you buy this cookstove paying in full upfront, under installment or using a loan from a financial institution?	Bought, full upfront payment (Cash)… 1 Bought, full upfront payment (loan from a financial institution) …2 Bought, under installment … 3⟶ **A.22**
A.19	How much was the full payment?	
A.20	What facility provided the loan / part-payment plan? (skip for cash payment)	IBank… 1 Program (e.g. GIZ/EnDev)….2 MFIs……………………………………3 Family/friends/employer……….4 Self-help group (women / youth) Other……………………………………5
A.21	How did you learn of this facility?	TV advert… 1 Radio advert…2 Billboard… 3 Sacco / group information… 4 Social media… 5 Community forum (church, chief's office etc.) … 6 Other… 555

A.22	How much is the **monthly** payment for this cookstove?	Purchased …1⟶**A.15** Receive for free/ gift/ donation….2 Self-built / self-installed stove… 3⟶**B**
A.23	What is the **MAIN** factor that influenced your decision to buy this cookstove?	It was easily available in the market……………………………….1 It was affordable…………………………………………………..2 Prospect of saving money from fuel savings……………………..3 It seemed more convenient to use than other stoves……………4 Less smoke/ pollution……………………………………………….5 Desire / aesthetic / aspirational appeal …………………………6 Access to financing options…………………………………………7 Recommendation from trusted party (e.g. friend, SACCO, group, etc.)……………………………….8 Convincing advert…………………………………………9 Speed of cooking…………………………………………10 Ease of lighting the stove ……………………………………11 Fuel efficiency ……………………………………………12 Effective space heating…………………………………13 Divisibility of fuel (can use fuel in small quantities) ……………..14 Ability to cook multiple types of foods (e.g. grilling, baking)……15
A.24	Did you receive training or information on how to use this cook-stove?	Yes……1 No…….2⟶**A.26**
A.25	What type of training/ information did you receive? (select multiple	Demonstration on how to use… 1 Brochure with information on stove… 2 Instructions by word of mouth…………3
A.26	Did you have an opportunity to use the stove on a trial basis before purchasing/owning it?	Yes……1 No…….2
A.27	What is the **MAIN** aspect of this stove that is most appealing to you?	Speed of cooking ……..1 Ability to cook indoors without smoke …….2 Ease of lighting the stove …………………………3 Fuel efficiency …………………………………………4 Effective space heating……………………………5 Divisibility of fuel (can use fuel in small quantities) ……….6 Ability to cook multiple types of foods (e.g. grilling, baking) …….7
A.28	What aspects of the stove would you like to be improved? (enumerator can select multiple responses)	Too small for some cooking pots … 1 Produces a lot of smoke (can't be comfortably used indoors) … 2 Fuel inefficiency … 3 Takes a lot of effort to light it … 4 Amount of fuel required for a re-fill…..5 Takes a longer time to cook………………6 Nothing…………………………………………7

A.29	Did the cookstove come with product warranty?	Yes……1 No…….2
A.30	Have you claimed/used warranty for this cookstove	Yes……1 No…….2
A.31	Why have you not claimed/used the warranty?	1. The cookstove has not broken down………1 2. The process is tedious……….2 3. Other….555
A.32	Do you know where to get technical support on repairs, maintenance and parts?	Yes……1 No…….2
A.33	Where would you get the support?	From a local technician (jua kali) ………………………………1 From a local technician (skilled/trained/specialized) .... …2 From the product distributor…………………………………… ..3
A.34	Have you had to repair this cookstove since you bought it?	Yes……1 No…….2
A.35	If yes how much was the cost of repair?	
A.36	Which fuel type do you use most for this cookstove? (This question is only for biomass cookstoves)	Charcoal………………………1 Wood…………………………..2 Animal Waste/Dung……………3 Crop Residue/Plant Biomass…...4 Saw Dust……………………….5 Biomass Briquette…………….6 Processed biomass (pellets)/ woodchips...7 Garbage/plastic……………….8
A.37	Which other fuel type do you use on this cookstove?	Charcoal………………………1 Wood…………………………..2 Animal Waste/Dung……………3 Crop Residue/Plant Biomass…...4 Saw Dust……………………….5 Biomass Briquette…………….6 Processed biomass (pellets)/ woodchips...7 Garbage/plastic……………….8

