Republic of Kenya
Ministry of Energy

Kenya Ethanol Cooking Fuel Masterplan

June 2021

Photos by (top to bottom): Annie Spratt; Victoria Priessnitz; Pixabay

SOUTH SOUTH NORTH
TOWARDS CLIMATE RESILIENCE

Supported by:
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ABOUT THIS DOCUMENT

This document is an output from the Mobilising Investment project for Nationally Determined Contributions (NDC) implementation, an initiative of the Climate and Development Knowledge Network (CDKN) that is contracted through and managed by SouthSouthNorth (SSN). The Mobilising Investment project is funded by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), on the basis of a decision adopted by the German Bundestag.

Throughout the development of the Ethanol Cooking Fuel (ECF) Masterplan, a consultative approach was taken with both government and non-government stakeholders. The master plan was developed under the sponsorship of the Kenyan Ministry of Industrialization and involved close coordination through a working group with representatives from the Ministries of Agriculture, Energy, Health, Environment, and the Sugar Directorate. Results were presented to the working group at three critical junctures for feedback. The full draft was then submitted to the working group for a consultative period. The private sector, donor community, and several development agencies were also engaged through a private sector forum.

To complement this consultative approach and for the purposes of data collection, the team carried out individual stakeholder interviews. Individual consultation was critical to ensuring that the plan was robustly developed.

DISCLAIMER

FOREWORD

In Kenya, Ethanol Cooking Fuel plays an important role in the clean cooking agenda. Nationally, 75% of households are still reliant on wood fuel, mainly in the form of firewood and charcoal. Consequently, the Government of Kenya is committed to support the uptake of clean cooking fuels and technologies, and to realize 100% access to clean cooking, by 2028.

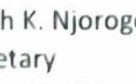
The demand for ethanol as a primary cooking fuel is projected to significantly increase in the near future. This is owing to the trend of more households, particularly in urban areas, shifting to Ethanol Cooking Fuel from kerosene and charcoal, and using it as a complementary fuel to LPG. Therefore, the development of a local bioethanol industry to satisfy the growing demand, while creating socio-economic and environmental gains across the value chain is imperative.

Kenya has conducive agro-ecological zones for feedstock production, either through sugarcane juice, molasses and cassava to support a local bioethanol industry. This Masterplan projects an additional 370,000 jobs mainly in feedstock production, KES 51 billion annually for smallholder farmers, 54 million trees saved by averting deforestation and saving up to 3,700 lives from household air pollution.

The growth of the bioethanol sector complements Kenya's wider bioenergy goals envisaged in the Bioenergy Strategy. On the supply end, this Masterplan carefully lays out the viable feedstock for bioethanol production, taking cognizance of availability and stability of the feedstock. It emphasizes the need to create supporting smallholder farmer ecosystems, by promoting access to finance, quality inputs, as well as timely information. On the demand end, it provides 10-year scenarios which project usage of 115-268 million litres annually with a majority of users based in urban areas, as rural distribution channels continue to develop.

This Masterplan provides answers to many questions on the development of a local bioethanol industry. It will complement the Ministry of Energy in realizing components of the Bioenergy Strategy and support the Inter- Ministerial Committee on Clean Cooking initiatives. Having been developed through an inter-ministerial working group comprised of Ministry of Energy, Agriculture, Health, Industrialization, Environment and Forestry, and input from non-state actors, I am confident that the Masterplan offers valuable information to support decision making across all sectors, in the context of clean cooking.

I am glad to unveil the Masterplan for public use.



Dr. Eng. Joseph K. Njoroge, CBS
Principal Secretary
MINISTRY OF ENERGY

CONTENTS

ACRONYMS

ACFC	Agro-chemical and Food Company Limited
AFA	Agriculture and Food Agency
ALRI	Acute Lower Respiratory Infection
CAPEX	Capital Expenditure
CO2eq	Carbon dioxide equivalent emissions
COPD	Chronic Obstructive Pulmonary Disease
DALYs	Disability Adjusted Life Years
ECF	Ethanol Cooking Fuel
GDP	Gross Domestic Product
GHG	Green House Gas
GOK	Government of Kenya
GWh	Giga Watt Hours
HAP	Household Air Pollution
HAPIT	Household Air Pollution Intervention Tool
HH	Households
ILUC	Indirect Land Use Change
KIHBS	Kenya Integrated Household Budget Survey (2015/16)
KITP	Kenya Industrial Transformation Program
KNBS	Kenya National Bureau of Statistics
LPG	Liquified Petroleum Gas
MT	Metric Tons
M^3	Cubic Meter
PPTs	Percentage points
SDGs	Sustainable Development Goals
SHF	Small Holder Farmer
SSN	SouthSouthNorth
VAT	Value Added Tax

TERMS AND DEFINITIONS

DALYS	Measure of overall disease burden, expressed as the years lost to ill-health, disability or early death
Dirty fuel	Cooking fuels that have serious health, environmental, and socio-economic impact (e.g., charcoal, and kerosene)
Distillation	Process of heating up a liquid then cooling
Fermentation	Process by which glucose is converted to ethanol
Feedstock	Raw material for ethanol production
HAPIT model	A model that facilitates impact comparisons of interventions which lower household air pollution
Liquefaction	Process from which glucose is obtained as a fermentable sugar
Molasses	By-product of sugar production used for ethanol production
Non-renewability factor	A measure of how sustainably fuel is sourced from the forest
PM 2.5	A common proxy indicator for air pollution
Primary fuel	Fuel source for household cooking that is used most frequently by that household

Purification	Process from which ethanol is separated from other reaction products and inert materia
Secondary fuel	Supplementary fuel source for household cooking that is used alongside primary fuel
Stacking	The use of other fuels/stoves alongside the primary fuel

FIGURES & TABLES

EXECUTIVE SUMMARY

1.1 Objectives

The Ethanol Cooking Fuel (ECF) Masterplan was commissioned by SouthSouthNorth (SSN) to support the establishment of an ECF industry in Kenya, with the objective of providing potential investors, policymakers, and researchers with an evidence base to guide the development of ECF infrastructure and distribution systems in Kenya. It also provides policy recommendations on how the Government of Kenya and other sector stakeholders can support the industry.

1.2 Context

The current Kenyan cooking fuel market is dominated by charcoal (14.6%), firewood (54.6%), Liquefied Petroleum Gas (LPG) (13.4%) and kerosene (14%) as primary fuels. The continued dependence on polluting fuels, defined by those that release pollutants when burnt such as charcoal, firewood, and kerosene, pose serious health, environmental, and socio-economic costs for Kenya. However, clean modern cooking fuels are gaining traction, and new suppliers are working with the government to overcome consumer awareness, affordability, and accessibility barriers. The continuation of these trends over the next decade is likely to offer ample opportunities for transformative advances in the adoption of more efficient and cleaner cooking solutions with ECF emerging as a viable clean and affordable cooking fuel.

ECF is a liquid biofuel that can be produced from a variety of feedstocks including sugary materials such as sugar cane, molasses; starchy materials such as cassava, potatoes, or maize; or cellulosic material such as wood, grasses, and agricultural residues. This masterplan highlights ECF production sourced from molasses, sugarcane juice, and cassava which were identified as the most likely sources of ECF in Kenya after applying an assessment approach that included evaluation of food security concerns.

If planned and implemented responsibly, a transition to ECF has strong potential to deliver on the objectives of key national strategies: Kenya's Big Four Agenda (food security, affordable housing, manufacturing, and affordable healthcare for all), the Vision 2030 (which aims to transform Kenya into a newly industrializing, middle-income country providing a high quality of life to all its citizens by 2030) and the Nationally Determined Contribution (NDC), including the Sustainable Energy for All Initiative and the National Climate Change Action Plan 2018-2022 (NCCAP). The ECF cooking transition also potentially contributes to efforts to achieve the global Sustainable Development Goals.

The projected increase in demand for ECF represents a significant opportunity for Kenyan farmers, ethanol producers, and distributors. The Kenyan government has the opportunity to develop a globally competitive ethanol production sector, that will be sustained without the need for long term import tariffs to survive. This will require careful attention to value chain design, the use of the right technologies & know-how, developing economies of scale and developing attractive markets for co-products. With the right policy and regulatory support, and implementation of effective safeguards, there will be investment flow that will trigger accelerated development of a domestic ethanol industry with high potential of growing the country GDP, increase incomes, improve health and protect the environment.

1.3 Demand

Ethanol cooking fuel is still at a nascent stage in Kenya. However, urban households are rapidly shifting their primary cooking fuels from kerosene and charcoal to cleaner fuels like liquid petroleum gas (LPG). In contrast, rural households continue to primarily use firewood. With this trend towards cleaner fuels, demand for ethanol as cooking fuel is projected to increase drastically over 10 years. Affordability and availability, enabled by sufficient domestic production and supply chain development, as well as greater awareness of the health and environmental benefits of ethanol can drive the demand.

This research estimates the demand for ECF in Kenya over a ten-year period, based on a projection model that considers six drivers: 1) demographic trends 2) current fuel use 3) affordability 4) availability 5) preference 6) stacking[1].

Total demand for ethanol across 3 scenarios, discounted for the estimated stacking of other fuels, was estimated to be:

- **8 million litres in year 1** rising to **115 million litres in year 10** (Scenario 1 – Low case)
- **16 million litres in year 1** rising to **192 million litres in year 10** (Scenario 2 – Base case)
- **24 million litres in year 1** rising to **268 million litres in year 10** (Scenario 3 – High case)

1.4 CAPEX required

Globally, several feedstocks are used to produce ECF, including molasses, sugarcane, corn, cassava, and sorghum. In Kenya, ethanol is currently exclusively produced through molasses feedstock, a by-product of sugar production. Ethanol production is therefore inextricably linked to sugar production. Ethanol as a cooking fuel is still nascent with just 1.2 million litres produced annually. A constraint to production is the national shortage of molasses due to the inefficient performance of public mills and the reduction of sugarcane farming.

To address this issue, two other potential feedstock sources were studied in this masterplan: **sugarcane juice** and **cassava**. These feedstock sources were selected based on their suitability for the Kenyan climate, ethanol production, and impact on food security. On the point of food security, maize was left out of the study.

The current production levels of all three feedstocks are inadequate to meet projected demand. In addition, sugarcane and cassava are not grown in the most agriculturally productive areas; production is concentrated in the Western region while the highest yields are in the coastal regions. Each pathway also has its own advantages and disadvantages:

> **Molasses** is a by-product of sugar production and is used to produce ethanol. Kenya also has significant technical experience in molasses-based production that can be leveraged. However, dependence on the sugar industry often results in shortages and price volatility. Currently, there is limited investment in ethanol production, mechanization, low adoption

[1] Stacking is a metric that captures the use of multiple fuel types by the same household

of high yield cane varieties and insufficient areas under cane to support an increase in production.

Sugarcane Juice to ethanol requires lower volumes of sugarcane (than molasses) and therefore less hectarage and CAPEX. It also allows for the use of bagasse as a bi product to generate energy. However, it would divert raw materials from sugar production creating competition with the sugar manufacturing industry. It also has a low shelf-life and faces similar productivity and yield challenges as molasses.

Cassava is not confronted with the same legacy challenges as the sugar industry. It also has higher potential yields than other feedstocks, produces bagasse that can be used to generate energy and allows for the production of other ancillary products (i.e. flour). However, the value chain has a number of challenges including a variety of diseases, quick rotting roots and challenges transporting the bulky produce.

The CAPEX required to meet the supply gap and support local production was sized for all three feedstock sources. Three scenarios (**30%**, **50%** and **100%** local ethanol production) were created to capture potential variability in the domestic production of ethanol over 10 years.

The analysis found that CAPEX for the local production of ethanol could range from KES 13 billion to KES 77 billion with 50% local production. Ethanol processing makes up most of the CAPEX required to expand the local ECF industry in Kenya (on average 78%), followed by feedstock production (on average 15%) and ethanol distribution (on average 7%). Between 2 to 7 ethanol plants are required to meet potential demand with Kisumu, Busia, Trans Nzoia, Kilifi or Kwale counties identified as the most conducive areas for ethanol plants due to the proximity to feedstock. Setting up new dispensers and purchasing tankers for last-mile distribution will also require major investment to expand the ethanol distribution network.

1.5 Impact

The creation of a local ECF industry has the potential to create new opportunities across the value chain. It will also generate positive environmental and health impacts at both the individual and national levels. It should also be noted that there are potential social and environmental risks associated with ethanol production including potential risks associated with land use displacement. These risks will need to be assessed at the planning stage together with a defined and agreed set of safeguards. This report estimates the potential impact of households switching to ECF on jobs, income, health, and the environment. The findings are summarized below:

Table 1: Summary of impact findings

Employment and earnings impact	• **Jobs:** Up to 370,000 jobs (with the majority in feedstock production) • **New income generated:** Up to KES 51 billion, with additional income of up to KES 180,000 per year for smallholder farmers
Environment impact	• **Deforestation averted:** Up to 54 million trees saved • **GHG emissions:** Up to 13.5 billion kgs of $C0_2$ equivalent saved

Health impact	• **Deaths averted:** ~3,700 deaths could be averted • **Disability-adjusted Life Years (DALYs) averted:** Up to 507,000 DALYs • **Economic value of deaths averted and DALYs saved:** ~KES 372 million in lost wages

1.6 Recommendations

The masterplan highlights several recommendations for government, donors and the private sector aimed at boosting demand and supporting local production. The potential impact and rationale for each are summarized in the tables below.

1.6.1 Recommendations to boost demand for ECF

1) Zero-rating VAT on ECF to level the playing field with LPG and kerosene and stimulate demand. LPG is zero-rated for VAT and since the 2018 finance bill kerosene has a concessionary VAT of 8%, up from zero rating since 2013[2]. The VAT on ECF inflates the price at which it is sold to the final customer. This has the effect of reducing ECF cost competitiveness with other cooking fuels and is dampening down the growth of the sector.

2) Short-term zero-rating of 25% import duty for denatured ethanol as a cooking fuel: Ethanol has a 25% import duty, compared to 0% for LPG and 9% for kerosene,[3] which inflates the price at which the fuel is sold to the final consumer. Ethanol import duties should be zero-rated in the short term while local production is established. The zero-rating should be accompanied by legally bind concession agreements to ensure distributors pass any tax reductions 100% to the customer.

3) Expand current awareness and communication campaigns to promote ECF and highlight the risk of traditional cooking fuels: Awareness and communication campaigns will help inform consumers about the dangers of traditional fuel sources, as well as the availability of affordable clean cooking solutions, such as ECF.

4) Work with the private sector and donor community to design stove financing options: The upfront cost of a clean cookstove can be a barrier to consumer uptake. Private sector consumer schemes and government/donor subsidies should be used to reduce upfront stove costs and enable more households to access ECF.

5) Expand and enforce existing regulations on kerosene and charcoal to other counties with the growth of the ECF market: Current regulations on the use of kerosene and charcoal in some counties should be expanded to discourage the use of "dirty" fuels and support adoption of clean alternatives such as ECF.

6) Harmonize the Bioethanol Vapour (BEV) stove import tariffs with that of LPG at 10%: The only impact of the current 25% import tariffs is to drive up the cost of stoves for consumers and prevent

[2] Kenya Finance Bill 2018
[3] LPG has an import duty at 0% and kerosene at 9% (Source: Dalberg, June 2018, Scaling up clean cooking in urban Kenya with LPG & Bio-ethanol, A market and policy analysis)

lower-income households from accessing ECF. Therefore, the government should harmonize tariffs with LPG to increase demand.

1.5.1 Recommendations to support local production of ECF

7) Create a post-master plan working group to identify and resolve supply challenges: Stakeholders across the value chain should work together to take the recommendations of this report forward and build a solution that works for all parties.

8) Secure funding from multi-lateral organizations to conduct feasibility studies on setting up ethanol plants: To encourage and attract investments, multi-lateral organizations should commission feasibility studies that examine the financial and operational feasibility of investing in feedstock and ethanol production.

9) Expand cane and cassava growing zones in high yield areas: Ethanol production relies heavily on the availability of feedstock such as sugarcane and cassava. As such, increasing investments in sugarcane and cassava development and land allocated for feedstock production in high yield areas (i.e. Western and the coastal regions) will be necessary to meet the potential demand for ethanol.

10) Stimulate the market with low-interest loans for local ethanol producers: To meet the CAPEX requirements across the ethanol value chain, a variety of financing options should be accessible to current and potential players in the ethanol industry i.e. through low-interest loans from government agencies.

11) Attract donor support to ensure efficient sourcing from small-holder farmers: The production of sugarcane and cassava needs to significantly increase to meet the projected targets. Small-holder farmers can play a key role enabled by efficient sourcing, aggregation, and climate-smart agricultural practices. Donors should support the establishment of these systems and work with ethanol producers to implement sustainable sourcing practices.

12) Leverage the existing one-stop-shop within the Kenyan Investment Authority to support investors: To support and attract investment in the industry, the GOK should leverage the existing one-stop-shop within the Kenyan Investment Authority to support players along the ECF value chain.

13) Provide tax rebates to ethanol producers that source directly from Kenyan farmers: The feedstock production of both sugarcane and cassava present an opportunity to create new jobs and increase income, with a focus on small-holder farmers. The GoK should incentivize ethanol producers to source their feedstock from Kenyan farmers through tax rebates.

14) Build international partnerships to create opportunities for technology/knowledge transfers: Partnerships between Kenyan institutes and foreign research institutes will allow for technology/knowledge spillovers, which will, in turn, improve feedstock yields and overall production.

15) Unlock climate financing to develop the ECF ecosystem at different stages of the value chain: The substantial environmental benefits of a switch to ECF makes the industry a viable recipient for climate financing from several multinational organizations. The Kenyan government should attract these funds by demonstrating the climate and environmental benefits of clean cooking options.

16) Deploy results-based financing that can enhance biofuel enterprise economics: Results-based financing from donors and international organizations can improve the competitiveness and sustainability of the sector by ensuring that players in the ethanol industry meet financial and non-financial targets, in order to continue to receive funding.

1 INTRODUCTION

1.6 Objectives and Outputs

The Kenyan ethanol cooking fuel (ECF) masterplan aims to support the establishment of an ECF industry in Kenya, with three key objectives:

1. To facilitate the penetration of ethanol cooking fuel to Kenyan households
2. To provide potential investors, policymakers, and researchers with an evidence base to guide the development of ECF infrastructure and distribution systems in Kenya.
3. To provide policy recommendations on how the Government of Kenya can support the industry.

This master plan was developed through the following activities:

1. **Modeling the potential demand for ECF in Kenya** across urban and rural households over a 10-year period (2020-2029)
2. **Modeling the required CAPEX to set up an ECF industry** taking into consideration the entire value chain including feedstock production, ethanol processing, and distribution
3. **Modeling the potential financial, environmental, and health benefits** of establishing an ECF industry
4. **Extensive stakeholder engagement to identify policy recommendations for government**

This document presents a comprehensive overview of the ECF opportunity in Kenya, as well as what it would take to set up a thriving industry.

1.7 Context

The current Kenyan cooking fuel market is dominated by firewood (54.6%), charcoal (14.6%), kerosene (14%) and LPG (13.4%) as primary fuels. However, the trend varies in urban and rural areas. Urban areas have seen a movement towards cleaner fuels like LPG while rural areas are still dominated by firewood. Nairobi is unique, with a far higher share of households using LPG (44%) and kerosene (47%) as primary cooking fuels (2017). The latter being the dominant fuel of the Nairobi low-income households. Even among those who use LPG as a primary cooking fuel, stacking, the use of multiple fuels and stoves in a household, is a common phenomenon. Therefore, the use of charcoal and kerosene is more widespread than what is indicated by primary fuel statistics.[4]

The continued dependence on dirty fuels[5] poses serious health, environmental, and socio-economic costs for Kenya. 8-10% of early deaths are attributable to indoor air pollution from charcoal and firewood cooking in Kenya[6]; this excludes the unquantified but likely substantial negative effects of kerosene cooking on lung function, infectious illness and cancer risks, as well

[4] Dalberg (2018). Scaling up clean cooking in urban Kenya with LPG and Bioethanol – A market & policy analysis.
[5] Dirty fuels refer to firewood, charcoal and kerosene and pose serious health, environmental, and socio-economic costs
[6] Stockholm Research Institute (2016) Discussion brief " How Kenya can transform the charcoal sector and create new opportunities for low-carbon rural development"

as burns and poisonings. Kenya loses 10.3 million m^3 of wood from its forests every year from unsustainable charcoal and wood fuel use[7]. This deforestation exacerbates food insecurity and harms the agricultural sector. Household biomass fuel use contributes over 22 million tonnes of CO_2 equivalent (CO_2eq) each year (as high as 35 Metric Tonnes of CO_2eq including fuel production emissions), which is equivalent to 30-40% of total Kenya greenhouse gas (GHG) emissions[8].

