MARKET POTENTIAL OF ETHANOL FOR CLEAN COOKING IN SIERRA LEONE

2024 REPORT

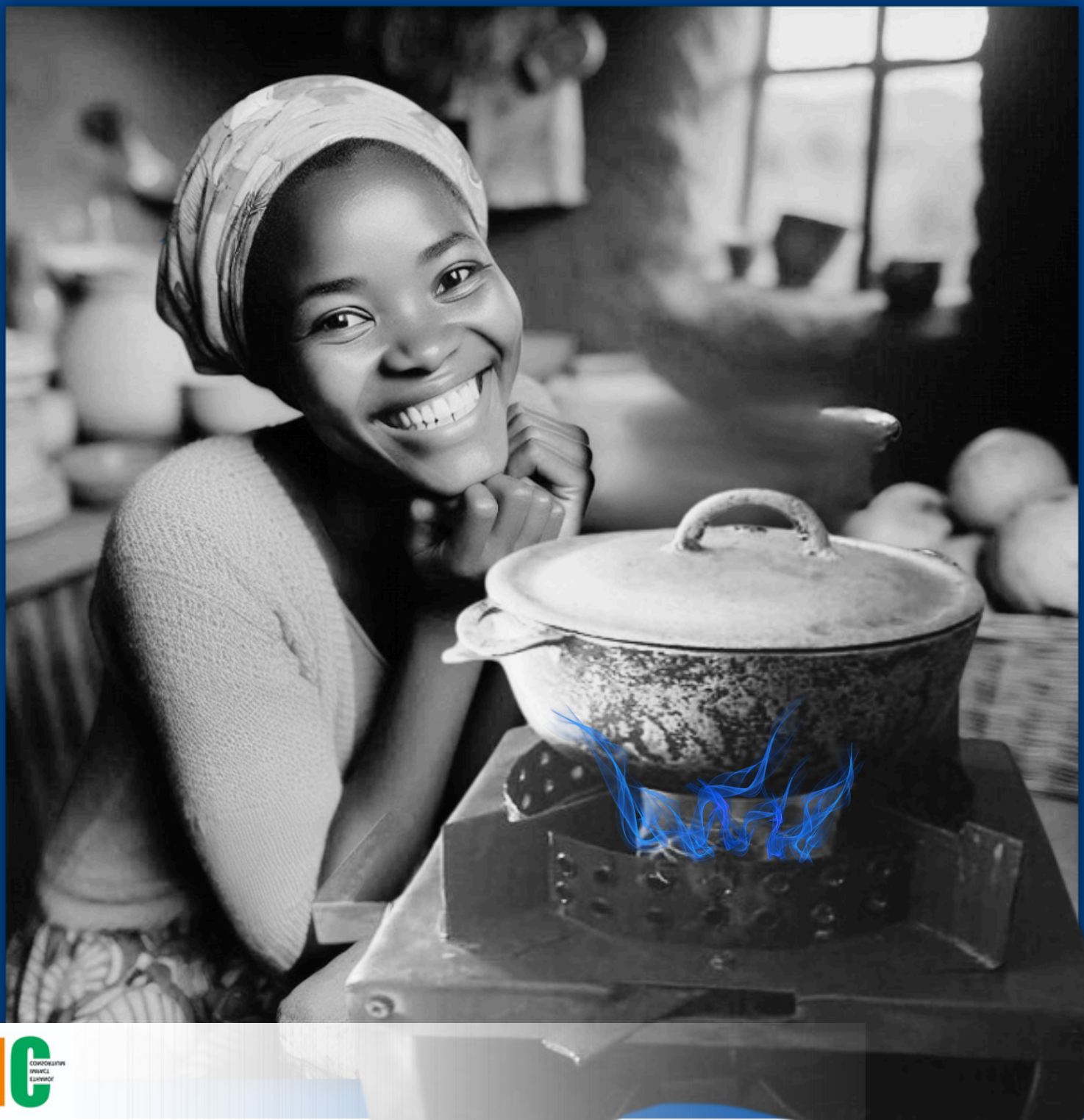

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Table of Contents

Acknowledgment *2*

List of abbreviations *1*

ESMAP definition on cooking energy solutions *1*

Preface *1*

Executive summary *2*

1.0 Introduction *1*

1.1 Background 1

1.2 Objective and Scope of Assignment 3

1.3 Overview of Energy for Cooking Landscape in Sierra Leone 4

1.4 Existing Policy on Cleaner Cooking Solutions in Sierra Leone 7

1.5 The Energy Ladder Concept 9

2.0 Methodology *11*

2.1. Locations of sites for the survey 11

2.2 Typology of cooking fuel/technology 11

2.3 Conceptual framework 12

3.0 Results and Discussion *13*

3.1. Key statistics and findings *13*

3.2. Primary and secondary cooking solutions 15

4.0 Lessons and Learnings *25*

4.1 market transformation from the trench (hole) fireplace known as three-firestone 25

4.2 market transformation from the growing use of charcoal 26

5.0 Conclusions and Recommendations *29*

5.1 Conclusions 29

5.2 Recommendations 30

References *34*

List of abbreviations

CPI Consumer Price Index
CCA Clean Cooking Alliance
DHS Data and Demographic and Health Surveys
ECOWAS Economic Community of West African States
ECREEE The ECOWAS Center for Renewable Energy and Energy Efficiency
EIC Ethanol Impact Consortium
EIC Energy Integrated Centers
ESMAP Energy Sector Management Assistance Program
GDP Gross Domestic Product
ICDI International Consulting for Development of Impact
ISO International Organization for Standards
ISO-IWA International Organization for Standards - International Workshop Agreements
LPG Liquefied Petroleum Gas
MOE Ministry of Energy
MRU Mano River Union
PGI Project Gaia
RBF Result Base Finance
SDG Sustainable Development Goal
SEforALL Sustainable Energy for All
SLIHS Sierra Leone Integrated Household Survey
TENN The Energy Nexus Network
TOC Theory of Change
USA United States of America

ESMAP definition
on cooking energy solutions

Although there are no accepted definitions of the terms "improved cook stoves," "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. These definitions, given below, were guided by the ISO IWA tiers of performance.

Clean cooking solutions	Cooking solutions with low particulate and carbon monoxide emission level (IWA ISO Tier 3-4 for the indoor emissions indicator, within the Global Alliance's Monitoring and Evaluation framework). These include stoves based on Petrol chemical fuels (Liquefied Petroleum Gas (LPG), natural gas, kerosene), electric stoves, and electromagnetic induction cook stoves
Cooking solution	Any combination of technology and fuel used for cooking
Fuel stacking	The phrase describes the use of multiple devices and fuels to satisfy household energy needs
Fuelwood	Solid biomass fuel from wood sources. The word is used synonymously with firewood
Improved biomass cookstoves	Biomass stoves that improve on traditional baseline biomass technologies in terms of fuel savings via improved fuel efficiency
Improved cooking solutions	Cooking solutions that improve, however minimally, the adverse solutions health, environmental, or economic outcomes of cooking with traditional solid fuel technologies
Primary cooking solution	Cooking solution that is most used (frequency of use)

Secondary cooking solutions	Second most commonly used cooking solution for households (frequency of use).
Traditional cooking solutions	Baseline cooking technologies that employ no functional considerations for fuel and/or thermal efficiency. Examples include the three-stone fire, clay stove, and metal charcoal stoves
Use rate	Percentage number of households in possession of and using a technology of fuel
Market Transformation	Structural or behavioral change in the marketplace that increases the adoption of energy-efficient technologies and practices.
Used and solutions	This study distinguished between cooking solutions that are owned and those that are used and the two should not be used interchangeably. A household may own but not use a cooking solution.

Preface- Government of Sierra Leone

Sierra Leone is facing critical socio-economic development challenges on climate vulnerability, deforestation, environmental degradation, economic development, health outcomes and gender inequality. In the country's quest for cleaner cooking solutions, ethanol is emerging as a promising alternative and renewable energy source of clean cooking fuel with the potential to address these pressing development issues simultaneously. Ethanol offers many promising opportunities as a clean cooking fuel.

First, compared to traditional biomass fuels, which pose significant health risks, especially to women and children, ethanol is an alternative pathway to improving health outcomes associated with indoor air pollution by reducing toxic and harmful emissions. Second, women make up 70% of agricultural workforce in Sierra Leone. By engaging women in ethanol production, distribution and use for cooking and processing agricultural crops, Sierra Leone can foster economic empowerment, social inclusion, gender equity and dignity of our women folk. Third, the relatively low-carbon footprint of ethanol contributes to climate resilience, offering a sustainable energy alternative that could help mitigates Sierra Leone's emissions and support adaptation efforts on vulnerability to climate change impacts. Finally, ethanol's potential to diversify the energy sector and stimulate agricultural productivity and value addition could enhance productivity and foster economic growth, creating employment opportunities, social inclusivity and driving forward the country's sustainable development agenda.

Currently, the Government of Sierra Leone through the Presidential Initiative on Climate Change, Renewable Energy and Food Security (PI-CREF) is leveraging strongly on existing partnerships while at the same time seeking additional partners all around the world to develop and implement its energy transition plan with energy for cooking as a major component of that undertaking. This includes sourcing funding from multiple development partners and funders, including climate finance and significant private sector investments in energy sector. In this respect, PI-CREF is using its mandate and technical expertise to facilitate policy coherence among relevant MDAs and supporting efforts to build technical capacity of relevant MDAs to better deliver on their mandates and development objectives. As a clean and sustainable energy source for cooking, there is no doubt whatsoever that ethanol represents a holistic cooking solution to Sierra Leone's energy sector.

Preface- EIC

COP28 in December 2023 and the IEA Clean Cooking Summit in 2024 are recent events that have helped to set the tone of urgency for making progress on clean cooking solutions in Africa. These events brought together stakeholders from governments, the U.N., the private sector, donors and institutions, many of whom made very positive announcements of commitments to addressing clean cooking and climate change action. In the context of these developments, the Ethanol Impact Consortium (EIC) has stepped up its advocacy for clean cooking with ethanol in Africa by conducting a workshop, planning for a pilot study in West Africa, and designing a country program with a sustainable model for capacity building and private sector intervention to strengthen the eco-system for clean cooking. EIC's founding partners, TENN, PGI and ICDI, form the pillars of an ethanol clean cooking initiative in Africa and will engage with partners from government, the U.N. and the private sector. The EIC's program on ethanol clean cooking will commence in West African countries and grow to East Africa. All stakeholders are welcome to join with the EIC in this initiative to embrace ethanol for clean cooking.