A.38	Who does most of the cooking in this household?	Head..........................1 Wife/Spouse.................2 Child/adopted child..........3 Grandchild.....................4 Niece/Nephew...................5 Father/Mother.................6 Sister/Brother..................7 Son/Daughter-in-law...........8 Brother/Sister-in-law.........9 Father/Mother-in-law.......10 Grandfather/mother.........11 Other relative................12 Servant/servant's relative...13 Other non-relative............14
B. HOUSEHOLD FUEL USE		
B.1	What type of fuel or energy source does this household use (enumerator can select multiple responses)	Kerosene....................... 1 Coal/lignite........................2 Charcoal............................3 Wood...............................4 Solar...............................5 Animal Waste/Dung..............6 Crop Residue/Plant Biomass......7 Saw Dust...........................8 Biomass Briquette................9 Processed biomass (pellets)/ woodchips...10 Ethanol.............................11 Biogas.............................12 LPG/cooking gas.................13 Electricity..........................14 Garbage/plastic...................15 Not applicable....................16 Other, specify............................555
B.2	How do you acquire this fuel?	Purchase (Go to pick up) ....1 Purchase (Delivered to house) ....2 Collect (collect firewood / produce own charcoal) 3
B.3	How far do you typically have to travel to purchase this fuel?	
B.4	In the past 12 months, how often was this fuel or energy source unavailable in the quantity you desired?	Often (more than once a month) … 1 Sometimes (4-12 times a year) … 2 Rarely (less than 4 times a year) … 3 Never 04 Don't know / Unsure … 888 Not applicable............444

B. HOUSEHOLD FUEL USE		
B.5	What type of fuel or energy source does this household use (enumerator can select multiple responses)	Mall retail store (kiosk)………………………………………… 1 Wholesale retail shop………………………………………… 2 Supermarket…………………………………………………3 Specialist store (e.g. petrol station, timber yard) ……………..4 Open market…………………………………………………5 Online…………………………………………………………6
B.6	How much did you spend on the [FUEL TYPE] for this stove in the last week/in a typical week when you use the stove?	________ (KES) Pays nothing ………111 Don't know…………………………888
B.7	How far do you typically have to travel to purchase this fuel?	
B.8	In the past 12 months, how often was this fuel or energy source unavailable in the quantity you desired?	3Kgs cylinder…………………………………………………1 6Kgs cylinder…………………………………………………2 13Kgs cylinder………………………………………………3 40Kgs cylinder………………………………………………4
B.8	How long in MONTHS does the LPG last?	
B.8	What is the brand of your current gas cylinder?	
C. PEPRAEPTIONS AND ASPIRATIONS		
C.1	Please indicate the **TYPE** of stoves you are familiar with from the list provided	Kenya Ceramic Jiko (KCJ)………………………………...1 Improved charcoal stove…………………………………2 Metallic charcoal stove…………………………………3 Three stone open fire……………………………………4 Kuni mbili stove (juakali)………………………………5 Potable firewood stove (manufactured)…………………6 Fixed biomass stove………………………………………7 Gasifier stoves……………………………………………8 LPG stove (multiple burner)……………………………9 Meko………………………………………………………10 Mixed LPG-Electricity stove……………………………11 Kerosene wick stove……………………………………12 Pressurized kerosene stove……………………………13 Electric coil stove………………………………………14 Electric induction stove………………………………… 15 Biogas stove………………………………………………16 Retained heat cookers……………………………………17 Solar cooker………………………………………………18 Liquid biofuel stove………………………………………19 Gel biofuel stove…………………………………………20 Nyama Choma Grill………………………………………21 Microwave…………………………………………………22