Clean modern cooking fuels, notably LPG, are available in Kenya, and new suppliers are working with the government to overcome consumer awareness, affordability, and accessibility barriers. LPG is well understood and increasingly common in urban Kenya, but despite continued investments in capacity, it is unlikely to become the primary cooking fuel for the majority of urban populations due to high costs and limited availability outside of Nairobi. Electricity for cooking is not viable today in Kenya and has minimal penetration (~2% in urban Kenya) due to the high costs of electricity tariffs and efficient electric cookstoves ($200+).

Ethanol Cooking Fuel (ECF) is a viable alternative as a clean and affordable cooking fuel. While still nascent, there has been significant investment in increasing access with Vivo Energy – a major distributor of Shell products in Africa, and KOKO Networks - a venture-backed, technology-based distribution company installing distribution systems and networks to increase national access, beginning with urban centres such as Nairobi and Mombasa. While other distributors including Safi International and Leocome are also operating in the market, none are investing at the same scale as KOKO Networks. The value-added (VAT) exemption for ECF in the government's latest budget will also help to bring down the cost for the consumer.

The projected increase in demand for ECF represents a significant opportunity for Kenyan farmers to build a domestic ethanol industry. With demand (under scenario 2 – base case) projected to be 192M litres in 2030, ethanol has the potential to generate significant income for the economy.

With the right support and investment into cultivation, manufacturing and distribution, the industry can create economic opportunities, increase incomes, improve individual's health and protect the environment, helping Kenya to fulfil its constitutional responsibilities, achieve its Big Four Agenda, Vision 2030, sustainable action for all initiative goals, and contribute towards national climate goals and the global Sustainable Development Goals.

- **The Big Four Agenda** is focused on (i) Enhancing Manufacturing from 9.2% to 20% of GDP by 2022, (ii) Achieving 100% food security, (iii) Delivering 100% Universal Health Care and (iv) building 500,000 new affordable homes.
- **The Kenya Vision 2030** aims to transform Kenya into a newly industrializing, middle-income country providing a high quality of life to all its citizens by 2030 in a clean and secure environment. This is achieved across 4 pillars – Economic, Social, Political and Enablers & Macro.

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[7] Dalberg (2018), "Scaling up clean cooking in urban Kenya with LPG and Bioethanol – A market & policy analysis p8

[8] Dalberg estimate based on bottom up build-up of Kenya cooking emissions based on fuel mix, average fuel volumes, and standard emission factors including CH4 and NO2, but excluding BC. Note that WRI CAIT total CO2 emissions for Kenya (2013) are estimated at 60.53 MT CO2eq total, which we believe is an underestimate as the number only includes <8 MT CO2eq of cooking related emissions. Our revised model suggests that the Kenya total emissions are actually in the 75-88 MT CO2eq range based on the most up to date cooking fuel mix and up cooking fuel combustion and charcoal production emission factors that are aligned with CDM defaults for Kenya

- **Kenya's Nationally Determined Contribution (NDC)** – Kenya submitted its NDC on 28th December 2016, when it deposited its instrument of ratification for the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC). The mitigation contribution intends to abate greenhouse gas (GHG) emissions by 30% by 2030 relative to the business as usual (BAU) scenario of 143 million tonnes of carbon dioxide equivalent (Metric Tonnes of CO_2 e).
- **The Global Sustainable Development Goals (SDGs)** are a collection of 17 global goals set by the UN General Assembly in 2015 for 2030. These include no poverty, affordable and clean energy, decent work, economic growth, and climate action.
- **The Constitution of Kenya** provides that every person has the right to the highest attainable standard of health and that the state has obligations to ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, including land.

The table below outlines how the domestic ethanol industry is aligned with government objectives:

Table 2: How the domestic ethanol industry is aligned to local and global initiatives

The Big Four Agenda		
Target	**Description**	**ECF Industry Impact**
Boost the manufacturing industry	Increase the manufacturing sector's share of GDP from about 9% in 2017 to 15% in 2022	• Investment in the ethanol industry will boost manufacturing, by creating a new industry
Create jobs for young people within manufacturing	The government plans to create 1.3 million manufacturing jobs by 2022	• Up to 3,480 jobs can be created in ethanol manufacturing depending on the extent of local production and the production pathway chosen
Food security	Achieve 100% food security; to reach 1 million farmers and unlock 150,000 acres of uncultivated land	• Investment in cassava and sugar cane will boost yields, providing feedstock for Ethanol as well as food for consumption. • The potential 54 million trees to be saved can protect the country's renewable surface water resources.
Universal Healthcare	Delivering 100% Universal Health Care	• In 2013, 1.66 million DALYs (on average) were lost in Kenya due to ill-health, disability, and early death as a result of Household Air-Pollution. With up to 507,000 DALYs saved by switching to ethanol, UHC will become more attainable.
Kenya Vision 2030		

Promote export-driven manufacturing	Boost the capacity and local content of domestically manufactured goods	• Investment in the Ethanol industry will provide a significant boost to manufacturing, with the potential to export into new markets
Increase forest cover	Increase the forest cover by 10% by 2022	• Reducing the use of charcoal will increase the forest cover, which will in turn increase water availability and reduce food security
Kenya's Nationally Determined Contribution (NDC)		
Reduce greenhouse emissions	Reduce greenhouse gas (GHG) emissions by 30% by 2030 relative to the business as usual	• Up to **13.5 billion kgs** of CO2 could be saved cumulatively over a ten-year period by switching to ECF
Sustainable Energy for All Initiative – Kenya Action Agenda		
Increase the penetration rate of clean fuels	Increase the penetration rate of clean fuels to 100% by 2028	• The development of a domestic ECF industry will contribute to the objective of increasing the uptake of clean fuels in Kenya
National Climate Change Action Plan 2018-2022		
Promote the transition to clean cooking	Reduce the number of household biomass related deaths from 49% of total deaths to 20%.	• The development of a domestic ECF industry will contribute to the objective of increasing the uptake of clean fuels in Kenya
Global Sustainable Development Goals		
Good Health and Well-being	Ensure healthy lives and promote well-being for all at all ages.	• ~3,700 deaths could be averted by households switching to ECF from other cooking fuels • Up to 507,000 DALYs could be saved over ten-years
Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all.	• With the removal of VAT on ECF sales and potentially lower costs from domestic production, ECF will be the cheapest cooking option
Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	• Up to 370,000 jobs can be created by a domestic ethanol market depending on the extent of local production and the production pathway chosen • Up to KES 51 billion can be generated in new income by a domestic ethanol market, with potential new income of up to KES

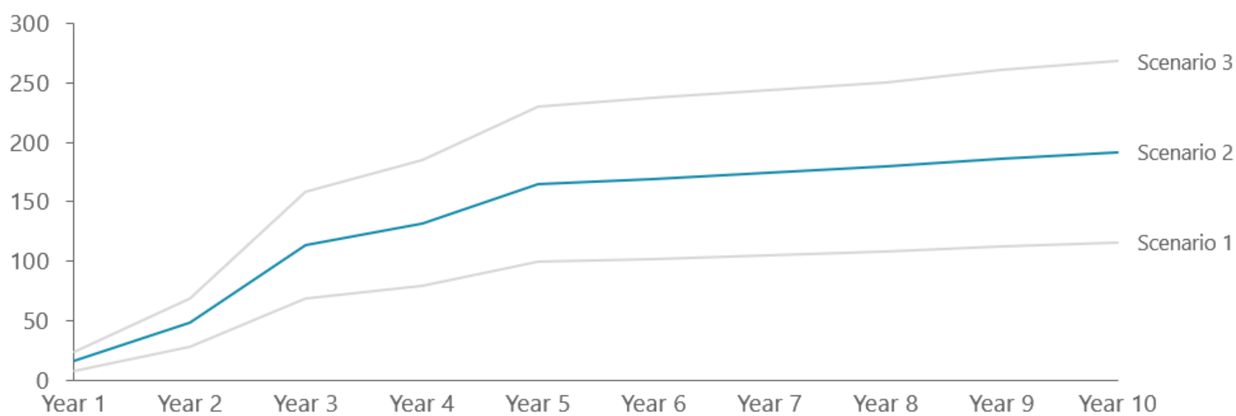
		180,000 per year for smallholder farmers
Industry, Innovation, and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	• The investment in ethanol manufacturing and distribution will boost industry and innovation in Kenya
Climate Action	Take urgent action to combat climate change and its impacts	• Up to 54 million trees could be saved over a 10-year period from households switching from charcoal to ECF • Up to **13.5 billion kgs of Co_2 eq** could be saved cumulatively over a ten-year period by switching to ECF

2 DEMAND FOR ETHANOL COOKING FUEL

2.1 Summary

- Firewood, charcoal, and kerosene are still the dominant cooking fuels in Kenya. However, urban households are rapidly shifting their primary cooking fuels from kerosene and charcoal to cleaner fuels like LPG. In contrast, rural households have shown less shift and are still dominated by firewood.
- With this trend towards cleaner fuels among households in the background, demand for ethanol as a primary cooking fuel is projected to increase drastically over 10 years. Affordability and availability, enabled by sufficient domestic production and supply chain development, as well as greater awareness of the health and environmental benefits of ethanol over traditional fuels, will be key to drive the demand.
- 3 scenarios were created to capture variability in demand assumptions. Total demand (in litres) for ethanol across 3 scenarios, discounted for the estimated stacking of other fuels, was estimated to be
    - **8 million in year 1** rising to **115 million in year 10** (Scenario 1: Low case)
    - **16 million in year 1** rising to **192 million in year 10** (Scenario 2: Base case)
    - **24 million in year 1** rising to **268 million in year 10** (Scenario 3: High case)

Figure 1: Estimated demand for Ethanol Cooking Fuel (millions of litres)

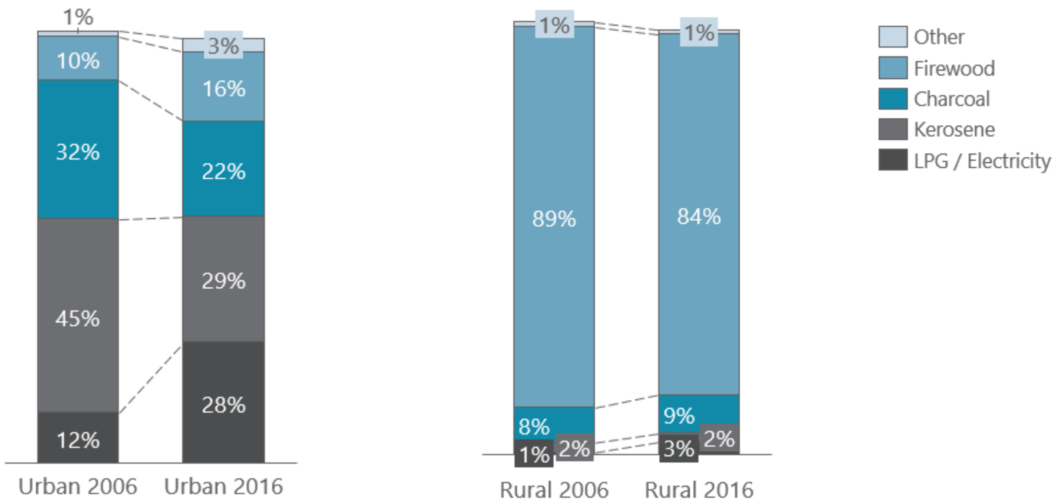


2.2 Current context of demand

The demand for the various kinds of cooking fuels has changed significantly over the last 10 years in Kenya. However, the degree of change has varied between urban and rural households. Urban areas have seen a decline in the demand for dirty fuels such as charcoal and kerosene by 10 and 16 percentage points (ppts), respectively, likely driven by the rising prices and the restrictive regulations in several counties. This has, in turn, led to increased use of LPG and firewood, which have increased by 14 ppts and 6 ppts, respectively. The rapid increase in LPG use demonstrates the potential for a further shift towards cleaner fuels, including ethanol among urban households.

However, primary cooking fuel among rural households continues to be dominated by firewood, only 5 ppts down in a decade to 2016. These trends are illustrated in the diagram below.

Figure 2: Cooking fuel use in urban and rural areas (Kenya National Bureau of Bureau of Statistic, 2016)



ECF use in Kenya is still at a nascent stage (included in the "other" category in the figure above) but there is significant potential to move households in both rural and urban from solid and dirty fuels to ethanol. Investment in the sector is also rapidly increasing. Vivo Energy – a major distributor of Shell products in Africa, and KOKO Networks - a venture-backed, technology-based distribution company are investing in distribution systems and networks to increase national access, beginning with urban centers such as Nairobi and Mombasa. KOKO Networks has currently installed up to 700 retail points across Nairobi, with plans to expand to Mombasa and other counties from 2020. In order to drive awareness, KOKO Networks is also running advertisements on media channels across the country. In addition, market activations and demos are currently being deployed in urban neighborhoods to provide potential users with the opportunity to test ECF and understand the benefits of using the fuel. While other distributors including Safi International and Leocome are also operating in the market, none are investing at the same scale as KOKO Networks.

2.3 Methodology and results of demand projection

This research estimates the demand for ethanol cooking fuel (ECF) in Kenya over a ten-year period, based on a projection model that accounts for various factors. The model relies on the most recent Kenya National Bureau of Statistics household survey, the 2015/16 Kenya Integrated Household Budget Survey (2015/16 KIHBS),[9] and displays approximate calculations.

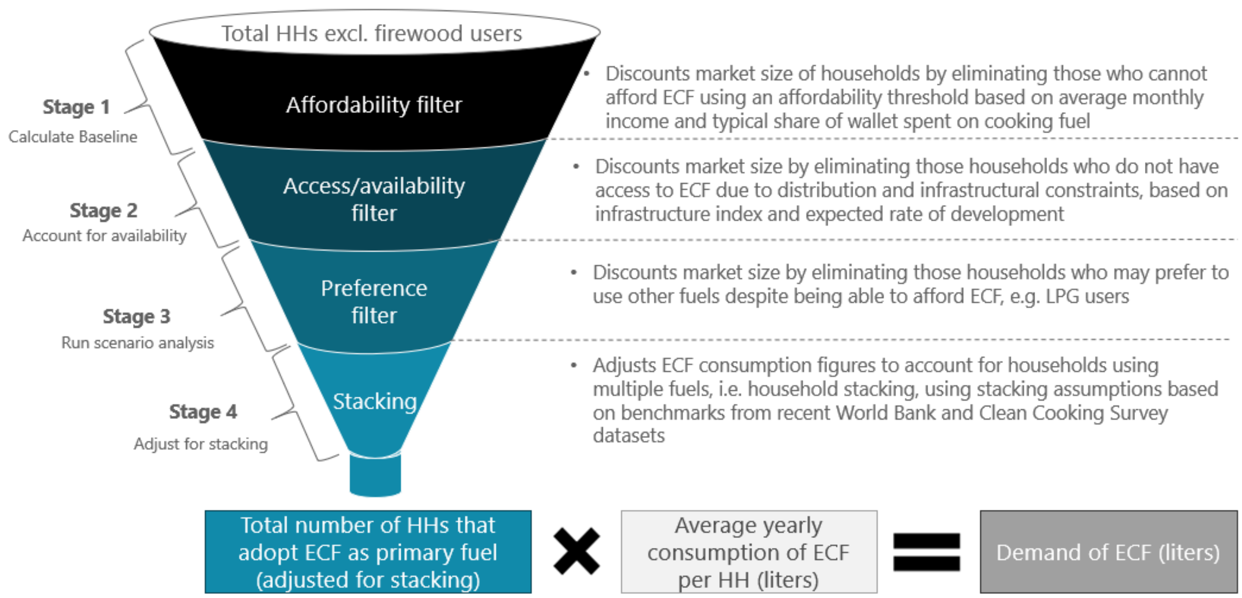
Two major variables were required to estimate the demand for ECF in Kenya over 10 years: **the number of households that will primarily use ECF** and the **average number of litres consumed per**

[9] The 2015/16 KIHBS is a nationally representative, population-based household survey that was conducted over a 12-month period from September 2015 to August 2016. The KIHBS survey sampled 24,000 households drawn from 2,400 clusters across the country.

household. 6 drivers were considered to calculate the number of households that will use ECF as their primary fuel. They are:

- **Demographic trends:** The estimated population growth and urbanization rates
- **Current fuel use**: The proportion of households that pay for fuel vs. those that use non-monetized fuels such as wood, animal dung, and grass for cooking
- **Affordability**: The proportion of households that can afford to purchase ethanol cooking fuel
- **Availability**: The number of households that can access ECF considering infrastructure constraints
- **Preference:** The number of households that will choose to use ECF given affordability and access
- **Stacking:** A metric that captures the use of multiple fuel types by the same household

Figure 3: Demand methodology



To calculate total demand, a four-part approach was employed:

1) Demographic trends, current fuel use, & affordability were used to calculate the baseline – i.e. the number of households that can afford ECF
2) The baseline was discounted to account for the availability of ECF in urban and rural areas
3) Three scenarios were created to capture variability in preference for and eventual uptake of ECF
4) Finally, the total volume of ECF demanded was calculated by multiplying the number of households (adjusted for cooking fuel stacking) by the average consumption (in litres) per household.

2.3.1 Calculating the baseline number of households

2.3.1.1 Demographic trends

The total number of households in Kenya over a period of 10 years was calculated by projecting the total population[10] by the average population growth rate[11] and dividing the population by the average number of individuals per household. Households were kept constant at 4 people for simplicity. Households were categorized into urban and rural areas by applying the percentages for urban/rural split from KHIBS. Finally, an urbanization rate[12] was applied to urban households to account for the movement of people to urban areas. The number of households in rural areas was then adjusted to account for this trend. The total number of households in urban areas was estimated to be ~5.2million in year 1 growing to ~6.5 million in year 10, while the rural households were ~6.2 million in year 1 growing to ~7.9 million in year 10. The total number of households starts at 11.4 million, growing to 14.4 million by year 10.

Table 3: Number of HHs in urban and rural areas

No of households	Year 1	Year 10
Rural	5,182,770	6,529,624
Urban	6,231,230	7,850,549
Total	**11,414,000**	**14,380,173**

2.3.1.2 Calculating the potential target market for ECF

To calculate the potential target market for ECF, the percentage of households in rural and urban areas who use different kinds of cooking fuel (firewood, charcoal, kerosene, LPG, and electricity) was sourced from KHIBS. Applying these percentages to the total number of households results in the number of households that primarily use each fuel type. Households that primarily use firewood (84% of rural households and 16% of urban households) were excluded from the calculation, based on the assumption that most users of firewood collect their wood for free, and would be unlikely to switch to a paid fuel (at least in the short term). This brought the potential target market to ~4.9 million households in year 1 and ~6.2 million households in year 10.