Executive Summary

Over the course of several years, numerous donor interventions have been conducted by development agencies, both local and international, through programs and research on energy use for electricity and industrial purposes. However, little or no attention has been given to energy for cooking. The Government of Sierra Leone, under the Ministry of Energy, routinely submits an annual budget to the Parliament for electrification and electricity supply and distribution. However, there hasn't been any allocation within this budget line dedicated towards the energy for cooking.

This lack of focus has resulted in the cooking energy sector remaining dormant, with little progress made towards meeting the Sustainable Development Goal 7 (SDG7) which aims for affordable and clean energy not only for electrification but also for cooking. The demand for cooking fuel and devices is not just limited to big urban districts but also extends to small rural towns and villages. Notably, the cooking energy landscape in Sierra Leone has always been dominated by women, with 88% of the respondents in this study being women. The traditional way of cooking, practiced daily by 94% of the respondents on daily basis, continues to be the norm.

The objectives of this study revolve around mapping the cooking energy landscape, exploring cooking devices and technological solutions, and assessing the market potential of bioethanol as an alternative cooking fuel source in Sierra Leone. The study aims to establish baseline indicators of the cooking sector, enhance stakeholders' conceptual understanding of the cooking sector, attract strategic private and public investments, and guide the policy formulation process.

To achieve these objectives and gain insights into urban communities, the EIC, an International Consortium, and TENN, a regional hub within the consortium, conducted a comprehensive field assessment. The primary goal of the assessment was to understand the challenges in the cooking energy sector, focusing on access, acceptability, and affordability in transitioning to cleaner cooking solutions. Given the similar synergies in the cooking energy sector among the consortium members, this study is particularly timely.

It is estimated that there are 3.2 million premature deaths annually worldwide due to exposure to smoke and other pollutants originating from household cooking fires. This issue continues to be a significant contributor of pollution-related diseases and deaths in Africa.

Various data collection methods were employed for this study, including literature and data review, household surveys, and key informant interviews. The main component of the study, the household survey, consisted of 200 interviews conducted by two data collection consultants from TENN and eight data collection assistants who are tertiary students. These interviews were conducted between May 23rd and 27th, 2023, across four districts: Kenema, Bo, and Makeni Districts in the provinces. The assessment continued in Freetown from June 8th to 9th, 2023. Printed questionnaires were utilized during the interviews, and household selection was guided by student assistants in each district.

The selection of these locations was based on their high population density (Kenema, Bo, Makeni, and Freetown), where various cooking devices and fuels are used. This approach aimed to understand the rate of cooking fuel consumption, the types of cooking devices in use, and the willingness to adopt new technological solutions.

In this study, the assessment of access, willingness, acceptance, and affordability of new technology solutions, as well as their user-friendliness for adaptation, revealed that 198 out of the 200 respondents interviewed, representing 99%, expressed their willingness to use new technology solutions if these conditions are met.

Table 1 (on the next page) provides a summary of the main cooking fuel sources used in the four districts covered by this survey. The study identified the common practice of stacking, wherein households in Sierra Leone use multiple cooking devices and fuels. When interpreting the study's findings, it is crucial for readers to differentiate between the term "main/primary cooking device" and "cooking fuel mainly used." The study focused on household cooking solutions and included a few commercial establishments such as eateries. From the study, it was found that 16% of the respondents use solid fuel or biomass as their primary cooking fuel source, while 2% use both biomass and improved technology solutions like gas and electricity.

Table 1 Type of fuel used mainly for cooking

Fuel mainly use to cook	Total no. of Respondent using the different cooking fuel	Percentage %
Firewood	34	17
Charcoal	114	57
Gas	7	3.5
Electricity	-	-
Agricultural Waste	-	-
Firewood & Charcoal	31	15.5
Firewood, Charcoal & Gas	4	2
Firewood, Charcoal, Gas and Electricity	3	1.5
Firewood, Charcoal, & Agricultural Waste	1	0.5
Charcoal and Gas	3	1.5
Charcoal, Gas and Electricity	1	0.5
Charcoal and Electricity	2	1
Total	200	100

The cost of cooking fuel and devices play a crucial role in determining the type of device used for cooking. Another significant factor is the level of awareness and knowledge about new cooking fuel and technology solutions, as well as the efficiency and durability of the devices.

However, most respondents in this study were unable to define these aspects. It's important to note that the cost of cooking devices varies based on their size and the location of purchase. For instance, the average cost of an improved stove in Kenema is Le 35 (less than $2), which is significantly lower compared to prices in Makeni, Bo, and Freetown. Despite the variety of cooking fuels and devices available in the market, 99% of the respondents in this study have little or no knowledge about bioethanol as a fuel source for cooking.

This study also reveals a significant market transformation in both cooking devices and the fuels used compared to previous decades. Traditional methods, such as the trench (hole) fireplace, commonly known as three-firestone, are gradually being replaced by various cooking technologies. Additionally, a variety of cooking fuels like briquettes, pellets, and biogas have been introduced to the market. This shift indicates the availability of more alternatives in the cooking sector, promoting easily accessible devices and fuels that align with the goals of SDG7, particularly in areas related to health, climate change, hunger, and energy.

Figure 1 Shows a locally made metal sheet using biofuel as a source of fuel

The introduction of bioethanol as a fuel source appears to be the right trajectory, as the market is well-prepared for new technological solutions.

1. Introduction

1.1 Background

The study was funded by the Ethanol Impact Consortium (EIC), which includes the International Consulting for Development of Impact (ICDI) in Vienna and India, and Project Gaia (PGI) in the US and Africa. On August 16, 2021, the Government of Sierra Leone adopted the Cleaner Cooking Energy Compact with the aim of intensifying efforts to achieve Sustainable Development Goal 7 on sustainable energy for all. Given that 99% of the population relies on biomass for cooking and lacks access to clean cooking fuels and energy-efficient cook stoves, and considering the country's significant deforestation challenges, the Compact outlines various targets addressing energy access, sustainability, efficiency, and international cooperation. These targets can be summarized as follows:

- Enhancing activities in the cooking sector to increase the use of LPG and energy-saving cooking solutions.
- Promoting sustainable production of wood fuels and energy conversion of organic waste.
- Improving the efficiency of biomass stoves and charcoal production.
- Strengthening cooperation between the Mano River Union (MRU) states and with the international community in the field of bioenergy, including conducting joint, integrated studies in renewables and bioenergy.

The fourth target is a matter of great concern for the government of Sierra Leone and also for the Ethanol Impact Consortium (EIC), ECREEE, and ECOWAS. EIC, comprising ICDI, Vienna and India, Project Gaia (PGI), the US and Africa, and The Energy Nexus Network (TENN) is actively involved in studying ethanol as an alternative clean cooking fuel in West Africa, including Sierra Leone. EIC focuses on impact program design, policy dialogues, interventions, and the management and implementation of ethanol and its uses in Sierra Leone. EIC assists communities in achieving energy independence through locally owned micro-distilleries.

The belief is that investing in ethanol significantly impacts family health, empowers women and girls, reduces deforestation, and mitigates harmful environmental emissions.

Sierra Leone stands out from other sub-Saharan countries economically, with a “lower-than-average” GDP growth rate of 4.09% from 2020-2021. National poverty rates have seen a decline to $3.2 a day, with extreme poverty rates dropping from 49% in urban areas to 74% in rural areas. The reduction in poverty was more rapid in rural areas, peaking between 2011-2018 but showing a slowdown in subsequent years. This decline in poverty was driven by improved access to basic services, assets, and infrastructure, along with increased human capital, which elevated household endowments and living standards. The expansion of education and higher educational attainment paralleled shifts in labor market requirements. However, the rewards for years of schooling below a certain level have decreased.

Despite these positive economic trends, per capita income growth is declining due to its slowly growing population, Sierra Leone ranks 161st globally. Notably, the fastest-growing economic sectors are education, telecommunications, information and communication technology (ICT), and trade, with a shift towards more productive work in services and industry, primarily in urban centers. There has been a slight increase in self-employment, primarily in urban areas among those categorized as "moderately poor" or "already better off." Approximately 5% of the heads of poor households work on their own farms or as unpaid family farm helpers. In these households, the poverty rate is more than double that of those in other employment categories.

Figure 2 Locally made charcoal cookstove

Despite Sierra Leone's remarkable economic growth, poverty reduction has been relatively slow. The extent to which poverty reduction occurs depends on how economic growth is defined. When defined based on changes in GDP per capita in the national accounts, poverty reduction appears slower. Household surveys have a more significant impact on poverty reduction because the GDP deflator implies a faster rate of inflation than the Consumer Price Index (CPI), resulting in lower "GDP growth per capita" compared to household consumption in the same period.

Consequently, the "poor" have benefited less from economic growth between 2012 to 2022 due to worsening inequality. This challenge compels the nation to address inequality issues &

ensure that economic growth translates into tangible improvements in the living standards of all citizens.

1.2 Objective and Scope of Assignment

The primary objective of this study was to assess the state of cooking energy at the household level in Sierra Leone. The study aimed to establish baseline indicators for the cooking sector, enhance stakeholders' conceptual understanding of the cooking sector among stakeholders, attract strategic private and public investments, and guide the policy formulation process.

The specific focus of this study was to explore the market potential for bioethanol as an energy source for clean cooking fuel in Sierra Leone. This research endeavor was conducted jointly by the Ethanol Impact Consortium (EIC) and The Energy Nexus Network (TENN). To achieve these objectives, a variety of data collection methods were employed, including literature and data review, household surveys, and key informant interviews. The household survey, constituting the central component of this study, encompassed 200 households across four main districts in the country: Kenema, Bo, Makeni, and Freetown.

The survey delved into the current state of cooking energy access, examining the types of cooking fuels used by households. Additionally, it assessed the potential rates of transition to bioethanol from prevailing cooking trends such as firewood, charcoal, and LPG. Furthermore, the study projected future demand volumes for cooking energy and associated costs, providing valuable insights into the dynamics of the cooking energy landscape in Sierra Leone.

Ethanol, sourced from starch-heavy plants and considered a biofuel, is being explored as an improved fuel for cooking across various continents (Gaia Citation 2019). Unlike petroleum-based fuels, ethanol is often viewed as a "clean fuel" because its combustion produces no black carbon or particulate matter. In a limited sense, it releases only the CO2 that the plant feedstock source absorbed during its growth period.

This report is designed to complement the Energy Compact for Sierra Leone, providing valuable insights and context. It serves as a guide to assess the state of energy access for cooking and explores the potential of bioethanol as an alternative fuel for households. By understanding the conclusions presented in this document, stakeholders can align their efforts with the broader objectives outlined in the Energy Compact, contributing to the enhancement of cooking energy solutions in Sierra Leone.