C.2	Pleased rank the stoves, indicating your top 2 most preferred and the bottom 1.	Top choice … 1 Second choice … 2 Least preferred … 22
C.3	The cost of the most preferred cookstove is high	Yes……1 No…….2
C.4	The most preferred cookstove is easily available in the local market	Yes……1 No…….2
C.5	The cost of the fuel for the most preffered cookstove is easily available	Yes……1 No…….2
C.6	The fuel for the most preferred cookstove is easily available in the local market	Yes……1 No…….2
C.7	Do you currently own the most preferred cookstove?	Yes……1 No…….2
C.8	What is the **MAIN** factor limiting you from owning your most preferred stove	Stove is unavailable in the market…1 Fuel is unavailable in the local market… 2 The stove is expensive … 3 Fuel for the stove is expensive… 4 Safety concerns… 5 Other (specify) …. 555
C.9	Do you currently own a fridge	Yes……1 No…….2
C.10	Do you know of any banks or programs that offer financing for improved cookstoves?	Yes……1 No…….2
C.11	How did you learn of this program?	TV advert… 1 Radio advert…2 Billboard… 3 Sacco / group information… 4 Social media… 5 Community forum (church, chief's office etc.) … 6 Other… 555
C.12	Would you enroll in such a program (including taking a loan)?	Yes…1 No… 2
C.13	Why wouldn't you enroll for the program?	Limited cookstove options under the program……1 High interest rate……………………………………..2 Short payment period………………………………………..3 Other ……………………………………………555
C.14	If you were to receive information on cookstoves, SELECT ALL the mediums of communication that would apply to this household.	Tv……………………………………………………….1 Radio……………………………………………………. .2 Smart phone………………………………………………..3 Computer/laptop……………………………………………4

D. WILLINGNESS TO PAY FOR COOKSTOVE		
(Interview: Please, describe and explain the benefit of having ICS) I would now like you to think about a situation that is not real. Imagine that you could pay a "lump sum" price for this cookstove. This cookstove can reduce the smoke and fuel consumption significantly. Possibly, your cooking time per meal will be shortened since firepower of this cookstove is stronger than the traditional cookstove.		
D.1	How much did you spend on the [FUEL TYPE] for this stove in the last week/in a typical week when you use the stove?	Yes………………………………1⟶E No……………………………….2
D.2	Imagine that you were offered this cookstove at this price today, and you were given 6 months to complete the payment. Would you accept the offer?	Yes………………………………1⟶E No……………………………….2 Don't know……………………..888
D.3	Why would you not accept the offer?	3Kgs cylinder……………………………………………………..1 6Kgs cylinder……………………………………………………..2 13Kgs cylinder……………………………………………………3 40Kgs cylinder……………………………………………………4
D.4	Why would you not accept the offer?	Yes…………………………………….1 No……………………………………..2 Don't Know……………………..888
D.5	Why would you not accept the offer?	Cannot afford the payment………1 Do not need the cookstove……….2 The cookstove is unreliable………3 Fuel cost is too expensive………..4 Other, specify……………………555
D.6	Instead of 12 months, imagine you were offered this cooking device at this price today, and you were given 24 months to complete the payment. Would you accept the offer?	Yes………………………………………1 No………………………………………..2 Don't know…………………………888
D.7	Why would you not accept the offer?	Cannot afford the payment………1 Do not need the cookstove……….2 The cookstove is unreliable………3 Fuel cost is too expensive………..4 Other, specify……………………555

E. CHARACTERIZATION OF COOKING AREA		
E.1	Enumerator, do you have a measuring device?	Yes…1 No…..2
E.2	What is the shape of the cooking area?	
E.3	Measure the length and the height for the roughly square kitchen	
E.4	Measure the length, width and height of the rectangular shaped kitchen	
E.5	Measure the diameter and height of the roughly circular shaped kitchen	
E.6	Can you show me the cookstove you spend the most time cooking on? **This is the MAIN cookstove, take a picture of the stove**	
E.7	Can you show me the cookstove you spend the second most time cooking on? **Take a picture of the stove**	