Table 4: Potential target market for ECF

No of households	Year 1	Year 10
Rural	900,000	1,100,000
Urban	4,000,000	5,100,000
Total	**4,900,00**	**6,200,000**

2.3.1.3 Affordability: Calculating baseline i.e. the number of households that can afford ECF

To estimate the number of households that can afford ECF, we calculated the percentage of household income that is typically dedicated to cooking energy, by dividing the average monthly

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[10] Kenya Integrated Household Budget Survey (KIHBS) 2016
[11] Data.worldbank.org. (2019). World Bank Open Data | Data. [online] Available at: https://data.worldbank.org.
[12] Cia.gov. (2019). The World Factbook - Central Intelligence Agency. [online] Available at: https://www.cia.gov/library/publications/the-world-factbook.

cost of cooking by average monthly household income[13]. This came to approximately 15% of monthly income. We then calculated the percentage of households that can afford to buy ECF at current prices of 95KES[14] per liter in rural areas and 100KES[15] per liter in urban areas. Applying these percentages to the target market above results in the number of households that can afford ECF. The increase in the number of households that can afford ECF is driven by yearly population growth, and the yearly increase in per capita income, estimated at 2%.

Table 5: Number of HH that can afford ECF

No of households	Year 1	Year 10
Rural	400,000	600,000
Urban	2,100,000	3,000,000
Total	**2,500,000**	**3,600,000**

2.3.2 Availability: Calculating the number of HHs that can access ECF

Availability assumptions account for the constraints in access and distribution of ethanol which could vary widely, particularly between urban and rural areas. These assumptions were based on the expansion strategy of the current major distributor of ECF, KOKO Networks. Availability is expected to increase rapidly in urban areas rising to 100% by year 5. In rural areas due to infrastructural challenges, access is expected to reach a maximum of 20% of households over the 10-year period.

Table 6: Number of HHs that can access ECF

No of households	Year 1	Year 10
Rural	0	100,000
Urban	630,000	2,900,000
Total	**630,000**	**3,000,000**

2.3.3 Scenario Analysis: Calculating the impact of preference on demand

After calculating the baseline number of households that can afford ECF, 3 scenarios were developed to capture the impact of preference on demand. Preference can be influenced by a number of factors including education, peer influence, cooking practices or taste. Each of these scenarios differ for urban and rural areas and range from low to high. The scenarios are the basis of the final demand scenarios and are summarized below:

Table 7: Scenario assumptions

Demand driver	Scenario 1 (Low case)	Scenario 2 (Base case)	Scenario 3 (High case)
Preference Scenarios	Most HHs continue to use other cooking fuels: Awareness and exposure to the benefits of ECF remains low with only 10% and 15% of HHs in rural and urban areas switching, in	ECF preference reaches moderate levels: A sizable no of rural & urban households switch to ECF. ~15% of urban HHs will choose to use ECF as their primary fuel in year 10 while 25% of rural HHs make the switch	ECF becomes one of the preferred cooking fuels: Highly successful campaigns and uptake, with 20% and 35% of rural and urban HHs respectively switching to ECF by year 10. ECF becomes more

[13] Monthly income data is available for ~6000 households
[14] Data estimate from KOKO Networks
[15] Data estimate from KOKO Networks

	year 10 while others mainly use alternatives		preferred than LPG, kerosene & charcoal

2.3.3.1 Preference: Calculating the no. of households that will adopt ECF as their primary fuel, given affordability and access

To account for varied household preferences in the choice of cooking fuel, assumptions were made on the proportion of households that will choose to use ECF as their primary fuel, given affordability and access. Scenario analysis was used to capture potential variability. The choice of ECF will depend on a range of factors, including awareness, local traditions and the perceived benefits to households amongst others[16]. As these factors change, the uptake of ECF is expected to ramp up relatively quickly. Households in urban areas were assumed to have higher uptake levels than households in rural areas given reduced awareness and exposure to clean cooking solutions in rural areas. In addition, cooking fuels are generally non-monetized in rural areas leading to a lower willingness to pay. Based on the assumptions outlined in the table above, the number of households that will choose to switch to ECF is calculated below:

Table 8: Number of HH that will switch to ECF

No of households		Year 1	Year 10
Scenario 1	Rural	0	12,000
	Urban	32,000	448,000
	Total	**32,000**	**460,000**
Scenario 2	Rural	0	18,000
	Urban	63,000	743,000
	Total	**63,000**	**761,000**
Scenario 3	Rural	0	24,000
	Urban	95,000	1,036,000
	Total	**95,000**	**1,060,000**

2.3.3.2 Stacking: Taking fuel stacking into consideration

Many households that switch to ECF as their primary fuel will still combine multiple fuels over the course of the year in practice. This is a behavior known as fuel stacking. The World Bank multi-tiered energy access survey data was used to calculate the percentage of households that stack in urban and rural areas, to count for stacking in the demand projection. This was calculated to be ~37% in rural areas and ~16% in urban areas[17]. For these households, an assumption was made that ~50% of their fuel needs would come from their primary fuel source, i.e. ECF. For households that do not stack, it is assumed that 100% of their cooking energy would come from ECF. The household figures above were then adjusted to reflect stacking.

2.3.4 Calculating the number of litres of ECF demanded

To calculate the total demand for ECF in Kenya over the next 10 years, the total number of households that will prefer ECF (adjusted for stacking) was multiplied by the average number of

[16] These factors are expected to change with increases in awareness, and as households begin to understand the importance of clean fuels to health, and the environment

[17] Fuel stacking percentages were based on the number of households that reported having a secondary cooking fuel source

litres consumed per household per year (~275 litres)[18]. The total demand for ECF from year 1 to 10 is summarized below:

Table 9: Total demand for ECF

Total ECF demand (litres)		Year 1	Year 10
Scenario 1	Rural	0	2,700,000
	Urban	8,000,000	112,300,000
	Total	**8,000,000**	**115,000,000**
Scenario 2	Rural	0	4,000,000
	Urban	16,000,000	188,000,000
	Total	**16,000,000**	**192,000,000**
Scenario 3	Rural	0	5,000,000
	Urban	24,000,000	263,000,000
	Total	**24,000,000**	**268,000,000**

Based on the methodology above the demand for ECF is expected to range from 8 million - 24 million litres in year 1, rising to a range of 115 million - 268 million litres by year 10. The rising demand is expected to be driven mostly by the urban areas, due to the dominance of firewood use in rural areas (which means that most households will be reluctant to pay for fuel) and the infrastructural challenge of supplying ECF to the more remote areas of the country.

CAPEX estimates and estimated impact discussed in the following chapters will be based on the base case scenario (scenario 2) where demand is estimated to range from 16 million litres in year 1 to 192 million litres in year 10.

[18] Dalberg (2018). Scaling up clean cooking in urban Kenya with LPG and Bioethanol – A market & policy analysis.

3 SUPPLY OF ETHANOL COOKING FUEL

3.1 Summary

- There are varieties of feedstocks that can be used to produce ECF, including sugarcane, corn, cassava, sorghum to name a few. Globally, sugarcane is most often used
- In Kenya, ethanol is exclusively produced through molasses feedstock, a by-product of sugar production. However, a national shortage of molasses is affecting production levels
- In order to solve this issue, two other potential feedstock sources were studied in this master plan: sugarcane juice and cassava. However, current production levels of both feedstocks are inadequate to meet projected demand. In addition, sugarcane and cassava are not grown in the most conducive areas; while the highest yields are in the coastal regions, production is currently concentrated in the Western region of Kenya
- The CAPEX required to support local production was sized for all three feedstock sources. Ethanol processing makes up most of the CAPEX required to expand the local ECF industry in Kenya (on average 78%), followed by feedstock production (on average 15%) and ethanol distribution (on average 7%)
- Between 2 to 7 ethanol plants are required; Kisumu, Busia, TransNzoia, Kilifi or Kwale counties are the most conducive areas for ethanol plants due to the proximity to feedstock
- Setting up new dispensers and purchasing tankers for last-mile distribution will be the major investments required to expand the ethanol distribution network

3.2 Context

Nearly all the ethanol used as a cooking fuel globally is produced and consumed in Africa, with small pockets of ethanol cooking activity in Latin America (e.g. Haiti and Brazil) and very limited pilots in Asia[19]. In Kenya, Ethanol as a cooking fuel is still a nascent industry with just 1.2 million litres produced annually[20].

All of Kenya's ethanol is made from molasses, a by-product of sugar production, making the ethanol industry entirely dependent on the sugar sector. The sector has faced many challenges in its recent past including increased competition from foreign producers, a decline in productivity at the farm level and failure in institutional structures, inefficient processing, and policy to address the issues. Most state-owned sugar companies have faced operational challenges and have since halted production and so the current major producers of sugar are private sector companies. These companies and their production levels are displayed below:

Sugar company	2018 Quantity of production (MT)
Mumias Sugar Company Ltd	88,201
West Kenya Sugar Company Ltd	925,894
Butali Sugar Mills	707,301
Kibos Sugar & Allied Companies	832,272

[19] World Bank (2017). Scalable Business Models for Alternative Biomass Cooking Fuels and Their Potential In Sub-Saharan Africa, p33

[20] Source: ACFC and KSAIL

Sukari Industries Ltd	518,534
Transmara Sugar Company Ltd	730,632
Kwale International Sugar	172,312
Nzoia Sugar Company	393,118
Chemelil Sugar Company	282,052

Note: Quantities are cane, not sugar

A few companies are also engaged in the production of ethanol cooking fuel, including Agro-Chemical and Food Company Limited (ACFC) and Kibos Sugar & Allied Companies (KSAIL). These 2 companies produce a total of ~1.2 million litres annually. Mumias Sugar Company has a functional distillery plant but is not currently operational. However, over the last few years, the industry has faced a scarcity of molasses driving prices up and severely affecting production.

State-owned sugar plants in Kenya are set to be privatized in 2020. The plants under privatization include Miwani, Chemelil, Nzoia, Muhoroni, and South Nyanza. If successfully completed as planned, it has the potential to revitalize the industry and increase the production of much-needed molasses. This would have a big impact on future ethanol production. Investors, donors and other stakeholders interested in ethanol production should work closely with the government taskforce currently evaluating the process.

3.3 Sources of Ethanol

Ethanol is a liquid biofuel that can be produced from a variety of feedstocks including sugary materials such as sugar cane, molasses; starchy materials such as cassava, potatoes, or maize; or cellulosic material such as wood, grasses, and agricultural residues[21].

This master plan highlights ECF production sourced from molasses, sugarcane juice, and cassava as the most likely sources of ECF in Kenya. Maize was studied as a potential feedstock but not considered due to concerns about food security. In close consultation with governmental and non-governmental stakeholders, three food security factors were used to assess the suitability of potential feedstock:

1) Availability of the feedstock (current level of production in Kenya)
2) Whether the feedstock is a staple food
3) the stability of the feedstock (yield, climate-resilient)

Sugarcane and cassava were chosen based on these criteria. Cassava is one of the most resilient crops in the tropics. According to research from the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), and the International Center for Tropical Agriculture (CIAT), the yields of cassava roots are predicted to increase based on the consequences of climate change[22]. Due to its climate resilience, the stability of cassava will be ensured. Additionally, Kenya's cassava value chain is currently underdeveloped, therefore investments into cassava (through high-quality inputs and improved productivity) can boost yields, which will, in turn, contribute to food security.

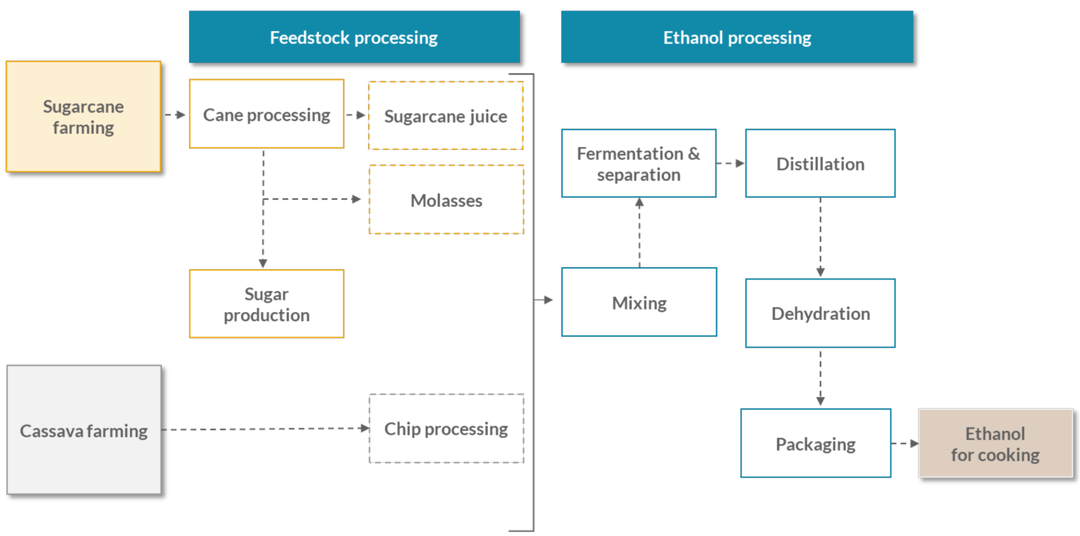
[21] World Bank (2017). Scalable Business Models for Alternative Biomass Cooking Fuels and Their Potential In Sub-Saharan Africa, p159. Global Alliance for Clean Cookstove (2015)

[22] Schubert C., Climate Change, Agriculture and Food Security (CGIAR), Cassava could prove to be Africa's ticket to food security under a climate change. [online] Available at: https://ccafs.cgiar.org/blog/cassava-could-prove-be-africa%25E2%2580%2599s-ticket-food-security-under-changing-climate#.XZYEq0YzY2x

An important consideration is the potential Indirect Land Use Change (ILUC) of producing biofuels. When biofuels are produced on existing agricultural land, the demand for food and feed crops remains and may lead to someone producing more food and feed somewhere else. This can imply land-use change (by changing e.g. forest into agricultural land), which implies that a substantial amount of CO2 emissions are released into the atmosphere. Therefore, sustainability risks will need to be assessed for each feedstock (sugarcane, cassava) right across the value chain.

The three pathways are displayed in the figure below.

Figure 4: Sources of ethanol cooking fuel



Source: Ricardo Martins (Greenlight); Ecofys, Bio-ethanol from cassava, 2007; Dalberg Analysis

Molasses based production

Molasses is a by-product of sugar production. The molasses-based process starts with the cutting and milling of sugarcane, which produces a juice with 10-15% solids from which sucrose is extracted. The bi-product of sugar production – molasses – is diluted and acidified and fed straight to the fermentation unit. The final steps are fermentation (converting glucose to ethanol), distillation and dehydration. Production through the molasses pathway requires the development of both the sugar industry and the ethanol industry since molasses is procured as a by-product in the course of sugar production. In addition, substantial quantities of sugarcane are required to support this pathway since the sugarcane used must support both industries. Molasses is one of the most common sources of ethanol worldwide and is the only source of ethanol currently existing in Kenya.

Sugarcane juice-based production

Sugarcane juice-based production follows several steps. Sugarcane is washed, peeled and extracted using a juice extractor. The sugarcane juice is then filtered and hydrolyzed. The final steps are fermentation, distillation, and dehydration. In contrast to molasses-based production, the quantity of sugarcane required for direct sugarcane juice-based production is significantly smaller, as the juice is exclusively used for ethanol production. The direct production of ethanol from cane juice is currently ongoing in Brazil and India. Brazil has been processing ethanol through direct cane juice for several years[23], however, in India, it has only recently been pioneered in 2018 due to an amendment to the Sugarcane Control Order of 1966 which allows sugar mills to manufacture ethanol directly from sugarcane juice[24].

Cassava based production

Ethanol processing from dried cassava chips and fresh cassava roots is a very different process. After harvesting, the roots are chopped into chips transported to drying floors and dried. Starch is treated by liquefaction and saccharification to obtain glucose as a fermentable sugar. At the fermentation stage, yeast is employed to convert glucose to ethanol. The final step is purification (separating ethanol from other reaction products and inert materials)[25]. Ethanol processing from cassava is developed in several countries due to the high starch content of cassava (e.g. Benin, Mozambique, Ghana, Nigeria, Indonesia, and Thailand).

Each pathway has its own advantages and disadvantages. These are detailed below.

Table 10: Advantages and disadvantages of the different pathways to produce ethanol (not exhaustive)

	Molasses	Sugarcane Juice	Cassava
Advantages	*Feedstock production* ▪ The molasses-based pathway allows for two industries & two revenue streams: both ethanol and crystal sugar *Ethanol processing*	*Feedstock production* ▪ The sugarcane juice-based production requires less sugarcane than the molasses-based model, which in turn means less CAPEX spent on farming & feedstock production ▪ It requires much fewer hectares than the molasses-based model	*Feedstock production* ▪ The cassava value chain is relatively new in Kenya and does not have the same legacy issues as the sugar value chain ▪ Cassava has a potential for higher yields than sugar under optimal conditions

[23] Yen L. S (2013). Direct fermentation of sugar cane syrup to ethanol. Faculty of Resource Science and Technology, UNIMAS [online] Available at: https://ir.unimas.my/id/eprint/8738/1/Direct%20Fermentation%20of%20Sugar%20Cane%20Syrup%20To%20Ethanol%20(24pgs).pdf

[24] The Economic Times (July 2018). Government notifies ethanol-making directly from sugarcane juice, B-molasses [online] Available at: https://m.economictimes.com/news/economy/agriculture/government-notifies-ethanol-making-directly-from-sugarcane-juice-b-molasses/articleshow/65161412.cms

[25] Kuiper L. et al (November 2007). Bio-ethanol from cassava, Ecofys. [online] Available at: https://probos.nl/biomassa-upstream/pdf/FinalmeetingEcofys.pdf

	▪ Kenya has 71 years of experience in molasses-based ethanol production & can leverage technical knowledge & existing production facilities ▪ It reduces waste of byproducts i.e. molasses ▪ It allows for the use of bagasse (fibrous residue from sugarcane) to generate energy that can be used to fuel the plant and supply the national grid	since the conversion ratios are much higher with sugarcane juice ▪ It generates less GHG than the molasses pathway ▪ Potential to cultivate faster-maturing varieties of sugarcane, further increasing annual productivity per hectare *Ethanol processing* ▪ It allows for the use of bagasse (fibrous residue from sugarcane) to generate energy that can be used to fuel the plant and supply the national grid	*Ethanol processing* ▪ Cassava based ethanol plant allows for the production of other ancillary products such as flour ▪ It allows for the use of bagasse (fibrous residue) to generate energy that can be used to fuel the plant and supply the national grid
Disadvantages	*Feedstock production* ▪ Supply of molasses is dependent on the sugar industry, which results in shortages and price volatility ▪ Yield of sugarcane in Kenya is currently low due to poor quality crops and crops not being planted in the most conducive areas in the country ▪ The number of hectares allocated to sugarcane production is too	*Feedstock production* ▪ Will be direct competition with the sugar manufacturing industry as both would be using sugarcane directly as a raw material ▪ Productivity of sugarcane is currently low in Kenya with poor quality crops ▪ Sugarcane juice's shelf life is only 24-48 hours which could result in losses	*Feedstock production* ▪ Kenya's cassava value chain is currently underdeveloped, leading to low yields ▪ Cassava can be damaged by several diseases including the brown streak virus ▪ Cassava roots rot quite quickly (24-48 hours) which could mean significant losses if roots are not stored and processed efficiently *Ethanol processing* ▪ The bulkiness of cassava roots could

	small to support the increase of production ▪ Deficit of investments in large-scale mechanized sugarcane farms		result in additional transport costs ▪ The treatment costs for effluent are higher for cassava-based plants than other plants

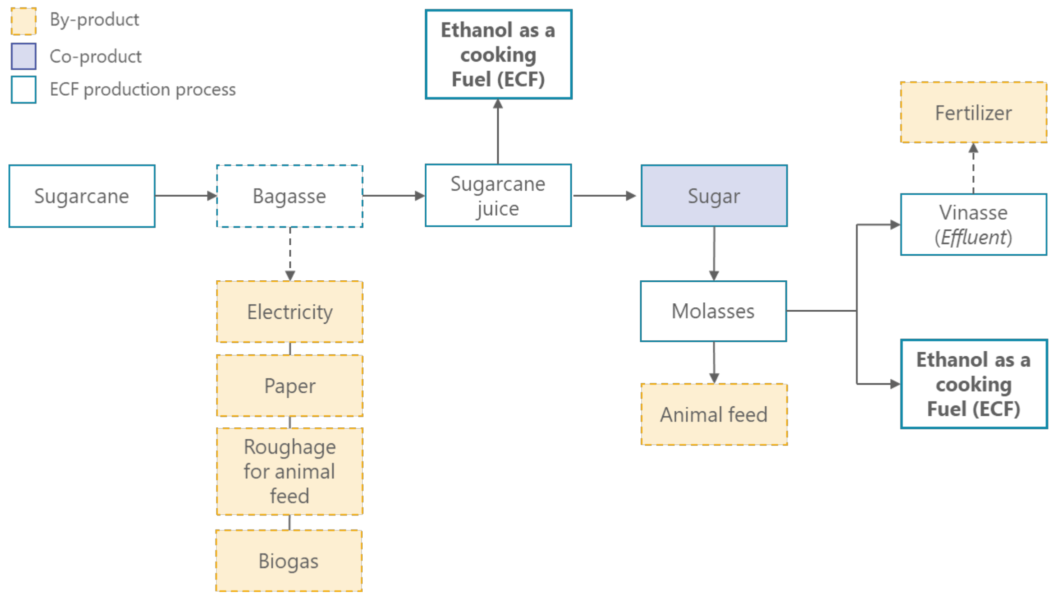
3.4 Additional revenue streams from local production of ECF

The co-products and by-products generated during the production of ECF can be used to improve overall production efficiency (i.e. bagasse to generate power) or to generate additional revenue streams that significantly boost the economics of production. For example, sugarcane and cassava-based ethanol production allows for the manufacturing of both ECF and high-protein animal feed or fertilizers. Recycling effluents (waste products) to create other products can also be a cost-effective way of disposing of otherwise toxic outputs from the ECF production process, which simultaneously has a positive impact on the environment. Specific co-products and by-products are described below.