1.3 Overview of Energy for Cooking Landscape in Sierra Leone

The cooking energy consumption of Sierra Leone's population, which exceeds 8 million, is predominantly sourced from biomass, constituting over 80% of the cooking energy used. Wood fuel serves as the primary biomass source, followed closely by charcoal. Imported Petroleum products represent the next significant source of cooking energy fuel, accounting for approximately 13%.

Figure 3 illustrates a locally made wood cookstove

In Sierra Leone, the majority of cooking energy production is concentrated in the household sub-sector. Biomass, in the form of fuelwood and charcoal, is predominantly used for cooking, while kerosene is utilized for lighting purposes. Liquefied Petroleum Gas (LPG) stands as the second most used cooking fuel in the West African region after wood fuel. However, countries in the region with high LPG adoption rates (above 30%) have had to implement subsidy schemes to encourage initial uptake. Whether Sierra Leone is prepared to adopt a similar approach remains open to discussion.

It is evident that LPG must be made affordable to achieve the goal of increasing its usage to 25% of the population by 2030, as outlined in the SE4All Country Agenda. Furthermore, there is a need for extensive awareness campaigns, as many potential consumers are not yet convinced of the safety of the product.

According to the results of the latest Sierra Leone Integrated Household Survey (SLIHS) in 2018, 72% of the population primarily used firewood as their cooking fuel, while 27.7% of households utilized charcoal. Notably, only 1% of households primarily used Liquefied Petroleum Gas (LPG). Consequently, 99% of the population relies on biomass for cooking.

According to Dr. Moses Fayiah, Nam Fellow Njala University - Department of Forestry, in his study “The-proportion-of-cooking-fuel-by-Region-and-Rural-Urban-in-Sierra-Leone” the data below shows the statistics of cooking fuel (Table 1.1).

The percentage of households using firewood decreased from 78.7 percent in 2011 to 72.0 percent in 2018, while the usage of charcoal increased from 20.2 percent in 2011 to 27.7 percent in 2018.

Fuel source	Eastern	Northern	Southern	Western	Rural	Urban	National
Firewood	90.02	96.25	93.15	28.50	97.23	50.09	78.76
Charcoal	9.59	3.04	4.82	70.39	1.79	48.83	20.22
Kerosene/oil	0.04	0.14	0.26	0.64	0.15	0.14	0.25
Gas	0.00	0.08	0.00	0.13	0.02	0.11	0.06
Crop residue/sawdust	0.26	0.33	1.54	0.01	0.78	0.10	0.51
Animal waste	0.03	0.02	0.15	0.11	0.03	0.15	0.07
Others	0.05	0.14	0.07	0.22	0.00	0.31	0.12
Total	100	100	100	100	100	100	100

Table 2 Statistics on fuel used for cooking in Sierra Leone

Firewood remains the primary source of cooking fuel in rural areas, although the percentage declined from 97.2 percent in 2011 to 95.2 percent in 2018. In contrast, only 32.8 percent of urban areas used firewood, a decrease from 50.1 percent in 2011. In urban areas, charcoal became the most common energy source for cooking, increasing from 48.8 percent in 2011 to 66.7 percent in 2018.

In rural regions, firewood continues to be the predominant source of cooking fuel. In these areas, inefficient fuelwood cooking methods are prevalent, with the most common being an open "3-stone fire". In urban centers, 3-stone fires are gradually being replaced by clay stoves and metal coal pots. However, it is noteworthy that 3-stone fires still play an essential role, even in urban centers, especially for food preparation that requires longer cooking times, such as during festivities.

From 2020 to the present, there has been a decline in the use of LPG as a cooking energy fuel. Many households that were previously using LPG have reverted to using firewood and charcoal as their primary sources of cooking energy fuel, relegating LPG to a secondary option. This decline is even more pronounced among those who initially used charcoal as their primary fuel; they have now shifted to firewood as their primary source and use charcoal as a secondary fuel. Other alternative sources of cooking energy fuel, such as agricultural waste and bioethanol fuel, are either not used as primary fuels or not used at all for cooking purposes.

Under the business-as-usual scenario of the International Energy Agency, the number of people without access to clean cooking facilities is expected to decrease marginally from an estimated 2.9 billion in 2019 to 2.3 billion in 2030. Annually, household air pollution is responsible for 3.8 million deaths and 50% of pneumonia deaths in children under 5, surpassi-surpassing the mortality rates of malaria and AIDS. The unsustainable production of charcoal and the collection of fuelwoods currently constitute the primary causes of forest degradation, particularly in Sierra Leone.

Population 8.4 million (2023 estimate)	**Woodland cover in Sierra Leone** 533,135 hectares of woodland representing 17.5% of the forest cover in Sierra Leone
Youthful Population 2.5m of the population are between aged between 15-35 years	**Solid Biomass for cooking** 99% of the population depends on solid biomass for cooking; 7,984 tons/day of firewood and 457 tons/day of charcoal are consumed in Sierra Leone
Poverty in Sierra Leone 44.2% of the population is below the poverty line (2020)	**Liquefied Petroleum Gas (LPG) usage** Only 1% of the households use Liquefied Petroleum Gas (LPG) and other cleaner technology

Table 3. Quick facts about Sierra Leone

A table summarizing the population and the number of households in Sierra Leone on a regional and aggregated basis based on the most recent data available. However, for precise and up-to-date figures, it's essential to consult the latest reports from Sierra Leone's Statistics Department or similar authoritative sources. Here is a representation based on typical data structures:

Region	Population	Number of Households	Average Household Size
Eastern	**1,642,370**	324,474	**5.1**
Northern	**2,508,201**	487,654	**5.1**
Southern	**1,437,000**	287,400	**5.0**
Western Area	**1,500,234**	300,047	**5.0**
Total	**7,087,805**	1,399,575	**5.1**

Table 4: Population and Household Distribution in Sierra Leone

Note:

The average household size is calculated as the total population divided by the number of households for each region.

The data provided here is illustrative and should be cross-verified with the latest census data or statistical releases from Sierra Leone's national statistical offices.

1.4 Present status of LPG in Sierra Leone that led to the revert from LPG back to charcoal

The decline in the use of Liquefied Petroleum Gas (LPG) and back to charcoal for cooking in Sierra Leone can be attributed to several interrelated factors: from the study, the respondents pointed out the following:

1. Economic Constraints:

Cost is the first factor in the decision-making of the type of cooking technology and fuel used by the respondents covered in the survey: LPG is more expensive than charcoal, making it less accessible for low-income households. The upfront cost of LPG cylinders and stoves is higher than that of the traditional charcoal stoves be it improved or not.
For them, LPG is an expensive fuel compared to charcoal, which can be bought in smaller, more affordable quantities.
From the survey, most of the respondents emphasized the price of LPG. The End user prices ranging high: $1.7/kg to $2.0/kg, due to the free price regime and higher cost of importation of small parcels of LPG (small vessels).

2. Availability and accessibility of Supply and distribution network:

Availability: The supply chain for LPG can be unreliable, with occasional shortages or inconsistent availability in rural and even some urban areas. This unreliability forces households to revert to more readily available charcoal. There are only2 existing Marketers of LPG in Sierra Leone namely NP and AFRIGAS.

Distribution Network: The distribution infrastructure for LPG is less developed compared to the widespread availability of charcoal. Limited distribution network of retail outlets for refills, most points of sale, mainly located in Freetown and some in the provinces. The refill must be available "immediately" (i.e., 5 minutes walking). Most people pick up a cylinder at a service station (most of which own a motorbike, car, or truck). It is necessary to make the refills available through outlets in various vicinity of their homes.

3. Cultural and Behavioural Factors:

Traditional cooking methods and food preferences often favor the use of charcoal. Charcoal is seen as providing better control over cooking temperatures and giving a preferred taste to the food, also certain amounts of bulky food cannot be cooked on LPG because of the sizes -

of the cooking pot and the quantity of food to be cooked.

Behavioral Resistance: Change in fuel usage requires behavioral adaptation, which can be slow. Households accustomed to charcoal might resist switching to LPG due to comfort with their existing cooking style.

4. Safety Concerns and lack of knowledge and training on the usage of LPG:

Safety concerns: There is a perception that LPG is more dangerous than charcoal due to the risk of explosions and gas leaks. This fear can frighten households from using LPG despite awareness of its benefits.

Knowledge and Training: There is often a lack of adequate information and training on the safe use of LPG, which can lead to mishandling and accidents, further reinforcing safety concerns.

5. Environmental and Health Awareness:

Limited Awareness: While LPG is cleaner and healthier, the awareness of its long-term health benefits compared to charcoal is limited among the general population. Efforts to promote LPG need to emphasize these advantages more strongly.

1.5 Existing Policy on Cleaner Cooking Solutions in Sierra Leone

The Ministry of Energy Sierra Leone (MoE) is charged with the responsibility to formulate and implement policies, projects and programs on energy and provide oversight functions across the entire energy supply chain for all sector agencies, such as the Electricity Generation & Transmission Authority (EGTC), Electricity Distribution & Supply Agency (EDSA), Electricity & Water Regulatory Commission (EWRC), and other energy providers and consumers. In recent years, the MoE has focused on advancing access to renewable energy through the formulation of key national policy documents, including the National energy policy and strategic plan, Renewable energy policy of Sierra Leone and Energy efficiency policy of Sierra Leone. These policies recognize the significance of cleaner cooking practices, yet they lack specific strategic interventions or references to bioenergy/biofuel for cooking let alone ethanol for cooking.

In response, the Government of Sierra Leone (GoSL) introduced the "Cleaner Cooking Energy Compact" in 2021 to address this gap. The compact was presented at the United -

Nations General Assembly in New York and it serve as a national document and reference for both the public and the private sector to accelerate cleaner cooking solutions in the -country. The Energy Compact Sierra Leone 2021 report highlights the pressing issue of biomass demand surpassing forest regrowth rates due to population growth, projected to exceed 10 million by 2030. This will accelerate deforestation, depleting the nation's forest reserves. With low electrification and a stagnant economy, Sierra Leonean households will rely on wood fuel for cooking. To mitigate this, the compact proposes:

1. Increase in the use of LPG to an adoption rate of 25% as an alternative to wood fuel.
2. Enhance Household access to energy-saving cooking solutions.
3. Promote sustainable production of wood fuels.
4. Encourage the use of organic waste, such as municipal and agricultural waste to energy conversion as new source for providing domestic cooking energy fuel.

    a. Increase Wood fuel efficiency by improving the efficiency of most biomass stoves to a minimum of 20% (Tier 2 stove efficiency).
    b. Increase the efficient production of charcoal by 40%.