A1.7 Categorization of cookstoves and fuels

Improved Cooking **Clean Cooking Solutions**

Cooking Solutions	Traditional Biomass Stoves		Improved Biomass Stoves			Modern[171]- Liquid, Gas & Electric Stoves			Renewable Fuel Stoves		
Stove Category	**Open fire**	**Legacy stoves**	**Basic ICS**	**Intermediate ICS**	**Advanced ICS[172]**	**Kerosene stoves**	**LPG stoves**	**Electric**	**Biogas**	**Biofuel stoves**	**Solar & Retained heat**
Emissions	Tier 0	Tier 0 -1	Tier 1	Tier 1 -2	Tier 3	Tier 3-4	Tier 4	Tier 4	Tier 3 - 4	Tier 3 - 4	Tier 4
Cookstoves & their description	1. Three stone	2. Metallic, biomass (+wood), stoves, no chimney	4. Built in or portable biomass (+wood) stoves, insulated, with chimney,	6. Built in, biomass (+wood), stoves incl rocket stoves[173]	9. Natural draft, TLUD[174], gasifier stoves	12. Kerosene wick stoves	14. Single burner stoves incl mekos	16. Electric coil stoves	18. Biogas digester systems	19. Liquid biofuel stoves	21. Solar cookers
		1. Metallic charcoal stoves, no insulation	5. Charcoal, ceramic stoves, basic & artisanal	7. Portable, biomass (+wood), stoves incl rocket	10. Natural draft, TCHAR[175], gasifier stoves	13. Kerosene pressurized stoves	15. Multiple burner stoves incl table tops & cookers	17. Electric induction stoves		20. Gel biofuel stoves	22. Retained heat cookers
				8. Improved charcoal stoves incl. rocket stoves	11. Forced/ Fan draft gasifier stoves						
Fuel Category	Solid biomass - Traditional or Renewable[176]					Fossil – fuels		Electricity	Renewable fuels		
Fuels	i) Firewood; ii) Charcoal; iii) Uncarbonized briquettes; iv) Carbonized briquettes; v) Pellets					vi) Kerosene	vii) LPG	viii) Electricity	ix) Biogas feedstock	x) Liquid xi) Gel	

[171] Modern refers to non-biomass stoves relying on Liquid/gas fossil fuels or electricity – World Bank (2012), State of the Clean Cooking Energy Sector in Sub-Saharan Africa
[172] If advanced ICS are used with fuels like pellets and briquettes they can be clean cooking solutions
[173] Rocket stove: has an L shaped combustion chamber or other design features that promote thermal efficiency
[174] TLUD: Top loading updraft gasifier cookstove
[175] TCHAR: Combination TLUD / charcoal cookstove, produce bio-char as a byproduct, which can be used for fertilizer or for charcoal cooking.
[176] Renewable biomass refers to wood, charcoal and agro-waste obtained from sustainable management practices of source land, crops and forests

A1.8 A pilot on the use of low-cost IoT enabled indoor air quality monitoring system

Overview

The pilot was done in two households; one in Gikambura in Kiambu County representing a rural household setting using fuelwood as their main cooking solution and another in Kibera slum, Nairobi County representing urban low-income households that depend on kerosene for cooking. The first household uses Three Stone Open Fire (TSOF) as their primary cookstove in a separate room from the main house. Two of the five household members took part in the exercise by wearing the bracelet on the continuous basis. One was the primary participant (in-charge of preparing most of the meals) and the second participant regularly assists with the cooking but in a supporting role. The monitor was placed in the cooking area at a level directed towards the primary cooking stove. Data collection was from Saturday (27th April 2019 midday) to (29th April 2019) morning allowing continuous data collection for 24 hours as outlined in the WHO guidelines.

A. Figure 1 shows the monitor installed at the cooking area of this household.

The second house was in Kibera slum in Nairobi County. Cooking in this household is done in the main house with no separate room. The household has five members including two parents and three children, with two members participating. Both the father and the mother took part in this study. It is also worth noting that the mother was almost always with their 8-month-old child and as such her exposure level are comparable the child's exposure levels. They use two types of stoves; the Kenya Ceramic Jiko (KCJ) which uses briquettes as the fuel and a kerosene stove. The KCJ is used for cooking dinner and for space heating while the kerosene stove is used for preparing breakfast and lunch-time meals. Data was collected from Tuesday (7th May 2019) evening to Thursday (9th May 2019) evening.

Technology

The Aero pro indoor air quality data logger had been designed (designed by engineers at EED Advisory to measure pollution arising from cooking solutions at the household level. This is complemented by a smart water-proof bracelet worn around the wrist of the household member to mark and record the time an individual entered and left the cooking area in a non-invasive manner. The monitor records data at one-minute intervals, logs data on an onboard SD card as a CSV file and has low power consumption which can last 3-4 days on 3000 mAh. It measures indoor air-pollution measurements by collecting readings that include particulate matter (PM_1, $PM_{2.5}$ and PM_{10}). This study focused on $PM_{2.5}$ which has a significantly higher contribution to negative health impacts[177]. In addition, the monitor comes with an onboard thermal camera to record stove temperature readings in manner that blends with the surrounding, ensuring minimal interference with the area under study. It also tracks human presence within the room thus acting as an activity detector that can detect and differentiate individual household members using Bluetooth technology. The movement in and out of the cooking are is then layered against the total level of pollution in the room. The devices are shown in A. Figure 2.