Sugarcane

For molasses-based production, sugar is a major co-product as described in section 4.3, adding an additional revenue stream to ECF. Bagasse, the fibrous residue that remains after the extraction of juice from sugar cane, is also generated in large quantities and has the potential to be used for the production of several by-products including 1) a roughage source for animal feed 2) in supplements for cattle-feed 3) as a raw material in board or paper manufacturing 4) as a fertilizer 5) in the production of biogas. Bagasse can also be used to generate energy that can be used to fuel the plant, and excess electricity can be exported to the national grid.

Figure 5: Potential co-products and by-products from sugarcane (non-exhaustive)



CASE STUDY: Brazil in 2016, produced 666.8 million tonnes of sugarcane and in the same year produced 35,236 GWh of electricity from sugarcane bagasse[26]. Burning bagasse to fuel production and exporting excess to the national grid was shown to reduce the cost of ethanol produced by approximately 8-10% on average[27]. For stand-alone plants, the capital costs of having to use high-efficiency boilers to produce steam to drive turbines and create electricity (instead of using bagasse) increased capital costs by around USD 40-60 million (28% to 42%.)[28].

Cassava

Cassava-based ECF plants also produce other ancillary products that create parallel revenue streams, including cassava flour, garri (a popular food in West Africa), starches for sizing paper and textiles, and sweeteners. The by-products of ethanol production can also be used as raw material for other products. For instance, the wastes and effluents from ECF production can be converted into nutritional supplements for animal feed. In some contexts, one-third of the feedstock that enters into ethanol production is enhanced and returned into the feed market[29].

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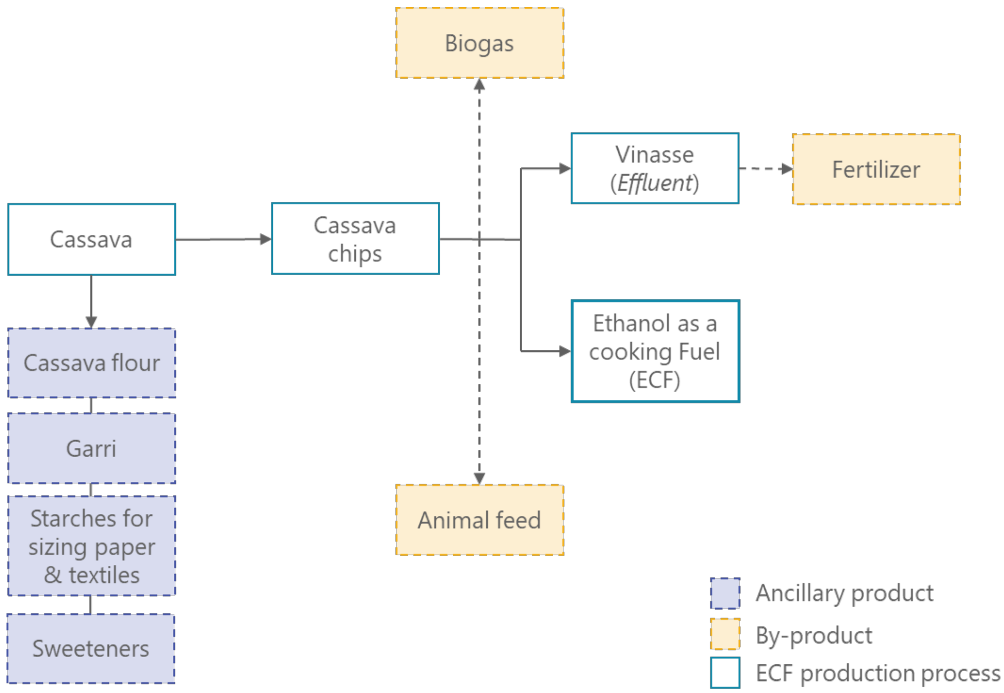
[26] Rubens Eliseu Nicula de Castro et al., (2018). "Assessment of Sugarcane-Based Ethanol Production", Intechopen
[27] CleanLeap, (2016). [online] Available at: https://cleanleap.com/4-bioethanol/42-conventional-bioethanol-production-costs
[28] Ibid.
[29] RFA, (2017). [online] Available at: https://ethanolrfa.org/co-products/

Figure 6: Potential co-products and by-products from cassava (non-exhaustive)



3.5 Supply gap & CAPEX required

3.5.1 Introduction

In order to understand the CAPEX required, the supply gap was assessed along the three stages of the ethanol value chain: (1) feedstock production, (2) ethanol processing, and (3) ethanol distribution. The supply gap was analyzed for the three sources of ethanol (molasses, sugarcane juice, and cassava) based on projected demand volumes. In each model, 100% of the ethanol is assumed to come from one feedstock. This allows for comparison between the different pathways, as well as enables stakeholders to form a view on overall market evolution when a mix of feedstock is used. The outline methodology used for each stage of the value chain is detailed below with the full methodology available in the Annex.

1. **Feedstock production**: The number of additional hectares that are needed to be allocated was calculated based on the quantity of feedstock required, and the projected yield of the feedstock[30] per hectare. The number of additional mechanized farms needed to be set up was calculated based on existing data on large scale farms in Kenya collected through stakeholder interviews.
2. **Ethanol processing**: The number of plants required was calculated based on ethanol required, plant capacities[31] and average utilization rates.

[30] The yield of the feedstock is assumed to grow over the 10 years due to improved quality of crops and mechanized production

[31] Projected capacities were collected from manufacturers of ethanol plants (ie. Praj Industries)

3. **Ethanol distribution**: The number of tankers, fuel station dispensers and retail store dispensers needed was determined based on projected demand, population density, and the capacities of these devices.

Three scenarios were created to capture potential variability in the domestic production of ethanol over 10 years as determined by the level of investments in ethanol processing and government policies implemented to incentivize production. These scenarios are listed below:

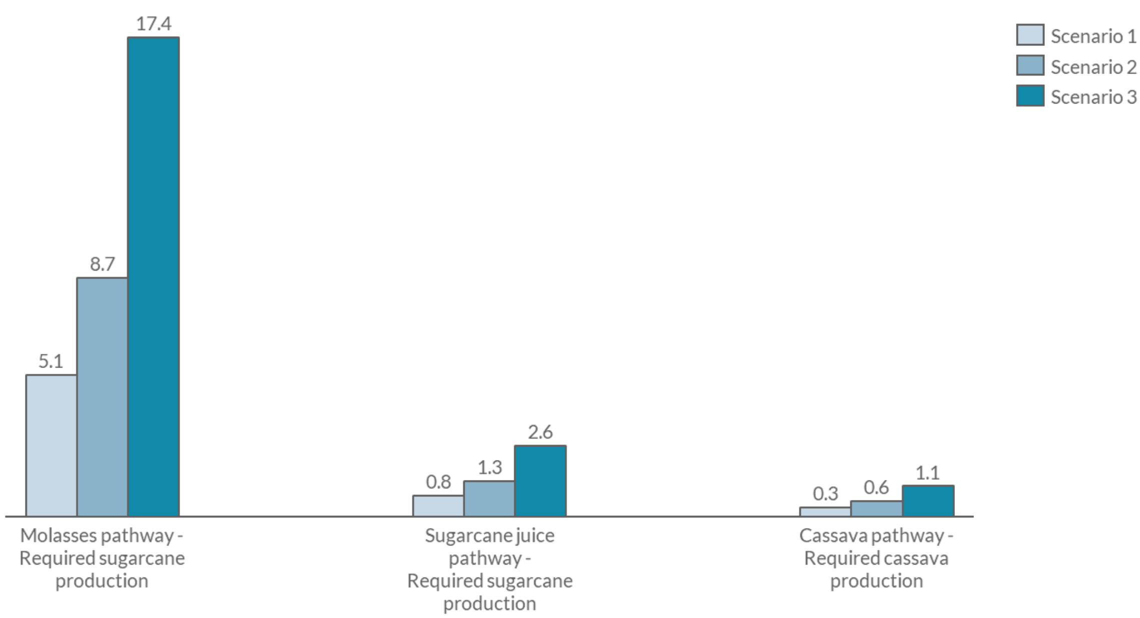
- Scenario 1: **30%** of ethanol processed locally
- Scenario 2: **50%** of ethanol processed locally
- Scenario 3: **100%** of ethanol processed locally

The supply and CAPEX models rely on the demand estimates as described in the Section 3, stakeholder interviews with ethanol factory supplier (Praj), ethanol and sugar producers (ACFC, KSAIL and KISCOL), government stakeholders (AFA - Kenya Sugar Directorate and Ministry of Agriculture), ethanol distributors (Koko Networks) and on data from the International Sugar Organization (ISO), FAO Database, and *AFA: Year Book of Sugar Statistics, 2018*.

3.5.2 Feedstock Production

3.5.2.1 Feedstock supply gap

Figure 7: Supply gap (at feedstock production stage) for different feedstock types (millions of tons per year)

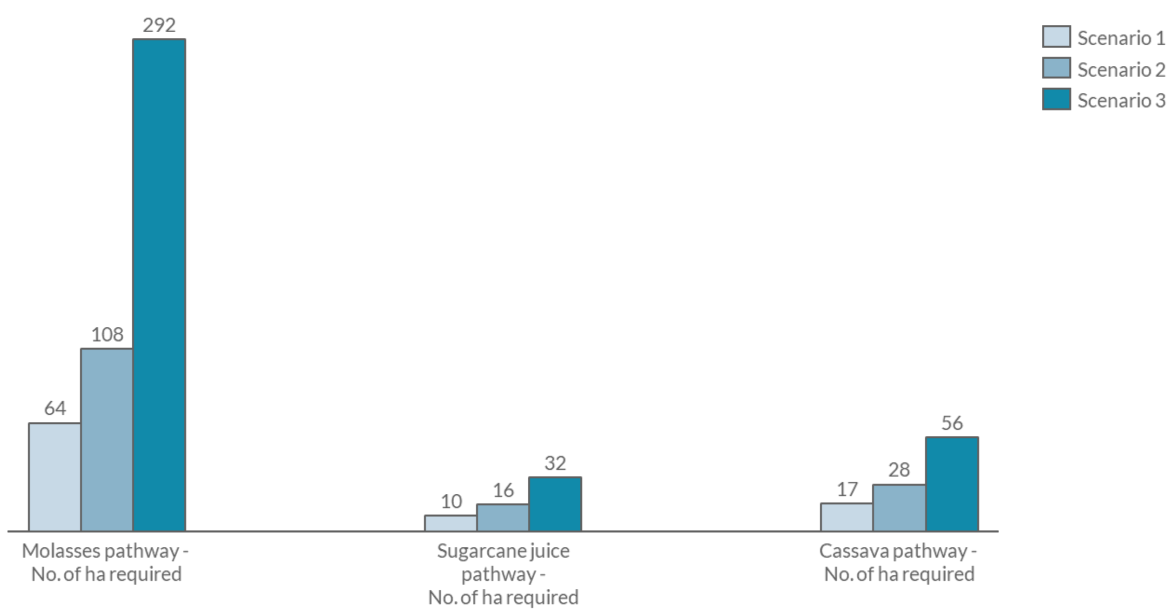


The feedstock supply gap for each of the different pathways is displayed above. The molasses pathway requires significantly more sugarcane than the sugarcane juice pathway, ranging from **5.1 Million to 17.4 Million tons** compared to **0.8 Million to 2.6 Million tons**, as the conversion rate of sugarcane juice to ethanol is much lower for molasses pathway. However, it is important to note that the molasses pathway will have two outputs, and therefore two revenue streams, with both ethanol and crystal sugar produced. Given Kenya's consistent deficit in sugar production vs.

consumption (~50% in 2018[32]), the additional production of sugar will be of benefit to the industry. For cassava-based production, the feedstock requirement is expected to range from **0.3 Million to 1.1 Million tons**.

The analysis above shows that the required amount of cassava production is significantly lower than sugarcane. But increasing cassava production to reach the required amount may face greater challenges than increasing sugarcane production. Cassava production is currently limited in Kenya with only **90,400 hectares** harvested.[33]Additionally, cassava production in Kenya is challenged by very low yields with an average of 12 tons per ha compared to a yield of **16 tons per ha** in Benin, **19 tons per ha** in Ghana, **23 tons per ha** in Niger[34], **24 tons per ha** in Thailand and **22 tons per ha** in Vietnam[35]. There is no mechanized large-scale cassava farm. Smallholder-led production will add a complication for farm-to-processing plant transport, due to the unique nature of cassava turning toxic in 24-48 hours after harvest. In addition, the bulkiness of the tubers makes processing challenging.

Figure 8: Land required for feedstock production (thousands of hectares)



When assessing the amount of land needed for feedstock, molasses-based production requires the most, ranging from **64,000 to 292,000 hectares,** again driven by the need for the sugarcane produced to support both the sugar and the ethanol industries. To support this production, the number of large-scale sugar farms needed to be set up in the coast region will be ~**2 farms** in the lowest case scenario up to ~**8 farms** in the highest case scenario, assuming 70% of requirements is produced by small-holders[36], and a large-scale farm has an average size of 10,000 hectares.

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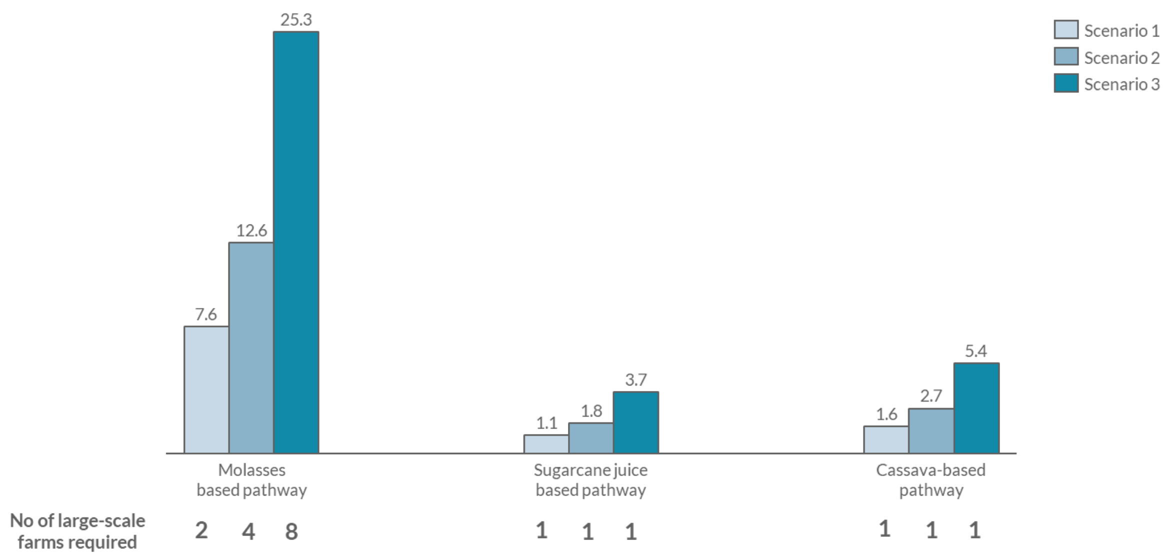
[32] AFA., (2018). Year Book of Sugar Statistics
[33] Faostat Database (2017)
[34] Faostat Database (2017)
[35] Ratanawaraha (2000). Status of Cassava in Thailand: Implications for Future Research and Development [online] Available at: http://agris.fao.org/agris-search/search.do?recordID=XF2016042293, FAO; Dalberg analysis
[36] The Food and Agricultural Organization (FAO) defines small-holder farmers as farmers who farm less than 2 hectares of land.

Similar analysis for sugarcane juice-based and cassava-based productions projects the required size of land to range from **10,000 to 32,000 hectares** and **17,000 to 56,000 hectares,** respectively. Based on the same assumptions above, **1 large-scale mechanized farm** will need to be set up in the coastal area.

3.5.2.2 Investments required to meet feedstock production gap

To meet the feedstock supply gaps described above, CAPEX investment into mechanized farming is required. CAPEX was estimated for each of the feedstock types based on the number of large-scale farms projected and the estimated cost of setting up a large-scale farm. CAPEX requirements for small-holder farmers were not calculated.

Figure 9: CAPEX requirement for large scale farms (billions *KES)*



For molasses-based production, the projected CAPEX was estimated to range from **KES 7.6 Billion up to KES 25.3 Billion.** The projected CAPEX for sugarcane juice-based production is estimated to range from **KES 1.1 Billion to KES 3.7 Billion** while the projected CAPEX for cassava production is estimated to be from **KES 1.6 Billion** to **KES 5.4 Billion**.

3.5.3 Ethanol Processing

3.5.3.1 Ethanol processing supply gap

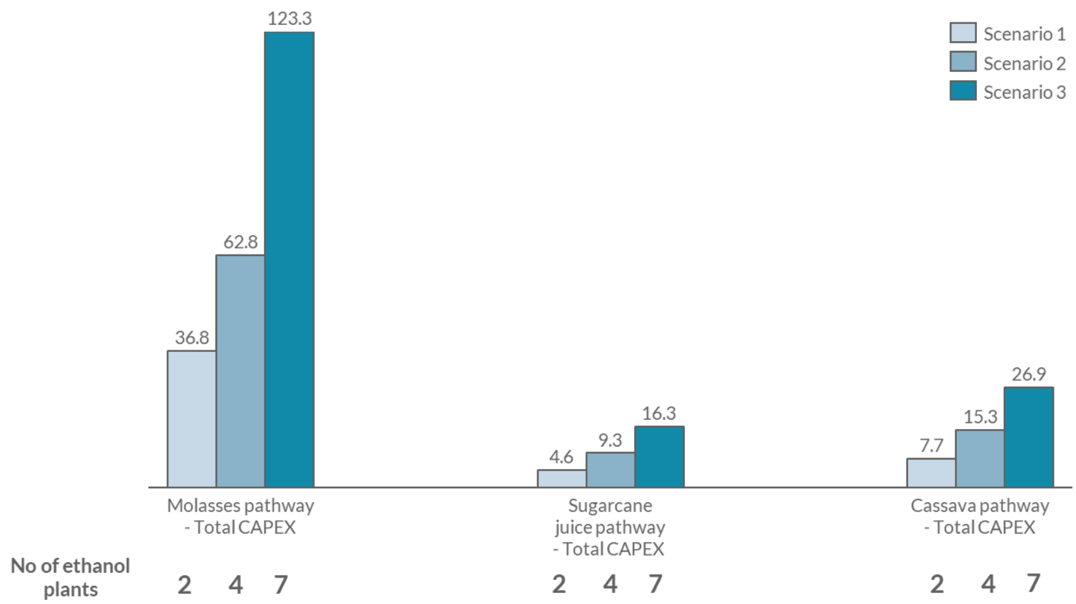
In line with the three scenarios described in the methodology section, the domestic production of ethanol is estimated to range from **30%** to **100%.** The ethanol gap ranges from **57 Million litres** in scenario 1, to **96 Million litres** in scenario 2 up to **192 Million litres** in scenario 3. The current domestic production of ethanol[37] will need to significantly increase over the 10 years to meet the projected supply. CAPEX will, therefore, be required to set up additional plants in the highlands or by the coast. The map displayed below highlights the projected areas of investments based on the current domestic sugarcane and cassava production.