1.6 The Energy Ladder Concept

The "Energy Ladder" illustrates the dominant sources of household energy across different income levels, ranging from very low incomes on the left to high incomes on the right. The poorest households primarily rely on wood and other biomass, including crop waste and dried dung. Those with higher incomes can afford to cook and heat with charcoal or coal. These fuels, spanning from crop waste and dung on the left to charcoal and coal in the middle of the visualization, are collectively termed as "solid fuels". Conversely, the fuels found on the higher [1] steps of the energy ladder are termed "clean fuels". When assessing the share of households using clean fuels for cooking—a vital metric in evaluating energy access—this definition of clean fuels is applied.

When it comes to the adoption of improved cook stoves, data from the study confirm that per capita consumption of both fuelwood and charcoal generally increases with the rising cost of other sources of cooking fuel. Consequently, most households continue to use firewood and charcoal as their primary cooking fuels. This trend suggests that biomass fuel is gradually being embraced rather than abandoned for "cleaner" alternatives, leading to a decline in the "Energy Ladder."

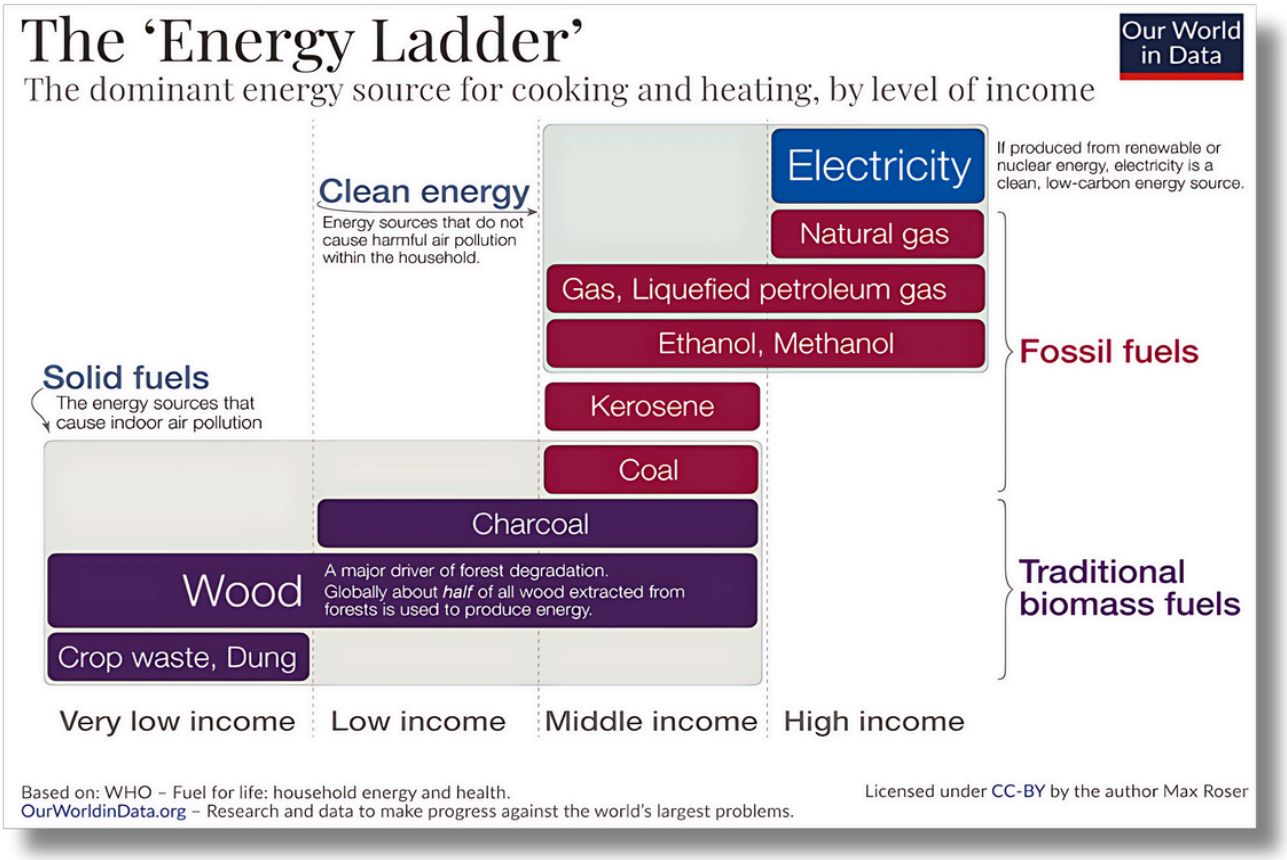


Figure 4: Figure representing "The Energy Ladder"

Introducing a new technology is a complex process, and our study revealed that the use of ethanol as a cooking fuel is no exception to this rule. Beyond its individual functionality, new technology must be integrated into the economic, social, and developmental context of a household, community, and country. In this context, our focus is on the social feasibility of improved cook stoves and bioethanol fuel as cleaner alternatives for cooking. This involves exploring their potential to enhance the cooking experience for women and delving into the realm of new technology.

2. Methodology & Tools

2.1. Locations of sites for the survey

In the heart of West Africa lies Sierra Leone, a nation rich in natural beauty and cultural heritage. However, for decades, many households in Sierra Leone have relied on traditional cooking methods, using firewood and charcoal. These practices, while deeply ingrained in the daily lives of its people, have posed significant health, environmental, and economic challenges. This is the story of Sierra Leone's remarkable journey towards embracing clean cooking solutions- a transition that promises a healthier, more sustainable future for its people.

Figure 5: Figure representing the map of Sierra Leone, its cities and the neighbour countries.

The survey was a cross-sectional study carried out in four main districts in Sierra Leone: Freetown, Makeni, Kenema, and Bo Districts. In Freetown, data was collected from 7 communities on the 8th & 9th of June 2023, encompassing both urban and rural areas, specifically Funkia community, Femi Turner, Marjay Town, Mile 13, Fonima, Dwazark, and Ascension Town. In Makeni, the survey took place from the 27th to 28th of May 2023, covering 5 communities: Makama, Ropolo, Rogbola, Izonlin Highway, and Yiks Road. Kenema was surveyed from the 23rd to 24th of May 2023, with 11 communities included: Seiyia Street, Tejan Street, Mbayama, Soso Town, Dauda Town, Fonikoh, Fatimeh Street, Jabba Street, Bockariegbay Street, Dambo street, and Circular Road.

In Bo, data collection occurred from the 25th to 26th of May 2023, covering 5 communities: Kandeh Town, Kebie Town, New London, Torwama, and Flawahun. In total, 18 communities were surveyed across the entire study, however, the above locations were chosen based on the fact that, there is possibility of finding all the cooking energy fuel and cooking devices available in Sierra Leone market and household.

2.2 Sampling Methods and tools

Random sampling was conducted of 200 hundred household, in four different cities, a questionnaire with twenty-five questions was printed and taken to the various communities mentioned above. One-on-one interviews were randomly conducted with either the head of the house or a representative of the household.

2.3 Typology of cooking fuel/technology

A household utilization survey was conducted to assess the use of bioethanol fuel for cooking, involving a sample size of 200 randomly selected households. Various factors were examined to comprehend the potential of bioethanol as an energy source for cooking and to gain insights into how this alternative fuel could integrate into the economic and social landscape of Sierra Leone.

Additionally, an energy market analysis was carried out during the survey. This involved interviews with individuals regarding their current primary fuel sources for cooking, the frequency of usage, and an assessment of existing improved clean cooking fuel options in the market.

In the comparison between cooking devices and cooking fuels, the study also considered the current prices of primary stoves and the fuels being used. Furthermore, an evaluation of the potential adoption of bioethanol fuel for cooking was conducted through a behavior and response analysis. This section provides a detailed explanation of each of these components of the study.

It is worth noting that all prices mentioned in the study are real prices, and the exchange rates utilized were those in effect at the time of the study (15th May 2023; 1 USD = NLe 23.4).

2.4 Conceptual framework

This study identifies the prevalence of stacking, where households use multiple cooking devices and fuels simultaneously. To interpret the study's findings accurately, readers must differentiate between the terms "main/primary cooking device," "fuel used for cooking," and "devices used for cooking at home" (refer to the preceding terminology section for definitions). The term "firewood" is all-encompassing and includes any energy source derived from woody biomass, including timber. "Charcoal" refers to any form of coal used for cooking, such as pellets, briquettes, agro-waste, etc. The study focused solely on household-

cooking solutions and excluded institutional settings, although a few commercial establishments (eatery shops) were included in the research.

From the supply perspective, this study examines 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, complete with a physical address like an office, manufacturing, assembly, or distribution facility. They offer standardized and branded products, provide warranties, and offer after-sales support. These formal entities are registered with the National Revenue Authority, contributing to the country's revenue generation by paying taxes for their businesses. Examples include AfriGas, Wonder Stove, and Green Smart Stoves, among others. The market comprises over 25 different stove brands, including both formal and artisanal ones.