[177] World Health Organization. (2005). WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide Who Guidance. WHO Press: Geneva

A. Figure 1: Aero pro air quality data logger and a smart bracelet

$PM_{2.5}$ concentration and stove temperatures for the household using TSOF were recorded as shown in A. Figure 3. The stove temperatures are important to ascertain that the peak concentration levels were recorded when the stove was in use and in noting the exact times the stove/s were switched on and turned off.

Figure 3 shows that as the temperature of the stove increases so does the concentration levels of $PM_{2.5}$. It can therefore be concluded that the source of pollution is the stove as the levels go down to almost zero when the stove is not in use. The peak concentration for TSOF was recorded at 1000 $\mu g/m^3$. Although this peak value could be higher as the monitor had been set to measure emissions up to 1000 $\mu g/m^3$. This is contrasted with the peak levels for kerosene stove which is approximately 800 $\mu g/m^3$ as shown in A. Figure 4. Note that the kerosene stove is used during the morning hours and lunch time. The charcoal stove also has peak levels of up to 1000 $\mu g/m^3$ which is greater than the levels recorded for kerosene. This could be because the kerosene stove is switched on instantaneously as opposed to the charcoal stove that takes time to light, and also most households take their kerosene stoves outside to put them off to avoid the smoke that result from the process.
The times when the participants (who were wearing the bracelets) were in the cooking area was analyzed and presented in A. Figure 5. Comparing A. Figure 3 and A. Figure 5, it can be seen that the participants were in the cooking area during peak concentration which poses a high risk to their health.

This data was then used to calculate pollution levels attributed to the cooking area per participant. The results are presented in A. Figure 6. The primary participant is exposed to 213 $\mu g/m^3$ which is 8 times higher than the WHO 24 hour mean guideline of 25 $\mu g/m^3$. The secondary participant is exposed to 26 $\mu g/m^3$ which is slightly higher than the WHO guidelines. Comparing the primary participant exposure levels with those of the secondary participant, the primary participant is exposed to 8 times the concentration levels of the secondary participant. It is also estimated that smoking one cigarette is equivalent to exposure at 22.7 $\mu g/m^3$ of $PM_{2.5}$. Comparing this with the exposure levels of the primary participant within 24 hours translates to smoking 9 cigarettes daily.

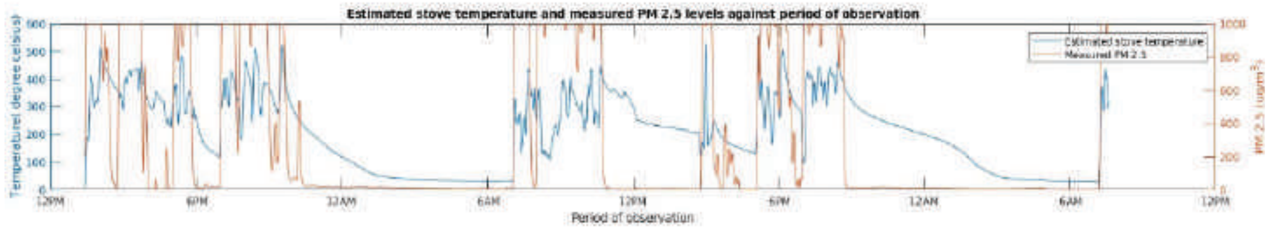
The pollution levels greatly reduce when the two households are compared. The house that uses both the KCJ (briquette) and a kerosene stove recorded 40.5 $\mu g/m^3$ of $PM_{2.5}$ for the primary participants and 4.2 $\mu g/m^3$ for the secondary participants. The data also shows that the mother was the most affected relative to the father who spends a lot of time outside the house. The mother together with 8-month child were exposed to 10 times the $PM_{2.5}$ concertation levels compared to the father. Table 1 shows how the different concentration levels impacts the human health. This shows that exposure 213 $\mu g/m^3$ of $PM_{2.5}$ poses a high risk on human health.