[37] The current production of ethanol as a cooking fuel is estimated at 1.2 Million Liter based on data collected from stakeholder interviews with ACFC and KSAIL

Figure 8: Projected areas of investments based on the current domestic sugarcane and cassava production

3.5.3.2 Investment required to meet ethanol processing gap

Figure 10: CAPEX required for domestic ethanol processing (billions of KES)



The number of ethanol processing plants required will range from **2 to 7** for each of the production pathways based on a plant size of 100KL per day. Kisumu, Busia, Trans Nzoia, Kilifi, or Kwale counties are the most conducive areas for establishing these plants due to existing sugarcane or cassava production and high yield in the coastal areas.

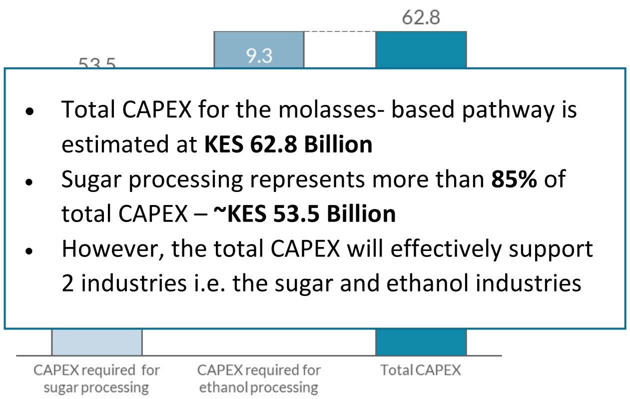
CAPEX required for each pathway varies. Molasses pathway will require total CAPEX ranging from **KES 36.8 Billion, 62.8 Billion to KES 123.3 Billion** for scenarios 1 to 3, respectively. The sugarcane juice CAPEX will range from **KES 4.6 Billion, KES 9.3 Billion to KES 16.3 Billion,** while the cassava pathway will require total CAPEX ranging from **KES 7.7 Billion, 15.3 Billion to KES 26.9 Billion**. Total CAPEX required to produce ethanol from molasses is significantly higher than the other two pathways since it also includes CAPEX for sugar production. For molasses-based production to be feasible both ethanol plants as well as sugar plants will have to be established. Some of these will be joint sugar-ethanol facilities, but several standalone sugar plants will also have to be set up. The number of standalone sugar plants needed is estimated to range from ~**4** in the lowest scenario up to **~13** in the highest scenario.

As illustrated by the graph below[38] CAPEX for sugar production makes up over **85%** of total CAPEX for processing in the molasses-based pathway. Therefore, a like-for-like comparison of the 3 different pathways should be cognizant of this [39].

[38] The graph only showcases the base case scenario of supply

[39] The cost of setting up a cassava-based plant is estimated at USD38M compared to a cost of USD23M for an ethanol only molasses-based plant

Figure 11: Breakdown of CAPEX for molasses-based production (billions of KES)



- Total CAPEX for the molasses- based pathway is estimated at **KES 62.8 Billion**
- Sugar processing represents more than **85%** of total CAPEX – **~KES 53.5 Billion**
- However, the total CAPEX will effectively support 2 industries i.e. the sugar and ethanol industries

3.5.4 Distribution

3.5.4.1 Projected ethanol distributed over 10 years under the base-case demand scenario

To inform CAPEX required for the expansion of distribution, infrastructure, and equipment, the expansion of distribution was first estimated, using Koko Networks as a case study example. To meet the projected demand for ethanol over 10 years, ethanol distributed will increase from Year 1 to Year 10 from **16M** to **192 Million Liter**[40]. In order to expand the distribution network, several investments will be required at every stage of the distribution. Distribution from the port to the fuel station, distribution within the fuel station, distribution from the fuel station to the retail store and storage in the retail store.

The table below summarizes the increase for each stage of the distribution based on a review of current distribution capacity and consultation with KOKO Networks [41].

Table 11: Equipment and tankers needed to expand distribution

Stage of distribution	Calculation	Number
Port to fuel station	No. of additional large tankers needed	26
Within the fuel station	No. of smart depots needed	68
Fuel station to retail store	No. of additional small tankers needed	146
Within the retail store	No. of dispensers needed	3,199

[40] The projections assume a base-case demand
[41] The detailed methodology used to calculate these figures is described in the Annex section of this report

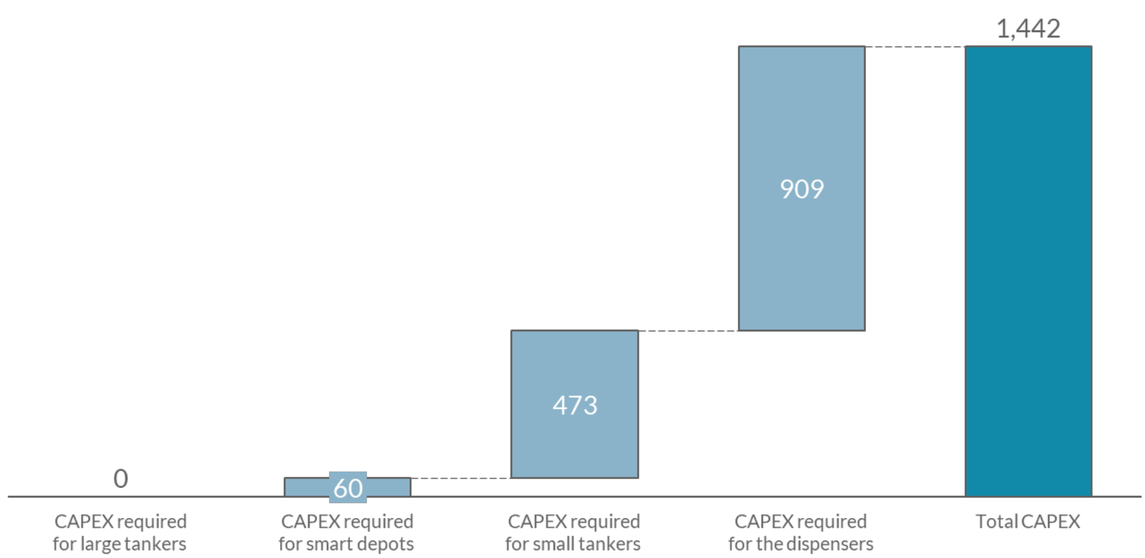
3.5.4.2 CAPEX required for ethanol distribution over 10 years

The total CAPEX required over 10 years to expand the distribution network is estimated at **KES 1.4 Billion**[42]. CAPEX required for large tankers is estimated to be negligible due to an excess of tankers in Kenya[43].

Therefore, two major investments will be required:

1. Setting up new dispensers in retail stores (~**63%** of total CAPEX)
2. Purchasing additional small tankers to distribute the ethanol to retail stores (~**33%** of total CAPEX).

Figure 12: CAPEX required for distribution (millions of KES)[44]



3.6 Summary: Total CAPEX required for ECF production

The graphs below summarize the total CAPEX required for each stage of production, processing and, distribution and for each production pathway. As illustrated, ethanol processing takes up the bulk of CAPEX. This applies to the three pathways – respectively **82%** of the overall CAPEX for the molasses pathway, **74%** for the sugarcane juice pathway and **79%** for the cassava pathway. CAPEX for feedstock production is the second-largest – respectively **17%** for the molasses pathway, **14%** for the sugarcane juice pathway and **14%** for the cassava pathway. Finally, CAPEX for distribution is relatively limited compared to the other two steps of the distribution value chain

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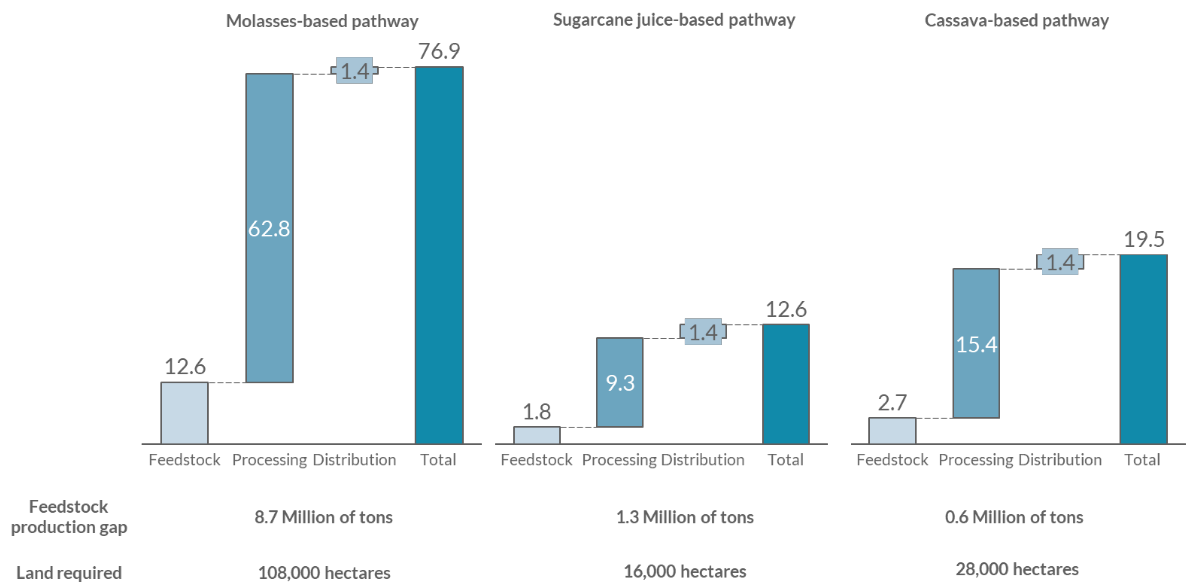
[42] The CAPEX projections assume a base-case demand
[43] Stakeholder interview with Koko Networks; Capital, Business (2018), Mombasa – Nairobi oil pipeline now operational. [online] Available at: https://www.capitalfm.co.ke/business/2018/07/mombasa-nairobi-oil-pipeline-now-operational/
[44] Total CAPEX required for distribution is estimated as of now using a discount rate. The detailed methodology is described in the Annex section of the report

– respectively, **1%** for the molasses pathway, **12%** for the sugarcane juice pathway and **7%** for the cassava pathway.

Figure 13: Total CAPEX required for ethanol production (billions of KES)



4 EMPLOYMENT, INCOME, ENVIRONMENTAL, & HEALTH BENEFITS OF A TRANSITION TO ETHANOL COOKING FUEL

4.1 Summary

- This section estimates the potential impact of households switching to ECF on jobs, income, health, and the environment. These include:
- **Employment and earnings impact:**
    - **Jobs created:** Up to 370,000 jobs (with the majority in feedstock production) can be created by a domestic ethanol market depending on the extent of local production and the production pathway chosen
    - **New income generated:** Up to KES 51 billion can be generated per year as new revenue by a domestic ethanol market, with additional income of up to KES 180,000 per year for smallholder farmers
- **Environment impact:**
    - **Deforestation averted:** Up to 54 million trees could be saved over a 10-year period from households switching from charcoal to ECF
    - **Greenhouse Gas emissions:** Up to 13.5 billion kgs of CO_2 equivalent could be saved cumulatively over a 10-year period by switching to ECF
- **Health impact:**
    - **Deaths averted:** ~3,700 deaths could be averted over 10 years by households switching to ECF from other cooking fuels
    - **Disability-adjusted Life Years (DALYs) averted:** Up to 507,000 DALYs could be saved over 10-years
    - **Economic value of deaths averted and DALYs saved:** Approximately KES 372 million in lost wages could be saved by saving productive days and years lost due to ill health

4.2 Employment & earnings impact

4.2.1 Employment Impact

The development of manufacturing is central to Kenya's Industrial Transformation Program (KITP), Vision 2030 and Big Four Agenda[45]. Initiatives are being driven by a desire to increase the productivity of the local industry, boost employment opportunities and build Kenya's competitiveness. The manufacturing sector in Kenya has faced significant challenges over the last 15 years, contributing to a drop in GDP and giving rise to fears of premature deindustrialization[46]. One of the goals of the Big Four Agenda is, therefore, to increase the manufacturing sector's share

[45] Kenya Association of Manufacturers (2018). Manufacturing in Kenya Under the 'Big 4 Agenda' - A Sector Deep-dive Report. Nairobi: KAM, pp.6-20.
[46] Kenya Association of Manufacturers (2019). Manufacturing Priority Agenda 2019: Closing the manufacturing gap through the Big 4 Agenda for shared prosperity. Nairobi: KAM, pp.1-15.

of GDP from 8.4% in 2017 to 15 percent in 2022, through interventions that support value addition[47].

The Government of Kenya (GoK) has also committed to creating 1.3 million manufacturing jobs by 2022. As local demand for ECF increases, there is potential for the local ethanol industry to expand to serve this demand, creating new jobs and opportunities across the value chain (feedstock production, ethanol production, storage, and distribution).

Ultimately, the potential job creation across the value chain that a local ethanol industry could generate is synonymous with the Big Four Agenda's goals, in that it boosts local production, supports efforts to boost food security and creates jobs.

4.2.1.1 Methodology

In order to calculate the overall jobs created from local ethanol production, this master plan assessed the potential number of jobs that could be created at each stage of the supply chain (feedstock production, ethanol production and ethanol distribution), for each potential feedstock, and against the 3 local supply scenarios described in chapter 3. The methodology for each stage is summarized below:

Smallholder Farmer Opportunity: To establish the potential opportunity for smallholder farmers under each feedstock, we drew on outputs from the supply/CAPEX analysis on the number of additional hectares of land needed to be allocated to meet demand and multiplied this by FAO data on the average number of smallholder farmers per hectare.

Job opportunities in ethanol production: To calculate the potential number of jobs that could be created in ethanol production, data on the number of plants required to meet demand was taken from the supply/CAPEX analysis. The number of plants required was then multiplied by the average number of staff per plant.

Job opportunities in ethanol distribution: To calculate the potential number of jobs created in distribution, data was taken from the supply/CAPEX analysis on the number of trucks/tankers required to meet the distribution differential (to both fuel stations and retail stores) in each supply scenario. This was then multiplied by the average number of drivers per truck/tanker.

4.2.1.2 Impact projection

The potential economic opportunities that could be created across the value chain are summarized in table 13 below.

Feedstock production: Across each feedstock, SHFs could either produce higher quantities or diversify from other production into sugarcane and cassava.

[47] Ibid.

The opportunity for SHFs is illustrated in the graphs below. Across all three value chains, SHFs are currently involved in the farming of the feedstock. However, an ethanol industry will allow for an increase in the number of SHFs involved in that value chain. If local production reaches 100%, an opportunity is created for an additional ~**365,000** sugarcane farmers for molasses-based production, and ~**40,000** sugarcane farmers for sugarcane juice-based production. Cassava based production could create an opportunity for up to **74,100** cassava farmers.

Figure 14: Number of SHF jobs/opportunity created (for 50% local production)

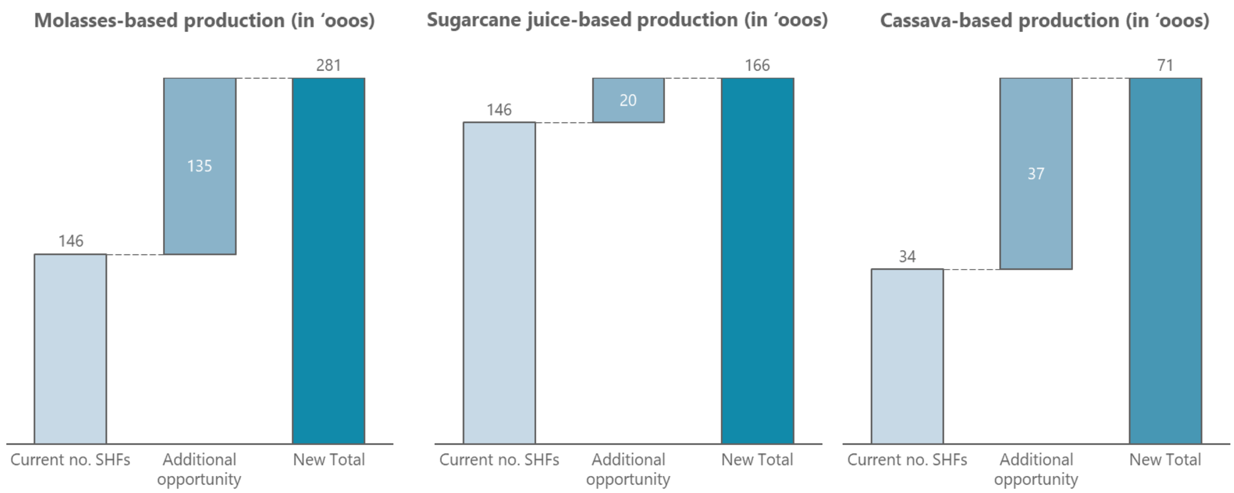


Table 12: Summary of potential job creation in feedstock production (over 10 years)

NB. Scenario 2 is commensurate with the projections in the supply gap assessment.

	Scenario 1 (30% local production)	**Scenario 2** (50% local production)	**Scenario 3** (100% local production)
Molasses	80,429	135,191	365,229
Sugarcane juice	11,980	19,966	39,933
Cassava	22,231	37,051	74,102

Ethanol production: The potential number of jobs that can be created in ethanol production range between **80** to **280** for cassava and sugarcane juice-based production and from **1,040** to **3,480** for molasses-based production, based on assumptions of 40 staff per ethanol plant and 160 staff per sugar plant. The levels of job creation for the molasses-based route is much higher than the other pathways as a result of the relatively labor-intensive sugar plants that have to be established for production to be viable.

Table 13: Summary of potential job creation in ethanol production

	Scenario 1 (30% local production)	**Scenario 2** (50% local production)	**Scenario 3** (100% local production)
Molasses	1,040	1,760	3,480
Sugarcane juice	80	160	280
Cassava	80	160	280

Ethanol distribution: The potential number of jobs that can be created in ethanol distribution remains the same across each production pathway and across the different local supply scenarios since ethanol will have to be distributed whether imported or sourced locally. **52** new jobs will be created for truck drivers transporting fuel to fuel stations and **292** new jobs will be created for truck drivers transporting fuel to retail stores.

Table 14: Summary of potential job creation in ethanol distribution

	Value
Number of truck drivers to	52
Number of truck drivers to	292
Total	**344**

Summary: The total number of economic opportunities that could be created by a domestic ethanol industry is summarized below. It ranges from **12,400** to **370,000** new opportunities, depending on the level of local production and the production pathway chosen. Local feedstock production, all of which are located in rural areas, contributes the most to the creation of economic opportunities in the ECF industry.