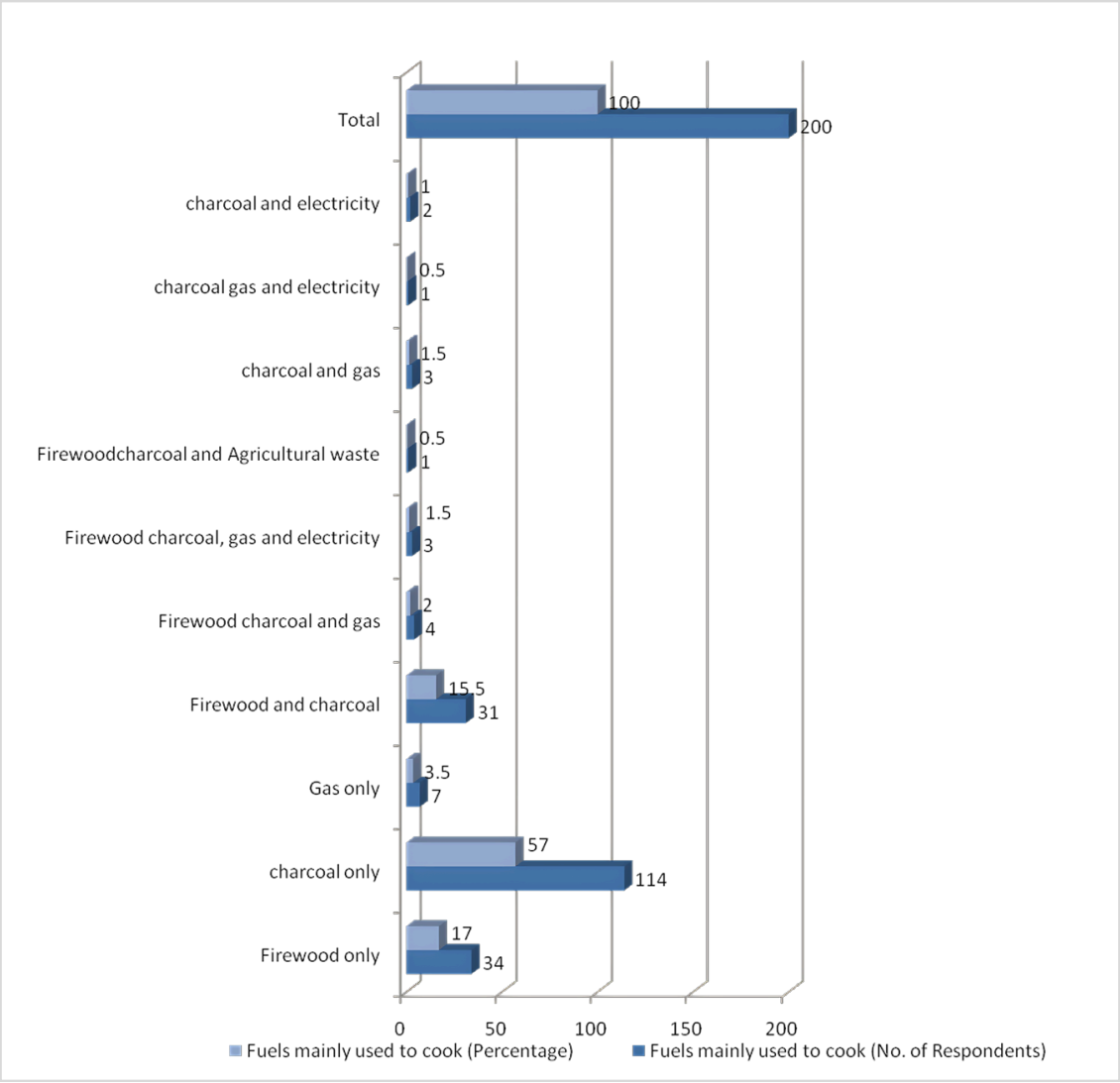
Informal sector players are significant contributors to cooking technologies. However, unlike formal organizations, they do not label their products or offer standardized versions. Informal manufacturers and entrepreneurs rely on tried and tested business models with little or no external financial support. The interviewed enterprises have been operational for an average of 15 years. There are opportunities for further improvement, including enhancing product quality and delivery methods, semi-automation of certain production processes, research and development on stove designs, market development, skills training, and support for product testing.

Figure 6 illustrates a locally made charcoal cookstove made out of scrap metals

3.0 Results and Discussion

3.1. Key statistics and findings

According to the findings, Graph 1, 17% of the respondents exclusively use firewood as their cooking fuel, while 57% rely solely on charcoal. When comparing these figures with the most recent nationwide statistics on cooking fuel sources, where 78% of households used firewood and 22% used charcoal, it becomes evident that firewood and charcoal are the two most commonly used fuels. Interestingly, these two fuels are interchanging positions, with charcoal experiencing an increase in demand while firewood's demand is decreasing. This trend aligns with the data presented in Sierra Leone's energy compact, which indicates that the country is predominantly reliant on biomass for cooking.

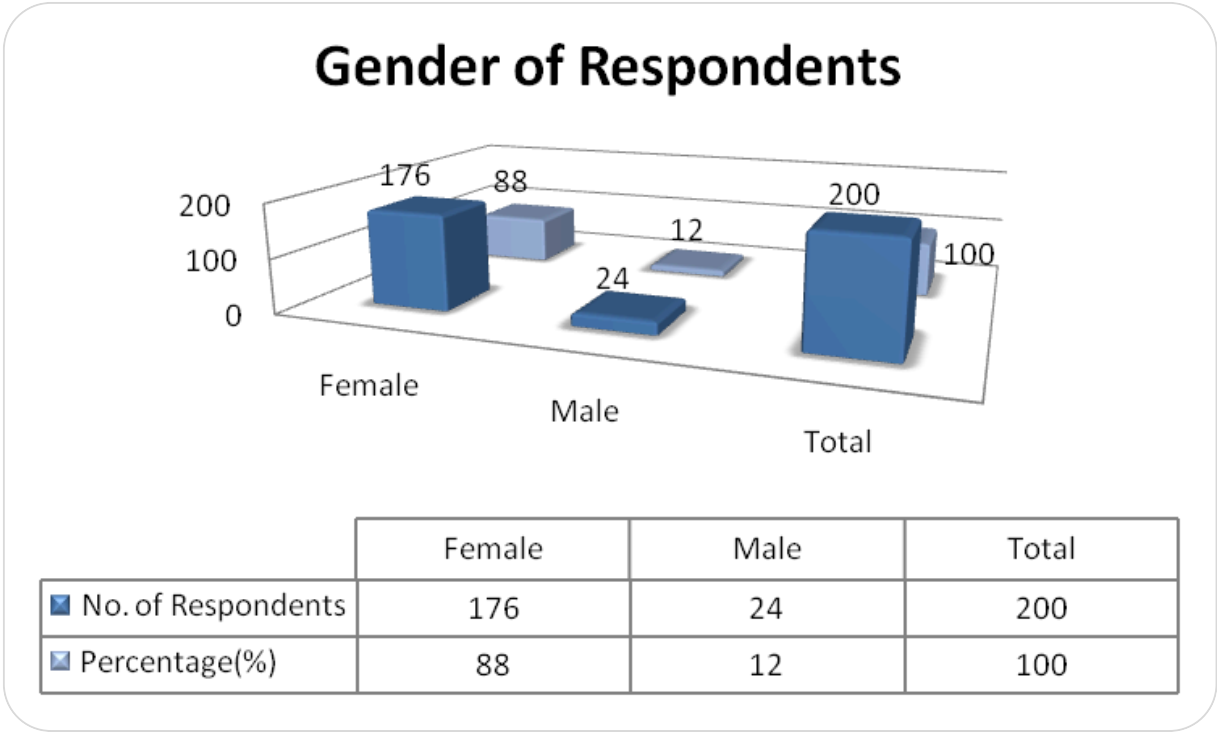


Graph 1 Fuels mainly use to cook

Despite the availability of LPG (Liquefied Petroleum Gas) in the market for a considerable period, only 3.5% of the respondents use gas as their cooking fuel. This preference for LPG is attributed to its cleanliness and safety compared to other fuel sources. Similarly, even with improvements in the country's electricity supply, fewer than 2% of the respondents use electric cookers for cooking, and they use electricity infrequently, mainly as a secondary fuel source. This situation highlights the importance of people's perceptions and willingness to transition to new technology.

3.2. Primary and secondary cooking solutions

The primary cooking solution serves as a key indicator of energy access in census data and demographic and health surveys (DHS). In this report, the term "primary cooking solution" refers to cooking solutions that are most frequently used by households. The survey provides data on both primary and secondary cooking device options, offering insights into the prevalent household stoves and fuel combinations. Specifically, the findings indicate that 17% of households use firewood, 57% use charcoal, 4% use gas, and less than 2% use a mix of all fuels, with charcoal as the primary source and the others serving as secondary options.



	Female	Male	Total
No. of Respondents	176	24	200
Percentage(%)	88	12	100

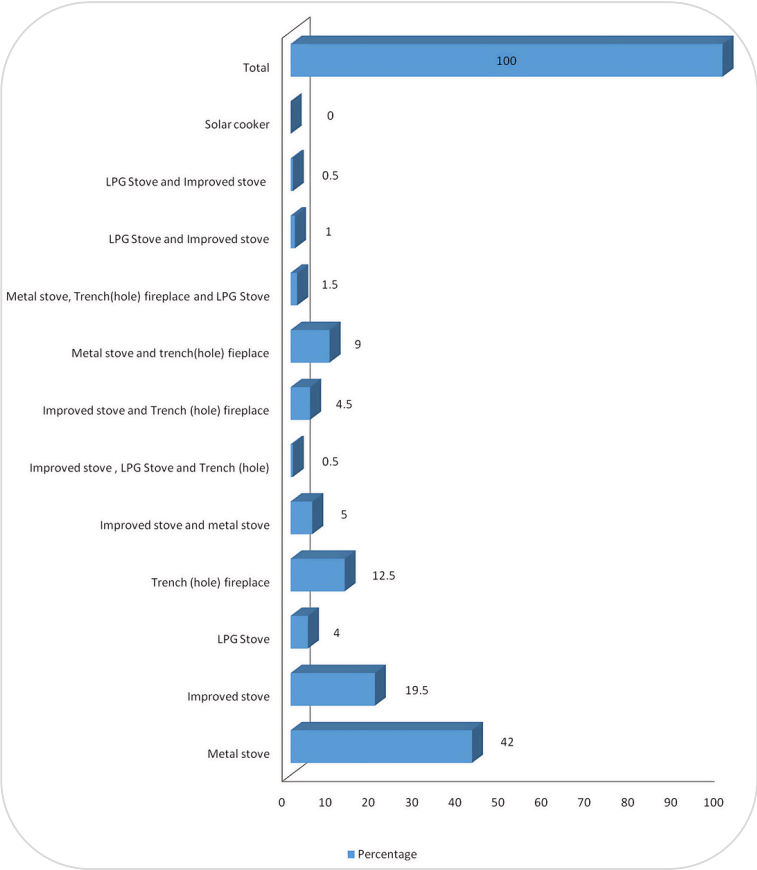
Graph 2: Gender composition of respondents combined in four Districts

The findings of this study support existing research, emphasizing women as the dominant gender in Sierra Leone's cooking sector and globally. Women, often referred to as cooking-

champions, constitute the largest user base for both cooking technology solutions and cooking fuel. Ensuring their safety and convenience is of paramount importance when introducing new technological solutions.

In this study, 88% of the respondents were women, with only 12% representing males. This statistic reinforces the significant role played by women in the cooking sector. It is worth noting that in Sierra Leone, men are generally perceived as the primary decision-makers regarding family expenditures and financial management.

Research and practical experiences have demonstrated that women are pivotal in the adoption of specific cookstoves and fuels. Clean cooking interventions often revolve around women, and access to cooking energy and alternative cooking technology directly influences female household members. Female-led households are more inclined to adopt clean cooking solutions, and women play a crucial role in raising awareness and generating demand for these solutions, leveraging their networks and community relationships. This willingness to embrace new technologies, such as bioethanol, is evident in this study.