A. Table 1: Impacts on health (Source: Environment Protection Authority)

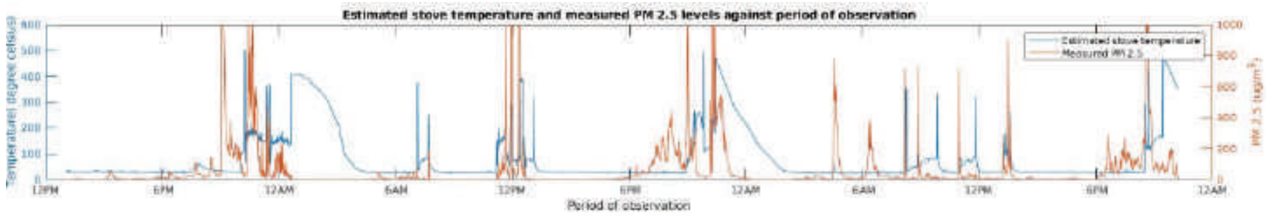
Health category	24-hour PM 2.5 $\mu g/m^3$
Low	0-8.9
Moderate	9.0-25.9
Unhealthy-sensitive	26.0-39.9
Unhealthy-all	40.0-106.9
Very Unhealthy- all	107.0-177.9
Hazardous (high)	Greater than 177.9
Hazardous (extreme)	Greater than 250

Conclusion

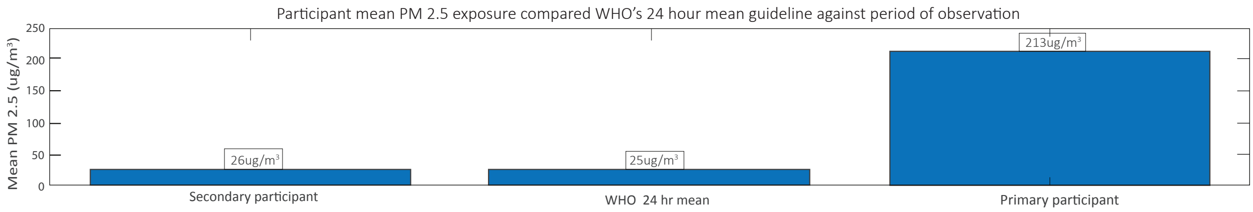
This pilot study was able to demonstrate the following; (i) cost-effectiveness meaning that several aero pro systems can be realistically deployed within a reasonable budget; (ii) measurements can be done against a household member; (iii) user can be classified based on their primary and secondary cooking solutions and typologies of exposure created which can help target interventions; (iv) total exposure solely attributed to indoor air pollution can be tracked over time; and (v) impacts of introducing improved cooking solutions can be quantitatively monitored. The next step would be to scale this study across several typology of traditional forms of cooking to strengthen the understanding of indoor air pollution.



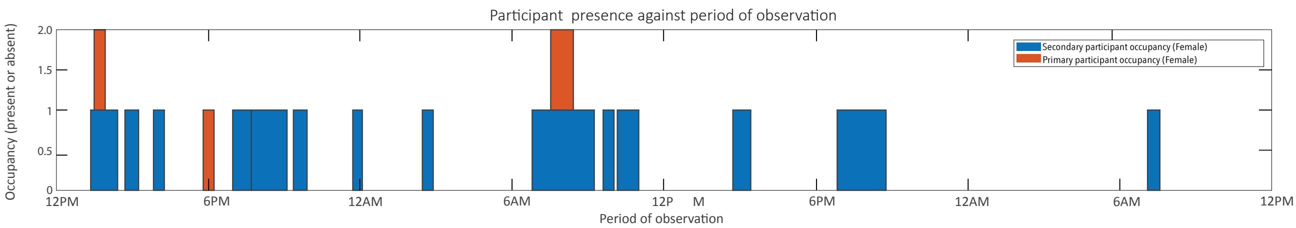
A. Figure 3: Estimated stove temperature and measured PM 2.5 levels against period of observation



A. Figure 4: Estimated stove temperature and measured PM 2.5 levels against period of observation



A. Figure 6: Participant presence against period of observation



A. Figure 5: PM 2.5 concentration levels in the household using TSOF

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