Table 15: Summary of total number of economic opportunities created across the value chain

	Scenario 1 (30% local production)	**Scenario 2** (50% local production)	**Scenario 3** (100% local production)
Molasses	81, 813	137, 294	369, 053
Sugarcane juice	12, 404	20, 470	40, 557
Cassava	22, 655	37, 263	74, 726

4.2.2 Earnings impact

As ECF demand increases and new jobs are generated, there will be a corresponding rise in earnings generated across the value chain at both the aggregate level for ethanol production and distribution, and at the individual level for smallholder farmers. This will contribute to Kenya's "Agricultural sector transformation and growth strategy" (2019-2029) that aims to increase small-scale farmer incomes from KES 465 per day to KES 625 per day (representing a ~35% increase).[48]

4.2.2.1 Methodology

The calculation for the earnings impact that a local ethanol industry could create is built upon the analyses on the potential number of economic opportunities created through local ethanol production. A similar approach was taken, and each stage of the supply chain was analyzed (feedstock production, ethanol production, and ethanol distribution). The methodology for each stage is summarized below:

Smallholder Farmer Opportunity: To establish the earnings potential for smallholder farmers under each feedstock, we drew on outputs from the supply/CAPEX analysis on

[48] Ministry of Agriculture, Livestock, Fisheries and Irrigation (2019). Towards sustainable agricultural transformation and food security in Kenya. Nairobi: MOALF&I, pp.2-13.

the total feedstock needed to meet local ethanol demand and multiplied this by the average price of feedstock per ton[49].

Ethanol production: To calculate the earnings potential in ethanol distribution, the total number of new jobs created in ethanol production was multiplied by the average monthly income for factory workers, taken from the Kenya National Bureau of Statistics' (KNBS) Economic Survey 2019.

Ethanol distribution: To calculate the earnings potential in ethanol distribution, the total number of new jobs created in ethanol distribution was multiplied by the average monthly income for drivers, taken from the KNBS Economic Survey 2019.

4.2.2.2 Impact projection

The potential earnings impact that could be created across the value chain is summarized in the tables below.

Feedstock production: If SHFs were to produce additional sugarcane to meet the demand of a local ethanol industry, up to KES 49 billion could be generated per year. At a disaggregated level for SHFs, this translates to an additional income of **KES 180,000** annually.

Table 16: Summary of potential earnings in feedstock production (KES per year)

	Scenario 1 (30% local production)	**Scenario 2** (50% local production)	**Scenario 3** (100% local production)
Molasses	14,000,000,000	24,000,000,000	49,000,000,000
Sugarcane juice	305,000,000	509,000,000	712,000,000
Cassava	132,000,000	221,000,000	443,000,000

Ethanol production: The potential amount of new earnings that can be generated in ethanol processing ranges between **KES 36 million** in the lowest case scenario and **KES 1.5 billion** in the highest case scenario. This translates to **KES ~450,000** per factory worker.

Table 17: Summary of potential earnings in ethanol processing (KES)

	Scenario 1 (30% local production)	**Scenario 2** (50% local production)	**Scenario 3** (100% local production)
Molasses	476,000,000	806,000,000	1,594,000,000
Sugarcane juice	36,000,000	73,000,000	128,000,000
Cassava	36,000,000	73,000,000	128,000,000

Ethanol distribution: The potential amount of new earnings that can be generated in ethanol distribution is KES 18 million for tanker drivers going from the port to fuel stations and **KES 102**

[49] Average 2018 price taken from: AFA., (2018). Year Book of Sugar Statistics

million for truck drivers transporting fuel between fuel stations and retail stores. These figures are standard irrespective of the type of feedstock. This translates to **KES ~350,000** per driver

Table 18: Summary of potential earnings in ethanol distribution (KES)

	Value
New income generated for truck drivers (to fuel stations)	18,000,000
New income generated for truck drivers (to retail stores)	102,000,000
Total	**120,000,000**

Summary: The total amount of new income that could be created by a local ethanol industry is up to **KES 51 billion**. A summary of the total income created across the value chain can be found below.

Table 19: Summary of new income created across the value chain

	Scenario 1 (30% local production)	**Scenario 2** (50% local production)	**Scenario 3** (100% local production)
Molasses	15,000,000,000	927,000,000	51,000, 000,000
Sugarcane juice	462,000,000	703,000,000	961,000,000
Cassava	290,000,000	415,000,000	692,000,000

4.2.3 Creating a supportive ecosystem for smallholder farmers

Agriculture continues to be a key driver of growth for the Kenyan economy, contributing to 21.9% of GDP and at least 56% of the total labor force[50]. The agricultural system is dominated by approximately 4.5 million smallholder farmers that make up between 70% and 80% of total agricultural production[51]. However, smallholder farmers in Kenya currently face a myriad of challenges ranging from limited access to markets, finance, low-yielding seeds, farm inputs, and mechanization, which invariably lead to low levels of productivity[52]. For instance, only about 4% of commercial bank lending is directed towards agribusiness, despite the percentage of Kenyans employed in agriculture or agribusiness-related services[53]. These challenges are compounded by

[50]FAO. (2019). Kenya at a glance | FAO in Kenya | Food and Agriculture Organization of the United Nations. [online] Available at: http://www.fao.org/kenya/fao-in-kenya/kenya-at-a-glance/en/
[51] Ministry of Agriculture, Livestock, Fisheries and Irrigation (2019). Towards sustainable agricultural transformation and food security in Kenya. Nairobi: MOALF&I, pp.2-13.
[52] AGRA. (2018). Africa's growth lies with smallholder farmers - AGRA. [online] Available at: https://agra.org/africas-growth-lies-with-smallholder-farmers/
[53] World Bank (2018). In search of Fiscal space. Government Spending and Taxation: Who benefits?. Kenya Economic Update 2018. Washington: World Bank Group, pp.2-10.

the effects of climate change, with projections showing that sub-Saharan African countries will be especially vulnerable to increases in temperature, changes in rainfall intensity and distribution and a rise in incidences of extreme weather events (e.g. droughts and floods), pests, weeds, and disease epidemics[54]. Smallholder farmers in Kenya are expected to have the lowest capacity to adapt[55].

To ensure that the economic opportunity of a local ethanol industry is fully realized, a supportive ecosystem for smallholder farmers, which is cognizant of SHF's increased vulnerability to climate change shocks, needs to be built. Figure 13 illustrates some of the complementary support that smallholder farmers will need to boost feedstock production.

Figure 15: Factors required to create a supportive smallholder farmer ecosystem

Value addition to agricultural commodities also remains low, with processed goods accounting for just 16% of Kenya's total agricultural exports, in comparison to 57% of imports. This means

[54] IPCC (2014), "Climate change 2014 impacts, adaptation, and vulnerability. part b: regional aspects", Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, New York, NY, p. 688.
[55] Winifred Chepkoech et al., (2018) "Farmers' perspectives: Impact of climate change on African indigenous vegetable production in Kenya", International Journal of Climate Change Strategies and Management, (40)4

that smallholder farmers' incomes and commodity values remain limited. Integrating sugarcane and cassava value addition through a domestic ethanol supply chain, therefore, has the propensity to significantly and sustainably increase smallholder farmers' incomes, as well as improve their livelihoods by:

a. Establishing a clear demand for sugarcane and cassava from a local ethanol industry

b. Increased access to productivity-enhancing products and practices.

Establishing a local ethanol industry with a supportive enabling smallholder ecosystem will ultimately help to tackle some of the challenges faced by smallholder farmers in Kenya and boost productivity by:

1) **Establishing nucleus farms:** absorbing smallholder farmers into nuclear farms will create a complementary employment opportunity whilst extending access to training on farming best-practices.
2) **Creating an extensive support network through out-grower schemes to increase yields:** to meet demand, smallholder farmers will need to be supported to achieve the high yields that are necessary to build up the supply.

Beyond this, partnerships need to be built to provide services to smallholder farmers. This is a central tenant of Kenya's "Agricultural sector transformation and growth strategy" (2019-2029) that is looking to support smallholder farmers through input vouchers and equipment (i.e. irrigation, processing, and post-harvest aggregation)[56].

4.3 Environmental and climate impact

The switch from charcoal and kerosene to ECF can have a significant positive impact on the environment and climate. For this report, the environmental impact from increased ECF use and decreased charcoal and kerosene were estimated by calculating (1) **averted deforestation** and (2) **Carbon dioxide equivalent (CO_2eq) emissions[57] averted.** Households that primarily use firewood were excluded from environmental impact calculations due to the assumption made in the demand analysis that most users of firewood collect their wood for free and would be unlikely to switch to a paid fuel (at least in the short term). The analysis will also, with less emphasis, capture some of the environmental impact of switching from LPG to ethanol. LPG has a significantly cleaner profile than the other fuels under consideration, however, still has more greenhouse gas (GHG) emissions when compared with ECF.

While this report focuses on the positive environmental impact of switching to ethanol, it is important to also consider the potential negative environmental impact of cultivating sugarcane or cassava allocated for ethanol production. If handled poorly, it has the potential to lead to the conversion of forests, natural grasslands and other higher carbon stock areas into agricultural land.

[56] Ministry of Agriculture, Livestock, Fisheries and Irrigation (2019). Towards sustainable agricultural transformation and food security in Kenya. Nairobi: MOALF&I, pp.2-13.
[57] CO_2eq emissions includes carbon dioxide equivalent emissions from carbon dioxide, methane, and nitrous oxide. Further details are provided in the impact section

This can be avoided by ensuring producers follow the strict guidelines laid out in the certification and ILUC mitigation plan[58].

4.3.1 Averted deforestation

Kenya loses 5,000 hectares of forest each year through deforestation[59]. Currently, Kenya's forest cover is estimated at 7.6% (3.467 million hectares) despite a restoration target of 10% set in the National Green Growth Strategy[60]. The current rate of deforestation is estimated to lead to an annual reduction in water availability of 62 million cubic meters, contributing to food insecurity and negatively impacting efforts towards the attainment of Vision 2030 and the Big Four Agenda [61]. A key driver of deforestation continues to be the demand for energy from charcoal and wood that currently stands at 68% of the total country's energy supply and 80% for Kenya's urban population[62]. With a growing and increasing urban population, pressure will continue to be exerted on Kenya's forests. If Kenya is to ultimately lower deforestation, then opportunities need to be created for fuel switching.

4.3.1.1 Methodology

A transition to ECF has the potential to significantly reduce the pace of forest degradation and deforestation in Kenya. To calculate the potential averted deforestation through increased uptake of ECF, this report estimated the aggregate number of trees saved due to households switching from charcoal to ECF. Kenya's current deforestation rate per household was calculated by considering current household charcoal consumption[63], the proportion of this consumption that is produced unsustainably, and the typical mass of a tree. Unsustainability was determined using the non-renewability factor – a measure of how sustainably fuel is sourced from the forest[64]. This deforestation rate was then multiplied by the number of households likely to switch under each scenario. The methodology assumes that the same type of wood is used nationally and remains constant over time.

4.3.1.2 Impact projection

Given that ~5 million (with fuel stacking adjustments) households are predicted to switch to ECF, **54 million trees** could be saved cumulatively over a 10-year period. A switch from charcoal to ECF

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[58] Peters D. et al (2016). Methodologies for the identification and certification of low ILUC biofuels, Ecofys. [online] Available at: https://ec.europa.eu/energy/sites/ener/files/documents/ecofys_methodologies_for_low_iluc_risk_biofuels_for_publication.pdf

[59] Government of Kenya (2018). "National Climate Change Action Plan 2018-2022". [online] Available at: http://cdkn.org/ wp-content/uploads/2013/03/Kenya-NationalClimate-Change-Action-Plan.pdf.

[60] FAO (2010). Global Forest resources assessment 2010. Rome: FAO, pp.5-7.

[61] Government of Kenya (2018). "National Climate Change Action Plan 2018-2022". [online] Available at: http://cdkn.org/ wp-content/uploads/2013/03/Kenya-NationalClimate-Change-Action-Plan.pdf.

[62] Wanleys Consultancy Services (2013). "Analysis of Demand and Supply of Wood Products in Kenya". Ministry of Environment, Water and Natural Resources, Nairobi, Kenya; Kituyi, E., Marufu, L., Huber, B., O. Wandiga, S., O. Jumba, I., O. Andreae, M. and Helas, G. (2001). Biofuel consumption rates and patterns in Kenya. Biomass and Bioenergy, 20(2), pp.83-99.

[63] As calculated from KIHBS data. This household charcoal use was converted to equivalent wood consumption, using a ratio of 7 from: Mjumita (2016). This is a global approximation that is commonly used in literature.

[64] Oimeke, R. (2012). "Charcoal Production and Commercialisation", Energy Regulatory Commission, Nairobi, pp. 9-10

would, therefore, increase Kenya's tree cover by over 64,000 hectares, contributing to efforts to curb deforestation and achieving the restoration target of 10% by 2030[65].

4.3.2 Averted carbon emissions

Kenya is seeking to modernize its cooking sector, which remains dominated by traditional biomass fuels that contribute significantly to its greenhouse gas (GHG) emissions. Through its Second National Communication to the United Nations Framework Convention on Climate Change in 2015 on its nationally determined contribution to meeting the Paris climate goal, and it's National Climate Change Action Plan 2018–2022, Kenya highlighted fuel combustion and charcoal production as a main contributor to GHG emissions in Kenya[66]. Yet despite these commitments, in 2013 Kenya emitted 60 million metric tons (MT) of total carbon dioxide equivalent emissions (CO_2eq). A transition to ECF has the potential to significantly reduce Kenya's carbon dioxide equivalent emissions and contribute to attaining Kenya's climate commitments.

4.3.2.1 Methodology

This report estimates the total CO_2eq saved due to houses switching to ECF as a national and per household calculation. The CO_2eq emissions for firewood, charcoal, and LPG were sourced from Global Alliance for Clean Cookstoves report[67], 'Comparative Analysis of Fuels for Cooking', that accounts for the total CO_2eq emissions required to produce, distribute, and use cooking fuels by a single household per year in Kenya[68]. A CO_2 equivalent differential was then calculated by subtracting ECF's CO_2eq emissions from the CO_2eq emissions of each fuel type. The total CO_2 saved was then calculated by multiplying each CO_2 equivalent differential by the number of households switching to ECF.

It is important to note that ECF made through sugarcane is derived from renewable biomass that removes CO_2 from the atmosphere during growth; therefore, the CO_2 emissions released from the combustion of these fuels are considered carbon neutral.

4.3.2.2 Impact projections

The CO_2 equivalent emissions saved due to increased adoption of ECF are summarized in table 20 below. Overall, if **5 million** households switch to ECF up to **13.5 billion kgs** of CO_2 equivalent could be saved cumulatively over a ten-year period, equivalent to 22% of the country's total emissions in 2013.[69]

Table 20: Summary of Co2eq differential by fuel type (over ten years)

	Kgs of CO2 equivalent saved

[65] Cited under the goals of Vision 2030

[66] Government of Kenya (2018). "National Climate Change Action Plan 2018-2022". [online] Available at: http://cdkn.org/ wp-content/uploads/2013/03/Kenya-NationalClimate-Change-Action-Plan.pdf.

[67] Global Alliance for Clean Cookstoves (2016). Comparative Analysis of Fuels for Cooking: Life Cycle Environmental Impacts and Economic and Social Considerations. Washington: GACC, pp.186-212.

[68] Global Alliance for Clean Cookstoves (2016). Comparative Analysis of Fuels for Cooking: Life Cycle Environmental Impacts and Economic and Social Considerations. Washington: GACC, pp.186-212.

[69] Climate Links, Greenhouse Gas Emissions Factsheet: Kenya. Kenya's total GHG emissions in 2013 were 60.2 million metric tons of carbon dioxide equivalent (MtCO2e)

Charcoal	6,931,000,000
Kerosene	4,649, 000,000
LPG	1,905, 000,000
Total	**13,485,000,000**

4.4 Health impact

Transitioning to ECF can have a significant impact on health due to reduced exposure to household air pollution (HAP) from burning solid fuels or kerosene. HAP is directly linked to several diseases, including lung cancer, stroke, ischemic heart disease, chronic obstructive pulmonary disease (COPD) in adults, and acute lower respiratory infection (ALRI) in children[70] (Global burden of disease data). These diseases can result in premature death or a disability that can affect life expectancy. In Kenya, exposure to HAP results in an annual average of 21,650 deaths (26% linked to lower respiratory infections) and 700,000 Disability-Adjusted Life Years (DALYs). A 'DALY' is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.

In 2013, 1.66 million DALYs (on average) were lost in Kenya due to ill-health, disability, and early death as a result of HAP. Ischemic heart disease and strokes account for most of the adult years lost, with ischemic heart disease accounting for an average of 145,596 years lost and strokes accounting for an average of 186,167 years lost.[71]

Kenya's 2014-2030 Health policy recognizes household air pollution (HAP) as a leading risk factor and the ministry of health continues to promote interventions that minimize exposure to indoor air pollution. One key intervention point is the promotion of clean cooking fuels such as ECF.

For the purpose of this report, the health benefits from a transition to ECF use (and decreased charcoal and firewood use) were estimated by calculating (1) **deaths averted**, and (2) **Disability-Adjusted Life Years (DALYs) saved** due to reduced HAP from fine particulate matter ($PM_{2.5}$)[72] exposure rates based on Global Burden of Disease outcomes. $PM_{2.5}$ is a common proxy indicator for air pollution, representing one of several health-damaging products of incomplete fuel combustion that are emitted at relatively high concentrations when firewood, charcoal, and other fuels are burned in open fires or cookstoves.

[70] Smith et. al. (2015). "Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution." Annu. Rev. Public Health 185–206.
[71] Based on outputs from the WHO: HAPIT model, version 3.1.1, using 2015/2016 KIHBS Data
[72] $PM_{2.5}$ refers to "Particulate Matter, 2.5 micrometers or less". These are air pollutants with a diameter of 2.5 micrometers or less, small enough to invade even the smallest airways and produce respiratory and cardiovascular illness

4.4.1 Methodology

In order to determine the health impact that a shift to ECF could have, pre and post-intervention exposure $PM_{2.5}$ values were inputted into the Household Air Pollution Intervention Tool (HAPIT version 3.1.1)[73]. The HAPIT model facilitates impact comparisons of interventions designed to lower household air pollution based on established GBD methods[74]. For this report, the pre-intervention $PM_{2.5}$ exposure rate concentrations for firewood, charcoal and LPG users were taken from a systematic review of field studies conducted by Pope et al (2017). The HAPIT was then used to estimate potential deaths averted and DALYs saved in Kenya due to uptake of ECF[75].

The World Health Organization (WHO) has published 'air quality guidelines' with safe levels of $PM_{2.5}$ for health, which recommends an annual average $PM_{2.5}$ level of 10 ug/m_3 and three interim targets. The interim targets reflect the difficulty in achieving optimal $PM_{2.5}$ levels and are set as actionable targets that promote a gradual shift from high to low concentrations. If Kenya is to achieve WHO's interim targets, significant reductions in the negative effects of exposure to HAP can be expected. The first (highest) of such targets is the interim-target 1 (IT-1), set at 35 $ug/m_{3.}$

Compared with both dirty fuels and LPG, ECF has a considerably cleaner emissions profile. It can be assumed that the concentrations of $PM_{2.5}$ in households using ECF will be below the WHO annual average Interim Target 1 (35 ug/m^3). However, there are two important caveats to note: in this report pre-exposure and post-exposure rates were assumed independent of fuel stacking and using indoor $PM_{2.5}$ exposure concentrations. This was done because there are few studies and little consensus on the effect of HAP exposure in outdoor cooking and a few studies that examine exposure rates whilst accounting for fuel stacking.

4.4.2 Impact projection

The health impacts of increased ECF adoption are summarized in table 21 below. Overall, if households switch to ECF, about **3,700** deaths could be averted over a ten-year period. In addition, up to **507K** DALYs could be saved.

Table 21: Summary of cumulative health impacts from increased adoption of ECF across demand scenarios

Metric	Charcoal	Kerosene	Total
DALYs	335,403	172,125	**507,528**
Deaths averted	2,883	848	**3,731**

[73] HAPIT model (2019) https://householdenergy.shinyapps.io/hapit3/

[74] The HAPIT model uses disease rates and relationships as described in the Institute for Health Metrics and Evaluation's 2013 Global Burden of Disease and Comparative Risk Assessments efforts and estimates potential health changes due to interventions designed to lower household air pollution. See https://householdenergy.shinyapps.io/hapit3/#

[75] Inputted pre- and post-exposure rates, with other HAPIT default values for Kenya left standard, with a counterfactual of 10 ug/m3. This counterfactual is a measure of the ideal exposures, below which there is no risk to health. HAPIT also takes into account background health, demographic, energy, and economic conditions in the countries for which the program has been designed.