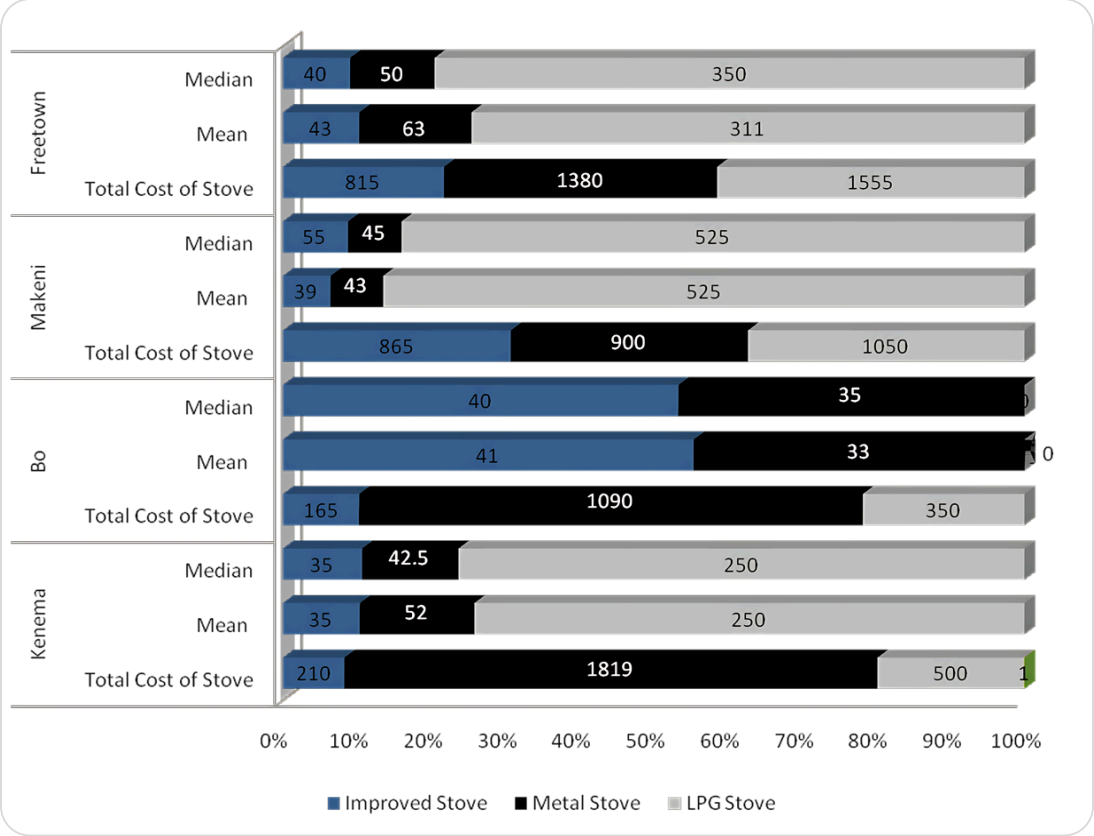


Graph 3 Cooking devices used for cooking

As consumers and users of improved cook stoves and fuels, women are not merely victims but vital contributors to the sector's scalability. It is essential to fully integrate women into the entire process, including raising awareness about the technology, design and development, distribution, and the supply chain. Notably, awareness of ethanol as a biofuel is minimal, with less than 2% of the respondents having used it as a cooking fuel before; for most respondents, ethanol is recognized as an alcohol rather than a cooking fuel.

In this study, 12.5% of the households surveyed continue to use the traditional cooking device known as the "three-firestone" trench (hole) fireplace, primarily relying on firewood-based cooking technology. Although the proportion of households using this method has decreased, provincial cities still have a significant percentage. Notably, a few households in the urban city of Freetown continue to use the trench (hole) fireplace on a daily basis. Additionally, 42% of the respondents use the metal stove, a slightly improved version of the traditional trench (hole) fireplace. The transition toward cleaner and safer cooking fuels and devices has given rise to the concept of stacking, where 23% of households use various cooking devices or a combination of at least two or more forms of cooking devices. Among these, the metal stove is the most common cooking device in the Sierra Leonean market.

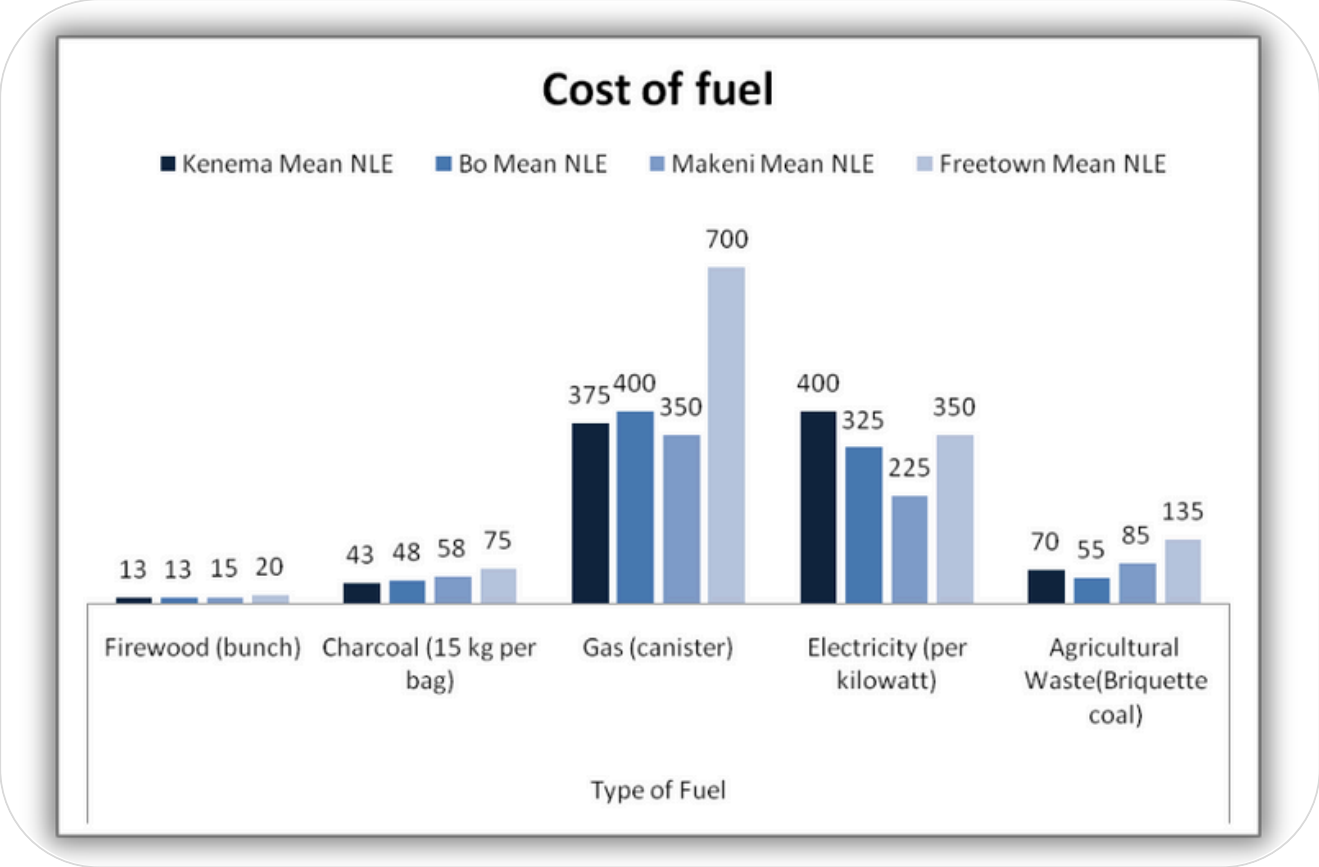
The study categorizes stoves into three types: metal stoves, improved stoves, and clean stoves, which include LPG, solar cookers, and electric cookers. Improved metal stoves are primarily produced by artisanal producers, who are local craftsmen selling cooking devices within their communities on a smaller scale. While some of these producers are registered under various agencies regulating their activities, a significant portion operates without any formal registration. This lack of registration poses challenges in maintaining an accurate database of producers in the sector.



Graph 4 Comparative cost of cooking stoves in four Districts in Sierra Leone

In our study, we found that the cost of stoves varies across districts, influenced by factors such as size and type. In Kenema and Bo, metal stoves are prevalent, constituting 42% of the market. These stoves are highly portable and widely accessible, available for purchase throughout the districts. However, they are non-repairable and prone to damage within a year of use. The cost of these metal stoves ranges from Le 15 to 80 per unit. In contrast, improved stoves, while offering better durability and functionality, come at a higher price, ranging from Le 30 to 800.

Over the years, there has been a decline in the number of households using LPG as their primary cooking device, with less than 1% of households owning an electric cooking appliance. This trend reflects the changing preferences and challenges faced by consumers in adopting alternative cooking technologies



Graph 5 Cost of fuel in four Districts in Sierra Leone

The cost of cooking fuel is a significant factor influencing the consumption rate of cooking energy, as it directly impacts the demand for cooking devices. Lower fuel costs lead to higher demand for specific stove types. Graph 5 illustrates that firewood and charcoal have very low costs, resulting in a high demand for metal stoves, where 42% of respondents have transitioned from trench (hole) fireplaces to improved stoves. In comparison, the demand for electric cookers, solar cookers, LPGs, and other devices is relatively low.

Figure 7 Cost of fuel in four Districts in Sierra Leone

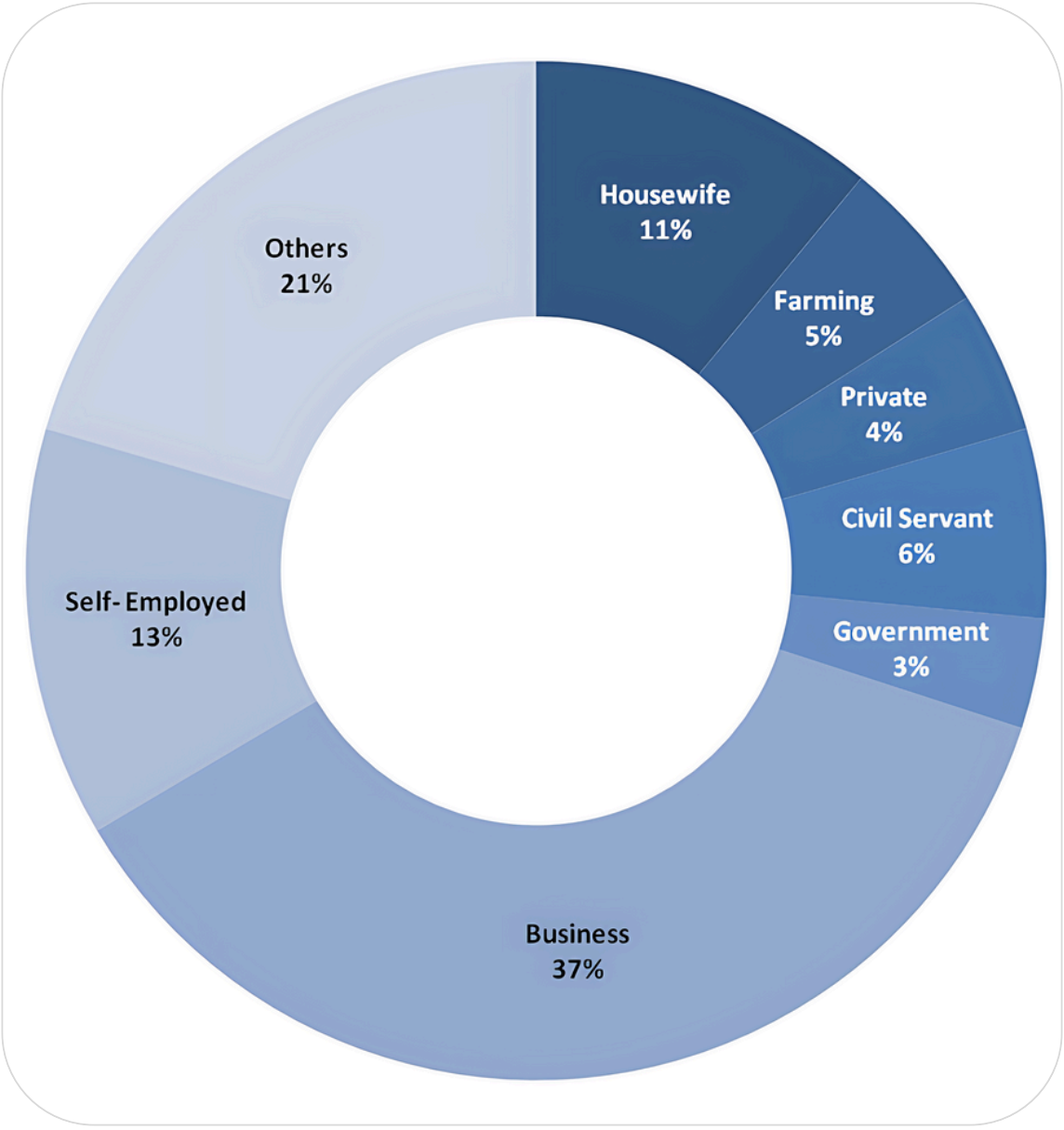
Biomass fuel continues to be prevalent in both urban and rural low-income areas. Alternative cooking technologies such as ethanol stoves, biogas, briquettes, pellets, and solar cookers remain rare, collectively used by less than 1% of Sierra Leonean households.

Figure 8 Locally made briquette

Figure 9 Locally made cookstove using biofuel

The uptake of clean fuels often results in a reduction in the use of traditional fuels, but it does not necessarily completely replace them. This has important implications for programs aiming to reduce or displace the use of traditional cooking fuels with cleaner alternatives like-

ethanol, especially concerning health impacts. Research has shown that even minimal use of polluting fuels in conjunction with clean fuels can complicate efforts to improve health. To meet the World Health Organization standards for PM2.5, traditional wood or charcoal burning must be limited to just 1-3 hours per week. The choice of cooking device and fuel is closely related, as they work in parallel with each other. The frequency of device usage is determined by the availability of the cooking fuel. According to our study, the primary stove is used regularly (daily) by 93.5% of respondents, while secondary stoves are used rarely, accounting for less than 7% of usage.



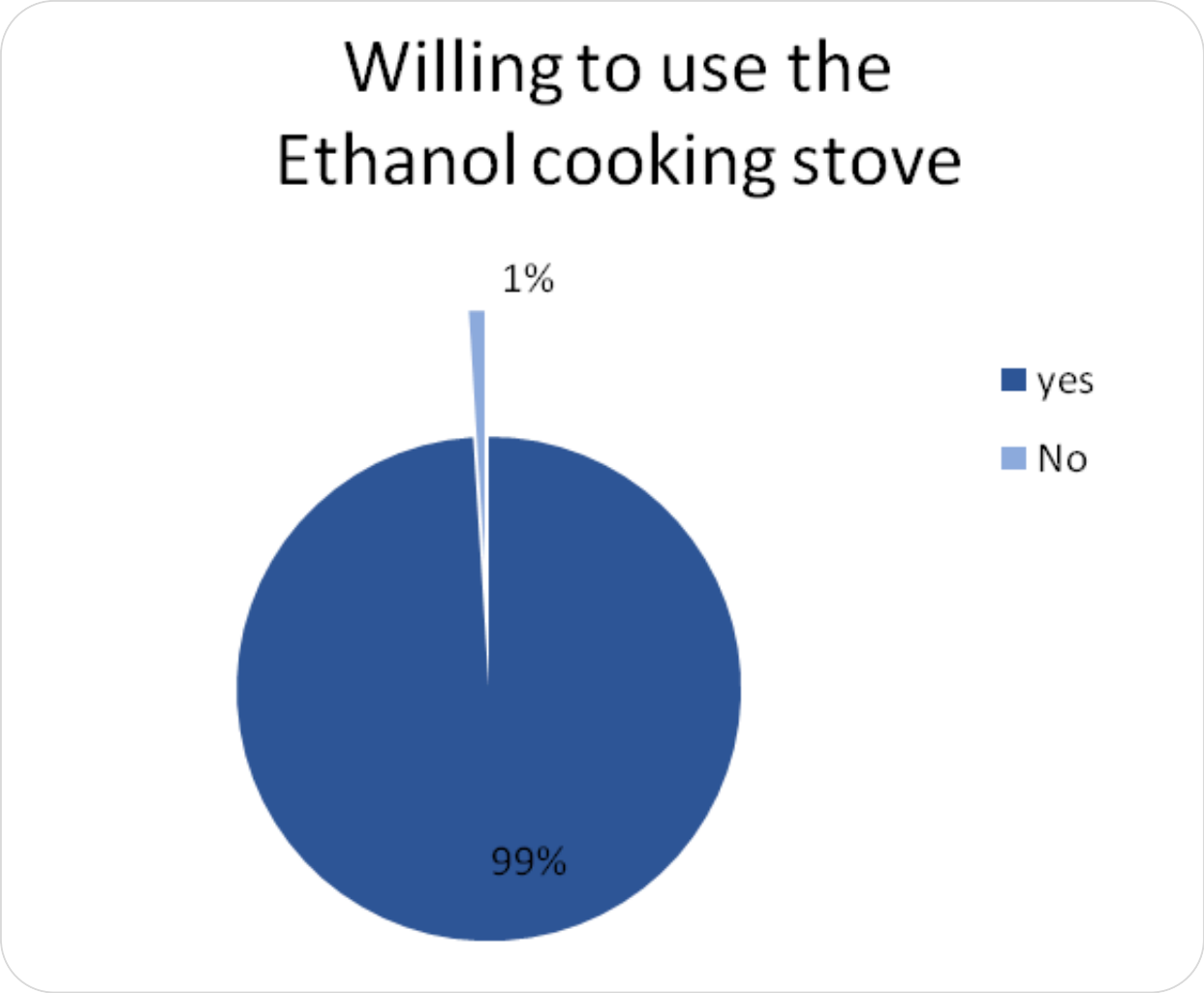
Graph 6 Source of Income influencing the social life style in four Districts in Sierra Leone

Occupation of Respondents Head of Household	No. of Participants	Percentage
Housewife	**22**	11
Farming	**10**	5
Private	**9**	4.5
Civil Servant	**12**	6
Government	**7**	3.5
Business	**73**	36.5
Self- Employed	**26**	13
Others	**41**	20.5
Total	**200**	100

Table 5: Analysis of Respondents Head of Household Occupation in four Districts in Sierra Leone

The social lifestyle is another determinant highlighted in this study. The heads of households play a vital role in the social and financial status of the family, influencing the type of cooking device and fuel used in the home. The occupation of respondents' heads of households varies, with 37% engaged in business activities, followed by 21% involved in farming and other occupations. The study participants, comprising 88% women as shown in Table 4, have spouses who are often the head of the home, engaging in the mentioned occupations. Figure 8 illustrates that 37% of respondents' heads of households are engaged in small businesses, which they rely on to support their families' needs, including food, school fees, and other expenses.

The nature of the head of the household's occupation determines the choice of cooking fuel used daily, as families adjust their cooking habits based on the household income. To facilitate the transition to cleaner cooking fuels and devices, it is crucial to increase the income of the heads of households.



Graph 7 Willingness of respondents to use new technology in four Districts in Sierra Leone

From Graph 7, this study reveals that 99% of the respondents are willing to adopt new cooking fuel/technology, integrating them alongside their existing solutions rather than completely replacing the ones they currently use. They are open to incorporating new technology into their cooking practices, provided they can ensure the reliability and affordability of the new options. Energy researchers have noted that households tend to incorporate new cooking solutions into their existing mix of options, rather than entirely replacing their current methods.

4. Lessons and Learnings

4.1 market transformation from the trench (hole) fireplace known as three-firestone

1.Perceptions and attitudes towards the problem

Cooking using the traditional trench (hole) fireplace, also known as the three-firestone method, is often seen as a traditional practice. Advocates for alternative cooking methods expect households to recognize this method as outdated, leading them to readily adopt newer forms of cooking technology. The three-firestone method is generally regarded as inferior due to its very low efficiency rates. Efforts to replace the three-firestone often fail to consider how alternatives can fit into the existing cooking setting. The choice to use the three-firestone is influenced by various factors beyond just the technology itself, including the type of housing design, available space, and the accessibility of appropriate and affordable fuels within reasonable distances.

2. Inaccurate assumptions

When promoting alternatives to the three-firestone method, emphasizing cost savings on fuel is a key message. However, it's crucial to note that this aspect is more appealing in areas where fuel wood is scarce. Many households continue to use the three-firestone method primarily because of its low cost and availability. Often, they obtain firewood for free from their farms, and even when they need to buy it, it is significantly cheaper than other fuel sources.

3. Cost and distribution

One can build a trench fireplace using three similar-sized, typically spherical stones is a straightforward and cost-effective method. These stones are readily available, eliminating the need for upfront costs of purchase or installation. Additionally, this traditional method requires no distributors, after-sales support, or specialized training for usage, making it easily accessible and widely adopted in communities.