The deaths averted and DALYs saved could be larger as the HAPIT model currently only focuses on five diseases and does not account for other associated conditions (i.e. burns, cataracts, tuberculosis, adverse pregnancy outcomes, blindness).

4.4.3 Economic value of deaths averted and DALYs saved

As HAP can negatively impact health, it can also have implications on economic activity due to productive working days or years lost through ill health or death. The following section estimates the economic implication of the deaths averted and DALYs saved by switching to ECF.

- **Economic value of deaths averted –** The economic value of HAP-related deaths averted was calculated by multiplying the average wage bill per year of individuals employed (in either the private and public sector) by the total deaths averted (as calculated in section 6.4.2).

- **Economic value of DALYs saved -** The economic value of HAP-related deaths averted was calculated by multiplying the average wage bill of individuals employed (in either the private and public sector) by the total DALYs saved (as calculated in section 6.4.2).

The economic value of deaths averted and DALYs saved due to increased ECF adoption is summarized in table 20 below. Overall, ~ **KES 372 billion** in lost wages will be saved over a 10-year period as a direct result of a switch.

Table 22: Summary of the economic value of deaths averted and DALYs saved (over ten years)

	Value
Economic value of DALYs saved	368,000,000,000
Economic value of deaths averted	2,712,000,000
Total	**371,000,000,000**

- **Total savings to the Government of Kenya due to reduced health burden** – There will be some significant cost savings for the GoK based on the number of HAP related diseases averted. From our analysis, up to **KES 2.6 billion** could be saved over a 10-year period. This calculation is based on the typical cost of treating HAP related illnesses (estimated at 390USD[76] for COPD - chronic obstructive pulmonary disease), the total number of DALYs and death averted, and the percentage of Kenyans covered by the National Health Insurance Fund (NHIF) estimated at 13%[77]

[76] Subramanian, S., Gakunga, R., Kibachio, J., Gathecha, G., Edwards, P., Ogola, E., Yonga, G., Busakhala, N., Munyoro, E., Chakaya, J., Ngugi, N., Mwangi, N., Von Rege, D., Wangari, L., Wata, D., Makori, R., Mwangi, J. and Mwanda, W. (2018). Cost and affordability of non-communicable disease screening, diagnosis and treatment in Kenya: Patient payments in the private and public sectors. PLOS ONE, 13(1).
[77]National Health Insurance Fund (2019). Strides towards universal healthcare for all Kenyans. Nairobi:NHIF, pp.1-2

4.5 Gender impact

A transition from cooking with solid fuels such as charcoal and firewood to primarily using ECF in the household has some clear implications on gender equity. Research points to a disproportionate burden borne by women due to their primary responsibility for fuel collection and cooking duties. It is estimated that women and children spend up to 4.5 hours per day on unpaid labor[78]. In some estimations, women contribute to 91% of households' total efforts in collecting fuel and water[79]. In Kenya, this equates to an hour each day spent collecting charcoal or firewood [80]. Whilst the demand assessment projects that urban households will be the first adopters of ECF when it penetrates the rural market there will be some time savings for women who spend time collecting traditional biomass (charcoal and firewood). There will also be time savings on cooking as ECF is more efficient based on energy concentration when compared to other fuels[81].

A switch to ECF would, therefore, have a gender impact, offering three clear advantages:

1. A time-saving advantage when compared to collected solid fuel
2. Reducing time spent on fuel collection would free up time for women to engage in income-generating activities
3. Reduced exposure to HAP and any HAP-related diseases
4. Time saved on cooking due to efficiency and energy concentration of ECF compared to other fuels

[78] OECD. (2016). OECDSTAT. [online] Available at: https://stats.oecd.org/index.aspx?queryid=54757
[79]Clean Cooking Alliance. (2018). Women & Gender. [online] Available at: https://www.cleancookingalliance.org/impact-areas/women/index.html
[80] Stockholm Environment Institute (2016). Bringing clean, safe, affordable cooking energy to Kenyan households: an agenda for action. The new climate economy. Stockholm: SEI, pp.1-4.
[81] Dalberg Advisors (2018). Cleaning up Cooking in Urban Kenya with LPG and Bio-Ethanol. SouthSouthNorth, Cape Town.

5 RECOMMENDATIONS

The following recommendations have been identified to boost the demand for ethanol and support the development of a domestic ethanol industry. They were developed in close consultation with the government, donors and the private sector. While the majority will need to be led and owned by the Government of Kenya (GoK), they will all require close collaboration between key stakeholders for successful implementation.

5.1 Recommendations to boost demand for ECF

5.1.1 Zero-rating of VAT on ECF to stimulate demand

Currently ECF attracts VAT at 16%, compared to LPG which is zero-rated and kerosene which has a concessionary VAT of 8%, up from zero rating since 2013[82]. The VAT on ECF inflates the price at which it is sold to the final customer reducing its cost competitiveness compared to LPG and kerosene. The result is reduced uptake of ECF for clean cooking. Importantly firewood and charcoal are unregulated and do not attract VAT. With the significant health and environmental co-benefits outlined in the masterplan, government policy should supports the growth of clean cooking fuels through zero-rating of VAT on ECF which will stimulate demand.

During the Kenyan 2019 budget speech, the Minister of Finance announced the zero-rating of Value-Added Tax (VAT) on ethanol cooking fuel (ECF). However this measure was not ratified as part of the 2019 Finance Bill. It is important for the growth of the sector that this policy incentive is confirmed in the 2020 Finance Bill.

It is also important to note that ethanol cooking fuel has additives making it unfit for human consumption, removing the risk of it being used in alcoholic beverages and therefore it will not undermine government revenues from beverage-grade ethanol.

5.1.2 Short-term zero-rating of 25% import duty for denatured ethanol as a cooking fuel

Denatured ethanol has a 25% import duty, compared to 0% for LPG and 9% for kerosene,[83] which inflates the price at which the fuel is sold to the final consumer[84]. Denatured ethanol imports are necessary to sustain the market in the short term while local production is established. The zero-rating will keep ethanol at a competitive rate with other fuel alternatives and help to build demand for ethanol nationally. This zero-rating will be made on the importation of technical denatured ethanol only, which is the grade suitable for cooking. This will mean that the importation of high-grade ethanol, produced for drinking, will still be taxed.

We recommend that the zero-rating only be kept in place before being reviewed and duties re-introduced as local production starts to rise, to ensure that imports do not discourage the development of the local industry. The removal of the import duty should also be accompanied by

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[82] Kenya Finance Bill 2018

[83] LPG has an import duty at 0% and kerosene at 9% (Source: Dalberg (June 2018). Scaling up clean cooking in urban Kenya with LPG & Bio-ethanol, A market and policy analysis)

[84] Dalberg Advisors (2018). Cleaning up cooking in urban Kenya with LPG and bio-ethanol, SouthSouthNorth, Cape Town

concession agreements based on a cost-plus formula building up from the landed price in Mombasa. This will legally bound distributors to pass any reductions of tax to the customer. If VAT zero-rating is applied to denatured ethanol cooking fuel, it could see consumer prices drop by 14%.

CASE STUDY: In 2005, the United States (US) imported 800 million litres of ethanol, the majority of which was from Brazil, under a duty-free system that covered both countries called the Caribbean Basin Initiative (CBI)[85]. Under this scheme, ethanol could be imported duty-free to the US. The low-cost imports helped meet an increase in demand in the US market without undermining the competitiveness of local producers[86]. The system helped meet demand and build the ethanol industry in the US, now one of the largest producers of ethanol worldwide. With the establishment of the industry, over the last decade, the US also placed import tariffs on ethanol, which has supported the growth of local production and led to the nation becoming a net exporter of the fuel[87].

5.1.3 Expand current awareness and communication campaigns to promote ECF and highlight the risk of traditional cooking fuels

Awareness and communication campaigns will help inform consumers about the dangers of traditional fuel sources, as well as the availability of affordable clean cooking solutions, such as ECF. The CHUJA clean cooking campaign[88], launched in 2019 in Kenya, highlighted the dangers of cooking with charcoal, firewood, kerosene, and illegally refilled gas canisters, while driving a movement to stop using these methods in favor of cleaner and safer alternatives. To date, the campaign has had close to 250,000 views on YouTube[89]. In addition, the Kenyan Ministry of Health has recently completed training for its Community Health Workers to raise awareness on household air pollution (HAP) across the country. This is part of a larger plan to roll our universal health coverage across the country, starting with Nyeri, Isiolo, Machakos, Kisumu, Nairobi, and Eldoret. These initiatives should be leveraged to address a widespread lack of information on the dangers of traditional fuels on consumer's health. By building on these two initiatives, the government can work with the donor community to increase national awareness and the demand for clean cooking options such as ECF.

CASE STUDY: The behavior change program funded by the Global Alliance for Clean Cookstove includes among others: (1) the FumbaLive campaign on improved biomass stoves in Uganda (2) the Purplewood clean cooking campaign in Bangladesh.

In Uganda, the three-month FumbaLive campaign employed a multi-media approach using 7 languages (radio, broadcasting dramatic spots, social media, outdoor media, and live events) to

[85] Nyberg J., Sugar-based ethanol, International Market Profile, Competitive Commercial Agriculture in Sub-Saharan Africa (CCAA) Study

[86] Jacobucci, B. (2005). Ethanol Imports and the Caribbean Basin Initiative. [online] Congressionalresearch.com. Available at: http://congressionalresearch.com/RS21930/document.php [Accessed 13 Sep. 2019]

[87] United States Department of Agriculture (2017) The Economic Impacts of US Tariffs for Ethanol & Biodiesel: [online] Available at: https://www.usda.gov/oce/reports/energy/The_Economic_Impacts_of_U.S._Tariffs_for_Ethanol_and_Biodiesel.pdf

[88] CHUJA campaign video. [online] Available at: https://www.youtube.com/watch?v=05adyqTUSd8

[89] Views as of 30th September 2019

reach consumers. Each event organized employed a team of entertainers traveling on a FumbaLive truck and gathered manufacturers selling cookstoves[90].

In Bangladesh, a campaign sponsored by Purplewood developed a communication campaign for cleaner cooking fuel. Under a division of the Ministry of Energy, the Sustainable Renewable Energy Development Authority (SREDA) leveraged the country's existing infrastructures to reach out to more than 15 million people[91].

5.1.4 Work with the private sector and donor community to design stove financing options

The upfront cost of a clean cookstove can be a barrier to consumer uptake. Credit schemes allow users to split the investment costs into affordable monthly rates offered through Microfinance Institutions (MFIs). These consumer schemes can enable more households to access ethanol as cooking fuel. Private sector consumer schemes can include micro-credit, savings, insurance, and fund transfers[92]. Such models have been deployed in other countries to support the uptake of clean cookstoves. An example is the case of the Infrastructure Development Company Ltd (IDCOL) in Bangladesh.

In addition, the government and donor communities should design subsidy schemes to reduce the high upfront cost of clean cookstoves, specifically targeting those living below the income poverty line. For example, in India, the government gave free LPG connections to rural women living below the poverty line. The scheme, together with a government push to replace polluting firewood in kitchens, has led to LPG coverage rising to 93% of the population today from 55% in May 2014.[93]

With any scheme, it is important that thorough credit checks are carried out to ensure financing options do not exacerbate the debt levels of consumers.

CASE STUDY: IDCOL is a specialized Infrastructure Development Company – owned by the Bangladesh Ministry of Finance, which provides credit support, guarantees, capacity building and other technical assistance to partner organizations (NGOs, microcredit institutions, and private organizations) that extend credit to consumers to purchase improved cookstoves[94].

IDCOL worked with the World Bank to improve access and financing for 1 million stoves by 2018[95]. The institution achieved this target by 2017.

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[90] Clean Cooking Alliance. (2016). Clean Cooking Alliance. [online] Available at: https://www.cleancookingalliance.org/market-development/demand-creation/campaign/fumbalive-uganda.html [Accessed 13 Sep. 2019]

[91] Clean Cooking Alliance. (2016). Bangladesh government boots behavior change communication for cleaner cooking

[92] Energypedia, Financing Mechanisms for Cookstove Dissemination: [online] Available at: https://energypedia.info/wiki/Financing_Mechanisms_for_Cookstove_Dissemination

[93] The Economic Times (March 2019). Government achieves 87% of 8 crore free LPG connections target. [online] Available at: https://economictimes.indiatimes.com/news/economy/policy/government-achieves-87-per-cent-of-8-crore-free-lpg-connections-target/articleshow/68322381.cms

[94] The Daily star, (April 2018). Idcol to help develop market for improved cooking stoves. [online] Available at: https://www.thedailystar.net/business/idcol-help-develop-market-improved-cooking-stoves-1563607

[95] USAID Website, Clean and Efficient Cooking Technology and Fuels. [online] Available at: https://www.usaid.gov/sites/default/files/documents/1865/cookstoves-toolkit-2017-mod8-collaboration.pdf

5.1.5 Consistent review and expansion of existing regulations on kerosene and charcoal to other counties with the growth of the ECF market

In order to stem increasing deforestation and the adulteration of petroleum products with kerosene, the GoK has placed a ban on logging in public forests and levies on kerosene. While this is a good start, the government should consider expanding these regulations across the country for maximum impact.

However, given that LPG remains expensive, and the ethanol market is still nascent, expansion of these regulations should only follow the growth and widespread establishment of the ethanol market to ensure consumers have a viable alternative.

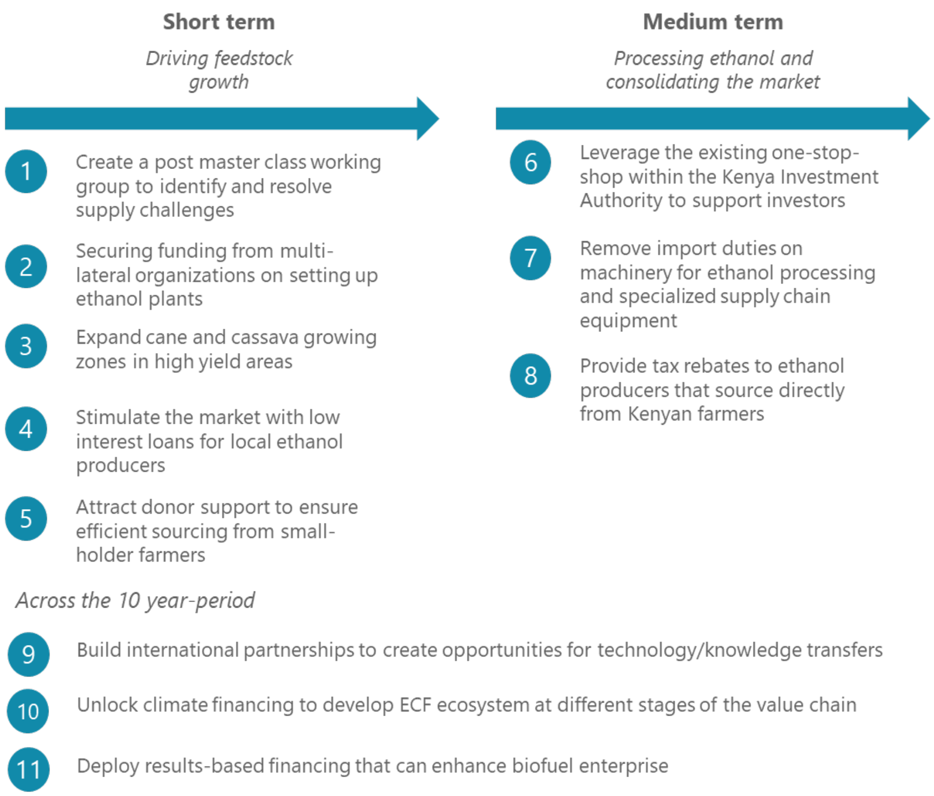
5.1.6 Harmonize the Bioethanol Vapour (BEV) stove tariffs with that of LPG at 10%

As it stands, ethanol distributors are forced to pay an additional 25% import tariff on all stoves. While local stove production is encouraged, there are currently no BEV stoves produced in Kenya. With no local industry to protect due to higher comparative costs of manufacturing, the only current impact of the tariffs is to drive up the price of stoves for consumers and prevent lower-income households from accessing ECF. Therefore, initially the import of bioethanol stoves will be required in order to grow the market, and ultimately to unlock investment for large-scale processing plants.

With this in mind, the Ministries of Industry, Energy, Environment, Agriculture as well as the President's Office have made submissions to Treasury in relation to harmonization of Bioethanol Vapour (BEV) stove tariffs with LPG stove import tariffs, at 10%.

5.2 Recommendations to support local production of ECF

The recommendations to support the local production of ECF should be prioritized in the short term (0-3 years) and in the medium term (3-10 years).



5.2.1 Create a post-masterplan working group to identify and resolve supply challenges

The Kenya ECF masterplan identifies opportunities for Kenya to develop an ethanol industry and fill the current supply gap. The recommendations set out below need to be driven forward by a multi-stakeholder working group with representation across the ecosystem. The ethanol value chain relies on a steady supply of feedstock at the right price, efficient manufacturing processes and a reliable distributor who is able to drive up demand. By working together to identify and discuss the potential challenges across the value chain, this working group can ensure all stakeholders are working together and can prioritize areas in need of intervention from both the government and the donor community.

5.2.2 Secure funding from multi-lateral organizations to conduct feasibility studies on setting up ethanol plants

Entering the ethanol cooking fuel industry requires significant financial investment at all stages of the value chain. To encourage investors, it will be critical to commission detailed feasibility studies on the industry. Feasibility studies should include analysis of production costs, potential revenues, financial returns. Several organizations including the World Bank, Energy, and Environment Development (EED) Advisory and the Clean Cooking Alliance have already begun to develop studies that examine the cooking fuel market in the country and explore potential opportunities. However, to attract investment, it will be necessary to go a step further and examine the financial and operational feasibility of investing in feedstock and ethanol production. These studies will be a starting point for investors as they venture into the market.

5.2.3 Expand cane and cassava growing zones in high yield areas

Ethanol production relies heavily on the availability of feedstock such as sugarcane and cassava. As such, increasing the land allocated for feedstock production will be necessary to meet the potential demand for ethanol.

However, efforts should be made to increase investment in sugarcane and Cassava development and increase areas under cane and cassava crops in high-yield regions. Currently, most of the sugarcane production is in Western Kenya region, an area with relatively low yields. However, sugarcane has the best yields in the coastal region[96]. Therefore, it is key to ensure that investors can access land to produce feedstock in the most conducive areas. Given the land laws in the country, county governments will have to be engaged in this process.

In this process, it will be critical to undertake a sustainability risk assessment for the feedstocks identified. These will need to be evaluated against greenhouse gas related and environmental and social risks including displacement. Should significant risk be identified, mitigation and monitoring recommendations will need to be developed to guide project implementation. In addition, farmers should adopt bioenergy sustainability best practices. These include principles shared by RBS such as ensuring operations improve food security, avoid negative impacts on biodiversity and maintain or enhance the quality and quantity of surface and groundwater resources.

CASE STUDY: In order to ensure the significant expansion in sugarcane production, Brazil, the second-largest producer of ethanol worldwide, provided guidelines for land allocation and rural development policies[97]. The government created the *National Agro-Ecological Zoning of Sugarcane*, commonly known as ZAE Cana. This policy instrument adopted the principle of zoning to the production of sugarcane. Through this instrument, the government could allocate land in the most conducive area (i.e. allocate land that does not require full irrigation, with slopes less than 12% and areas without risks for biodiversity).

[96] Yield can go up to 110 tons/hectares by the coast in irrigated areas (Source: Kwale Sugar)
[97] ELLA, Sugarcane Agro-ecological zoning: Greening the expansion of ethanol [online] Available at: https://assets.publishing.service.gov.uk/media/57a08a03e5274a31e000039a/130520_ENV_BraEthPro_BRIEF4.pdf

5.2.4 Stimulate the market with low-interest loans for local ethanol producers

To meet the CAPEX requirements across the ethanol value chain, a variety of financing options should be accessible to current and potential players in the ethanol industry. This will be critical to meet both initial and ongoing CAPEX investments.