What is the problem you are trying to solve?	Who is your key audience?	What is your entry point to reaching your audience?	What steps are needed to bring about change?	What is the measurable effect of your work?	What are the wider benefits of your work?	What is the long term change you see as your goal?
Dirty cooking	Household women, youth and communities	* The private sector: cook stove producers, importers. * Country's national and sub-national support	* Introduction of ethanol use in cleaner cooking *Pilot communities and/or households for ethanol use as a cleaner cooking fuel	* Transition from dirty solid and liquid fuel to ethanol(litre/HH) for cooking	* Improved Social, Economic, Health, & Environment * Ethanol as a cleaner biofuel *National scale up for ethanol use *Reduce cooking time & increase efficiency.	*Reduce health problem of women in kitchen *Attract investment in bioenergy industry as a channel for energy transition.
Health problem	Household women and community	*Biofuel and cleaner cooking policies * Strong regulatory support	* Behavioral change for energy transition * Cleaner cooking innovation	*Adoption of new technology and cleaner stoves (units/HH)	*Improved cooking solution and healthy environment * Clean cook stove technology	* Support livelihood of women * Reduce harmful effects of indoor air pollution
Climate change	Household women and community	* Enhance cooperation * Partnerships with local and private sector	* Awareness and capacity building * Radio discussions, giggles, * Establish school club at primary and high school level to present news articles about climate change (children could influence the behavior of parents about cleaner cooking). * Build marcomm story on ethanol clean cooking	* Tons of CO2 emission saved from emission to atmosphere	* Clean cooking industry innovation * Creation of employment for the youths * Increase bioenergy use and energy efficiency	* Adaptation to clean cooking solution and mitigate climate change impacts * Meet commitment of NDCs to UN on SDGs * Industry competitiveness

Table 6: Theory of Change (Toc) Ethanol Clean Cooking

4.2 market transformation from the growing use of charcoal

There is a strong enthusiasm within the cooking energy sector for transformation, particularly regarding the adoption of new cooking fuels and technologies that are safer, affordable, and accessible. The charcoal market in Sierra Leone has experienced significant growth over the past decade, with a rising number of households relying on charcoal as their primary cooking fuel. Sub-Saharan Africa has seen around 195 million people using charcoal as their primary cooking fuel, and an additional 200 million using it as a secondary fuel. Currently, an estimated 140,400 households use LPG stoves as their primary stove in Sierra Leone. This figure is from the national population size which is 7.8 M against the 1.8% rate of access of LPG in Sierra Leone as quoted by the Statistic Sierra Leone.Despite this, the study indicates that only 1% of households have used LPG within the last year, with some reverting back to charcoal due to the escalating costs of gas.

Several challenges have been identified by households using bioethanol cooking stoves. These challenges include modifications needed for the stoves, such as increasing the stand, difficulties in accessing bioethanol fuel from producers, and limited availability of the fuel in large volumes. These factors highlight the complexities involved in transitioning to new cooking technologies and fuels.

5. Conclusions & Recommendations

5.1 Conclusions

The findings from the survey conducted in Freetown, the capital city, and three provincial districts (Bo, Kenema, and Makeni) in Sierra Leone are as follows:

- Sierra Leone is a homogeneous country, with the majority of the population facing similar challenges. Most households rely on biomass energy sources like firewood and charcoal for cooking, while only a small portion of the population uses LPG and other cleaner technologies.
- Some households that initially transitioned from firewood to charcoal have reverted back to firewood due to seasonal variations and fluctuations in their financial stability.
- Firewood is preferred in the dry season because it is more affordable, while charcoal is used in the rainy season when firewood is damp and difficult to ignite, especially in open kitchens.
- There is a strong willingness among people in the cooking energy sector to transition to cleaner and safer fuels and technologies. They are particularly interested in cooking devices and fuels that are not only environmentally friendly but also affordable and readily accessible.
- The concept of using bioethanol fuel and ethanol cooking stoves is relatively new to the majority of Sierra Leoneans. In the areas covered by the study, there were no bioethanol stoves or fuel available in the market for sale, leading to limited knowledge about this alternative cooking option.
- Only two households in the surveyed areas were found to be using a bioethanol prototype stove designed by a startup entrepreneur (Kondayama Biofuel Investment) for their cooking needs.

- The households using bioethanol cooking stoves have encountered several challenges, including:

  a. Prototype Modifications: The existing bioethanol stove prototype requires modifications in terms of its controller, height, and size to enhance its usability and efficiency.
  b. Fuel Availability: There is a need for a consistent and large supply of bioethanol fuel to meet the demand of customers, highlighting a potential issue with fuel availability and accessibility.

- The majority of households in Sierra Leone utilize multiple cooking devices and fuels, incorporating options such as firewood, charcoal, and LPG, among others.

- Stoves that use charcoal as fuel are relatively affordable, priced between NLe30 to NLe180 at maximum. LPG stoves are comparatively more expensive, ranging from NLe250 to NLe800.

- Some charcoal-fueled stoves can be repaired after wear and tear. The repair expenses are relatively low, ranging from Le10 to Le15.

- The cost of the stoves that use charcoal as fuel is relatively cheap between Le 15 –Le 80 as compared to LPG stoves, which cost around Le 300 to Le800 maximum.

- Several households living in the same community purchase items from different markets based on their needs. As a result, different amounts of time are taken to access the market.

5.2 Recommendations

The 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 have yielded mixed results. The potential of ethanol as a fuel source for cooking will yield positive outcomes when policy and legislative interventions, as well as market-based innovations, have been adequately examined. Fuels and technologies such as electricity, briquettes, pellets, bioethanol, solar cookers, and fireless cookers have been promoted over several decades. However, their prevalence and use at the household level remain marginal.

This study finds that access to cleaner technology does not necessarily mean the 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. Therefore, emphasis should be placed on access but also on use. Incentives should be two-fold in nature, promoting access and use simultaneously. Although cost is the most important determinant of access and use, other critical factors such as flexibility to use, availability of fuel, payment terms, type of food cooked, and the number of household members for whom the food is prepared are part of the hyper-complex matrix of choice.

The key recommendation from the study is a call for the development and implementation of the Cooking Sector Market Transformation Program. The purpose of this program would be to fundamentally change the cooking sector, going beyond the aim of introducing bioethanol as a cooking fuel source. It aims to bring new players into the sector, ranging from the producers of the devices and fuel to the distributors, sellers, buyers, and policymakers. This study establishes a baseline by elaborating on the status of access to fuels and devices, and it also provides a new market for bioethanol. This study also underscores the design of the Theory of Change (TOC) and the implementation strategies. Although there is no universally accepted definition of market transformation, common elements include policy and regulatory interventions, the introduction of new technology, the emergence of new businesses (such as ethanol products), new business models, reduction in market barriers, and increased awareness of products. Some of the proposed efforts to realize the potential of ethanol as a cooking fuel source, as identified in this study, include:

- **Increase access to alternative cooking fuel/technology** – The Ministry of Energy, together with development partners in the cooking sector, should institutionalize regular cooking surveys to track progress and innovate new ideas to increase access to new fuels and technologies for cooking.

- **Design of problem approaches** – The core problem within the cooking sector is the widespread use of traditional technologies and fuels. In Sierra Leone, a significant portion of the population relies on metal stoves that use charcoal as fuel for cooking. However, these metal stoves are not durable, do not conserve energy, and are challenging to repair for certain households. Despite their shortcomings, they remain popular due to their lower cost when compared to improved stoves. Applying design problem approaches can aid in revamping these old designs by enhancing them to meet international standards and fulfill all necessary criteria.

- **Prioritizing solutions and interventions** – The introduction of LPGs in the Sierra Leone market demonstrates how government policy, when aligned with private sector interests, can lead to positive market transformation. These efforts should be accelerated and expanded to include other cleaner and safer solutions. Given that the knowledge of using bioethanol cooking stoves and bioethanol as a cooking fuel is new in Sierra Leone, extensive public education is essential, especially concerning the safehandling of ethanol cooking fuel. Bioethanol is well-known for its volatility and flammability; therefore, it is crucial to educate the public on how to operate bioethanol cooking stoves safely and handle the stove storage with care.

- **Support for technology advancement and business development**– Although ethanol is a new technology in the cooking space of Sierra Leone, the prototypes of the few ethanol stoves available in the market indicate a clear need for new ethanol stoves and fuel options. Numerous innovations and improvements must be incorporated into the existing samples and prototypes in the market. Collaboration between universities, research institutions, and the EIC (Energy Innovation Center) needs to be further strengthened to yield more efficient, locally made solutions.

- **Strengthening of sectoral coordination** – TENN, as the coordinating organization in Sierra Leone, needs to be further strengthened in its role of facilitating the scaling up of clean cookstoves and fuels. This can be achieved through convening and coordinating the sector, advocating for enabling government policies, creating public awareness, and providing capacity building. Additionally, there is a need to expand the EIC membership base to include players in the distribution phase, particularly the manufacturers and retailers.

- **Facilitation of access to finance and fiscal incentives, especially for informal sector artisans** – With evident financing gaps along the cooking sector value chain, facilitating access to finance is crucial to addressing a critical barrier to improved and clean cooking solutions. Both formal and informal financial institutions, acting as ecosystem enablers, should be provided with suitable funding sources that can be directed toward this sector. Recent national program experiences indicate that almost all clean fuel and stove programs incorporate some form of performance-based incentive or subsidy. Creating programs that leverage Results-Based Financing, support co-finance opportunities with government or multilateral partnerships, or provide assistance utilizing carbon finance as a mechanism to apply subsidies within the private sector can be highly effective strategies.

- While there is some availability of bioethanol stoves and fuel in the country, consumer decisions are significantly influenced by cultural preferences, affordability, and the accessibility of wood fuels and charcoal.

    - The government should leverage subsidies or cost reductions through programs like Results-Based Financing (RBF) whenever possible to decrease the initial cost of cook stoves and ongoing fuel purchases.

    - Engage appropriate entities such as the Ministries of Finance, Energy, Health, and Environment to implement mechanisms such as reductions in import duties and taxes. These measures can facilitate lower operational and consumer costs in the cooking sector.

    - Implement civic campaigns emphasizing the co-benefits related to the adoption of bioethanol cook stoves, such as improved health, safety, environmental preservation, ease of use, and more.

- Addressing the human capital gap is critical for structural transformation and is especially important for the agricultural sector. Improving productivity, quality, quantity, and relevance of skills is essential in this regard.

    - Focus on capacity building programs that can equip workers with knowledge and resources to enter the workforce. Bioethanol economies are well positioned to deliver green jobs, offering trainable positions in agriculture, manufacturing, fuel production, and sales.

    - Leverage agricultural and technical knowledge from international groups that can provide insights on appropriate farming techniques and inputs to utilize farmland more efficiently. Additionally, seek training in optimized production and manufacturing facility operation to enhance productivity and sustainability.

- Develop and implement policies that create enabling environments for the private sector to flourish, such as providing tax exemptions or implementing fiscal policies that incentivize new or expanding businesses.

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By prioritizing clean cooking solutions, we illuminate paths to achieving not just SDG 7 (Affordable and Clean Energy), but also SDG 3 (Good Health and Well-being), SDG 5 (Gender Equality), and SDG 10 (Reduced Inequalities), fostering a brighter, healthier, and more equitable world for the Present & Future.