One way to support the local industry is through the provision of low-interest loans from government agencies whose mandate is to support local agricultural and industrial development. Such agencies include the Kenyan Industrial Development Bank, the Agricultural Finance Corporation, and the Industrial and Commercial Development Corporation. Patient low-interest loans should be made available to players across the value chain.

CASE STUDY: To develop the ethanol industry, the Brazilian government has consistently made low-interest loans available to ethanol producers through its development bank. In 2012 the bank launched the Prorenova program which provided a credit line of $2.25 billion to support sugarcane farms and ethanol processors across the country[98]. The loans were deployed at a total interest rate of 10% and over a period of 72 months[99]. In addition to building the industry, these loans have encouraged a capital-intensive model of sugarcane farming by providing farmers with the upfront capital to purchase machinery[100].

5.2.5 Attract donor support to ensure efficient sourcing from small-holder farmers

The relationship between small-holder farmers and ethanol producers is central to meeting the demand for ethanol over 10 years. As discussed in the supply/CAPEX section, the production of sugarcane and cassava needs to significantly increase to meet the projected targets. Small-holder farmers can play a key role as long as the systems are in place to ensure efficient sourcing and aggregation. The Ministry of Agriculture, local governments and donors must collaborate to support small-holder farmers with targeted extension services including access to finance and quality inputs. When ethanol manufacturers are set up, this same consortium of partners should work with SHFs to support the negotiation of off-taker agreements, therefore guaranteeing vital supply to factories and a guaranteed income for farmers

CASE STUDY: The Farm to Market Alliance (FtMA) – an alliance of eight agri-focused organizations that have designed support schemes (i.e. loan facilitation and contracting)[101] to reach out to farmers across 14 different farming regions in Kenya for soya, sorghum, and green grams. Through 295 crop aggregators, FtMA bridges the gap between farmers and key-value chain actors. The total value chain financing has reached 310,000USD with 3 financial institutions and 11 input & equipment suppliers. The sugarcane and cassava value chain in Kenya will greatly benefit from

98 USDA foreign agricultural service (2012), Brazil report - GOB to support sugar-ethanol sector
99 USDA foreign agricultural service (2014) – Brazil report - GOB to support sugar-ethanol sector
100 Ben McKay et al (2014), The politics of sugarcane flexing in Brazil and beyond, Transnational institute Agrarian Justice Program. [online] Available at: https://www.tni.org/files/download/flexcrops04.pdf
101 Farm to Market Alliance Website. (2019). Kenya. [online] Available at: https://ftma.org/kenya/

a similar aggregation system – bringing the small-holder farmers together with the major stakeholders along the value chain.

Considering SHF's heightened vulnerability to climate change shocks, farmers should also be supported with training and resources for climate-smart agriculture that restores soil health and bolsters the resilience of smallholder farming systems. This includes access to conservation tillage, soil and water conservation, legume crop rotations, improved seed varieties and use of animal manure. Supporting SHFs in this way will promote environmental sustainability and the rehabilitation of productive ecosystems while increasing food and agricultural production.

5.2.6 Leverage the existing one-stop-shop within the Kenyan Investment Authority to support investors

Kenya ranks 128 out of 190 countries in the "starting a business" indicator in the World Bank *Ease of doing business report*, below other African countries such as Rwanda and Mauritius. The indicator measures the number of procedures, time, cost, and deposited capital required to obtain approvals and registrations in order to establish a business in the country.

To support and attract investment in the industry, the GOK should leverage the existing one-stop-shop within the Kenyan Investment Authority to support players along the ECF value chain. The center can help investors and industry actors to source information on laws and regulations (e.g. zoning laws), receive support on land allocation and initial setup and obtain the approvals and licenses required.

CASE STUDY: The Ethiopian government established the Ethiopian Investment Agency which provides investors with a central port of call for obtaining licenses, permits, registration of capital, among other services[102]. The agency also supports investors in sourcing land for their projects, installing utilities, and obtaining residence permits when necessary. The initiative is part of a larger drive by the government to boost the manufacturing sector and attract foreign investment to the country.

5.2.7 Provide tax rebates to ethanol producers that source directly from Kenyan farmers

As discussed in the impact section, job creation is a key priority for the GoK. The feedstock production of both sugarcane and cassava presents an opportunity to create new jobs and increase income, with a focus on small-holder farmers. The GoK should incentivize ethanol producers to source all of their feedstock from Kenyan farmers. This can be achieved through tax rebates, awarded to producers who can show that their feedstock is coming from Kenyan Farmers. The scheme can guarantee a market for farmers, and ensure a reliable steady income for their families

[102] Ethiopian Investment Agency (2015). Overview of Ethiopian investment opportunities and policies. [online] Available at: http://mci.ei.columbia.edu/files/2013/10/Invest-in-Ethiopia-Focus-Mekele-by-EIA.pdf

while supporting local ECF plants through tax rebates. In implementing this scheme, the government should ensure that small-holder farmers are supported to be resilient

CASE STUDY: East African Maltings Limited (EAML) – a subsidiary of East African Brewery Limited (EABL) – has established a long-term partnership with the GOK to build a sorghum value chain in Kenya. The Kenyan Revenue Authority provides tax rebates to EAML in return for evidence that they source all their sorghum from Kenyan farmers. As of 2018, EAML was working with 60,000 farmers.

5.2.8 Build international partnerships to create opportunities for technology/knowledge transfers

Feedstock production in Kenya has remained sub-optimal when compared to other countries, despite the availability of improved seed varieties, irrigation methods, and better farm practices. In addition, advancements in sugar refining and ethanol processing technology provides an opportunity for more efficient production. Partnerships between Kenyan institutes, e.g. the Kenya Agricultural and Livestock Organization (KALRO) and foreign institutions (e.g. the Brazilian Agricultural Research Corporation – Embrapa, the US Grain Council or Indian ethanol technology suppliers) will allow for technology/ knowledge spill-overs, which will, in turn, improve feedstock yields and overall production. Other countries have used such partnerships to boost the local knowledge base and improve production.

CASE STUDY: Mozambique has a long history of collaboration with other nations in the development of its ethanol industry. Over the past decade, Brazil has completed multiple feasibility studies, invested millions of dollars in feedstock production, sugar refining, and ethanol processing, conducted training on new ethanol technology, and entered into bilateral and trilateral agreements with Mozambique[103]. Collaboration with international organizations such as Project Gaia has also facilitated knowledge transfers and the broader development of the industry.

5.2.9 Unlock climate financing to develop the ECF ecosystem at different stages of the value chain

International organizations can play a key role in unlocking additional finance for the ECF industry in Kenya. As discussed in section 5, a switch to ECF results in substantial environmental benefits, significantly reduced greenhouse gas emissions and averted deforestation. This makes the industry a potential opportunity for climate finance. Several organizations including the Norwegian Carbon Procurement Facility (NorCaP), Swedish Energy Agency (SEA), the World Bank (with their Carbon Initiative for Development program), the Green Climate Fund (GCF), and the Global Environment Facility (GEF) are deploying finance globally towards projects that promote energy efficiency and low carbon emissions[104], and ECF projects could benefit from this. With the potential to save up to 2.6 billion kgs of CO2 eq cumulatively over a ten-year period by switching to ECF, The Kenyan

[103] MIT Press Journals. (2016). Unpacking Brazil's Leadership in the Global Biofuels Arena: Brazilian Ethanol Diplomacy in Africa. [online] Available at: https://www.mitpressjournals.org/doi/pdf/10.1162/GLEP_a_00369
[104] Global Alliance (2014), Climate finance report

government with support from international organizations should work to attract these funds to the ethanol cooking fuel sector.

CASE STUDY: The Kyoto Protocol, an international treaty that commits countries to reduce greenhouse gas emissions created the Clean Development Mechanism (CDM) which allows emission-reduction projects to trade "Certified Emission Reduction" units to other countries or entities[105]. As of 2017, the program had 61 registered cookstove initiatives globally[106]. New initiatives that drive emission reduction such as the development of an ethanol for cooking fuel industry could benefit from carbon finance.

5.2.10 Deploy results-based financing that can enhance biofuel enterprise economics

Results-based financing from donors and international organizations can improve the competitiveness and sustainability of the sector by ensuring that players in the ethanol industry meet targets in order to continue to receive funding. The targets should be developed in close consultation with the Climate Finance Unit under the Ministry of Treasury. Targets could be used to incentivize manufacturers to source from local smallholder farmers, manufacture sustainably using renewable energy and create jobs – especially among youth and women.

The model has been deployed extensively in the health and education sectors to reward higher-performing institutions. Typically, a clear performance and evaluation framework is designed through which beneficiaries of the funding will be evaluated. If employed in the ECF sector, the evaluation framework should be cognizant of the fact that the market is still nascent and potential beneficiaries need time to set up their plants and develop the market.

CASE STUDY: The World Bank has used results-based financing extensively, to drive greenhouse gas emission reduction. Several funds and facilities, including the Forest Carbon Partnership Facility (FCPF), the BioCarbon Fund Initiative for Sustainable Forest Landscapes (ISFL) and the Carbon Initiative for Development have been deployed to support projects that drive emission reduction including projects focused on the purchase of ethanol cookstoves (Madagascar), rural electrification (Senegal), off-grid renewable energy (Ethiopia), among others. Up to $2 billion in payments have been made since 1999.

[105] United Nations climate change website
[106] Household Energy Network (2017), Enablers to Cookstoves. [online] Available at: https://climatefocus.com/sites/default/files/Boiling%20Point%2069%20Galt%20%26%20Mikolajczyk.pdf

ANNEX

Annex 1: Data Sources & Acknowledgments

Throughout the engagement, a consultative approach was taken with both government and non-government stakeholders. The master plan was developed under the sponsorship of the Ministry of Industrialization and involved close coordination through a working group with representatives from the Ministries of Agriculture, Energy, Health, Environment, and the Sugar Directorate. Results were presented to the working group at three critical junctures for feedback. The full draft was then submitted to the working group for a three-week consultative period. The private sector, donor community, and several development agencies were also engaged through a private sector forum.

To complement this consultative approach and for the purposes of data collection, the Dalberg team carried out individual stakeholder interviews (stakeholders listed in table 1). Individual consultation was critical to ensuring that the plan was robustly developed. Dalberg engaged several stakeholders including:

- Kenyan sugar and cassava industry companies
- Ethanol distribution companies
- International ethanol factory/processing equipment manufacturers
- Public sector and regulatory bodies
- Institutional investors with experience in financing sugar, ethanol, and downstream fuel distribution

Many of these interviews were facilitated by **Mr. OP Narang**, MD Opnar Consulting Ltd., former MD of ACFC (1995-2011) and sugar/ethanol industry expert. Using his extensive industry experience, Mr. OP Narang supported us in securing stakeholder engagement and navigating the sector.

Table 1: Stakeholder list

Name	Organization	Position	Brief description
Dan Kithinji Esther Wang'ombe	Ministry of Energy and Petroleum	Deputy Director, Renewable Energy	Government working group member
Timothy Ogwang	Ministry of Agriculture, Livestock, and Fisheries	Deputy Director	Government working group member
Juma Mohammed	Ministry of Agriculture – roots and tubers division	Head, Roots, and Tubers	Stakeholder Interview
Charles Mutai Stephen M. Kinguyu	Ministry of Environment	Director, Climate Change Directorate Deputy Director, Climate Change Directorate	Government working group member

David Wanjala Hyrine Nyong'a Kinguru Wahome	Ministry of Industrialisation, Trade, and Cooperatives	Deputy Director, Chemicals and Minerals Assistant Director, Private Sector Development Deputy Director	Government working group member
Lolem Lokolile	Ministry of Health	Head, Health Care Waste and Climate Change	Government working group member
Richard Magero Fredrick Kebeney	Agriculture and Food Authority (AFA), Sugar Directorate	Interim Manager, Technical & Advisory Services Interim Senior Agronomist	Stakeholder Interview; Government working group member
Raju Chatte	Kibos Sugar and Allied Industries Limited	Director	Stakeholder Interview
Paul Omondi	Muhoroni Sugar Company	Acting General Manager	Stakeholder Interview
Selvanathan Suresh	Kwale International Sugar Limited	Head of Operations	Stakeholder Interview
Ashok Agrawal	ACFC	CEO	Stakeholder Interview
Greg Murray Richard Taylor Ed Agnew	KOKO	CEO Chairman Business Development and Communications	Stakeholder Interview; Private Sector Forum
Linda Davis	Giraffe Bioenergy	CEO	Stakeholder Interview
Keya Makenzi	MIVRAF	Agricultural officer	Stakeholder Interview
Rupesh Hindocha	Faber Capital	Partner	Stakeholder Interview
Makarand Joshi	Praj Industries	Business Development Africa	Data Collection
Ashok Singh	ISGEC	Assistant Manager, International Marketing	Data Collection
Sunil Kagwad	Mojj	Director	Data Collection
Suresh Patel	Elekea Limited/KEPSA	Managing Director	Stakeholder Interview
Kelechi Kingsley	Cassava Options	CEO	Stakeholder Interview
David Wanjohi Patricia Mbogo	Clean Cooking Alliance	Regional Head Program Manager, East Africa	Stakeholder Interview; Private Sector Forum
Gerry Ostheimer	Below50	Managing Director	Stakeholder Interview

Maxwell Musoka	GIZ	Component Leader, EnDev	Private Sector Forum
Jechoniah Kitala	Practical Action	Manager	Private Sector Forum
Clare Baker	LivelyHoods	Director of Development	Private Sector Forum
Timothy Ranja	SNV	Sector Leader, Energy	Private Sector Forum

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Annex 2: Detailed methodology – Supply

1. 1. Detailed methodology used to assess the required feedstock production and the projected investments over 10 years

The methodology below applies to the three feedstocks studied in this Master Plan.

Molasses-Based production

To determine the molasses production required to meet the projected levels of ethanol in Kenya, a two-step approach was adopted: (1) assessing the current level of sugarcane production (2) assessing the gap based on projected sugarcane required to produce ethanol.

The current sugarcane production in Kenya was calculated based on the average yield of sugarcane per hectare and the number of hectares harvested for sugarcane production from the *Year Book of Sugar Statistics, 2018*[107]. The data was confirmed by a stakeholder interview with the Kenya Sugar Directorate.

In order to assess the projected level of molasses, several conversion ratios were used (1) a conversion between ethanol and molasses (2) a conversion ratio between sugarcane and molasses and (3) a conversion ratio between sugar and molasses. These ratios were determined based on data from the *International Sugar Organization* (ISO), Vogelbusch Biocommodities and confirmed with stakeholder interviews with sugar and ethanol processors in Kenya (ACFC, KSAIL, and KISCOL).

Table 1: Conversion ratios used to estimate the required sugarcane production

Conversion ratio	Ratio	Source
Litres of ethanol/ton of molasses	312.5	Vogelbusch Biocommodities
Ton of sugarcane/ton of molasses	29	International Sugar Organization
Ton of sugar/ton of molasses	3	International Sugar Organization

107 From the Year Book of Sugar Statistics, the number of hectares harvested for sugarcane production is 73,080 and the yield of sugarcane is 60 Tons/Ha in 2018

In addition to the projected level of production, the number of hectares needed to be allocated for sugarcane production was projected based on the average yield per hectare[108].

Finally, the percentage of domestic sugarcane production required for ethanol production was estimated based on cumulative production data over 10 years assuming a constant growth rate. The growth rate was calculated based on a CAGR of sugarcane production from 1961 to 2017 in Kenya (3.94%).

Sugarcane juice pathway

In order to determine the projected level of sugarcane-based on direct cane juice required to produce ethanol, the following conversion ratio was used: 75 litres of ethanol/ton of sugarcane juice[109] . In addition to the projected level of production, the number of hectares needed to be allocated for sugarcane production was projected based on the average yield per hectare[110].

The methodology employed to estimate the CAPEX required for sugarcane production relies on the split between production from small-holder farmers and from large-scale sugar farms[111].

Only the CAPEX for large-scale sugar farm machinery was calculated. With no machinery to invest in for small-holder farmers, and aggregation costs falling under OPEX, they were not included in the calculation. Data was collected from KISCOL – the only mechanized plant in Kenya, and KSAIL. Below is the summary of the data collected from stakeholder interviews.

Table 2: Projected CAPEX required for large-scale sugarcane production

Type of Information	Data	Source
CAPEX per T of sugarcane produced (KES)	48	Stakeholder interviews with Kibos Sugar based on a production of 3500TCD and upfront CAPEX of USD 5M

Cassava based production

In order to assess the projected level of cassava production[112], several conversion ratios were used (1) conversion ratio between ethanol and cassava chips, (2) conversion ratio between cassava chips and cassava fresh roots. Data was gathered from a Kenyan fuel ethanol biorefinery Giraffe

[108] The average yield of sugarcane is assumed to be constant over 10 years and equal to 80T/Ha based on technology improvements and improved quality of crops
[109] Report of the Commission on Development of Biofuels, 2003
[110] The average yield of sugarcane is assumed to be constant over 10 years and equal to 80T/Ha based on technology improvements and improved quality of crops
[111] 70% of total sugarcane production is assumed to be sourced from small-holder farmers
[112] Unlike the methodology used for sugarcane production, the projected level of cassava production is not calculated as a differential with current production as cassava is not currently used to produce ethanol in Kenya

Bioenergy, from cassava-based ethanol production in Thailand[113] and confirmed with a stakeholder interview with the experts on cassava tubers and chips from the Ministry of Agriculture.

Table 3: Conversion ratios used to estimate the required cassava production

Conversion ratio	Ratio	Source
Litres of ethanol/ton of cassava chips (L/T)	388	Giraffe Bioenergy
Ton of cassava fresh roots/ton of cassava chip (T/T)	2.25	Analysis based on Thailand data collected on ethanol production

To project the number of hectares needed to be allocated for cassava production in Kenya, an assumption was taken on the average yield per hectare[114].

Additionally, the percentage of domestic cassava production required for ethanol production was estimated based on cumulative production data over 10 years assuming a constant growth rate. The growth rate was calculated based on a CAGR of cassava production from 1961 to 2017 in Kenya (1.72%).

The methodology employed to estimate the CAPEX required for cassava production relies on the split between production from small-holder farmers and from large-scale sugar farms[115]. The CAPEX for cassava production was calculated using a proxy-based on data collected from sugarcane production[116].

Based on the methodology described above, the projected gaps for different feedstocks were analyzed below.

Table 4: Analysis of the projected gaps for different feedstocks under scenario 1

	Molasses	**Cane juice**	**Cassava**
Quantity required to produce the projected amount of ethanol as a cooking fuel in Year 10 (MT)	5,257,149	766,706	333,458
Quantity currently used for ethanol as a cooking fuel (MT)	109,091	-	-
Gap (MT)	5,257,149	766,706	333,458

Table 5: Analysis of the projected gaps for different feedstocks under scenario 2[117]

[113] Kuiper L. et al (November 2007), Bio-ethanol from cassava, Ecofys [online] Available at: https://probos.nl/biomassa-upstream/pdf/FinalmeetingEcofys.pdf
[114] The average yield of cassava / hectare is estimated at 20T/Ha based on a stakeholder interview with the Ministry of Agriculture
[115] 70% of total cassava production is assumed to be sourced from small-holder farmers
[116] Due to the lack of large-scale cassava production in Kenya, no data could be collected
[117] Ibid

	Molasses	Cane juice	Cassava
Quantity required to produce the projected amount of ethanol as a cooking fuel in Year 10 (MT)	8,761,915	1,277,843	555,763
Quantity currently used for ethanol as a cooking fuel (MT)	109,091	-	-
Gap (MT)	8,761,915	1,277,843	555,763

Table 6: Analysis of the projected gaps for different feedstocks under scenario 3[118]

	Molasses	Cane juice	Cassava
Quantity required to produce the projected amount of ethanol as a cooking fuel in Year 10 (MT)	17,523,831	2,555,686	1,111,526
Quantity currently used for ethanol as a cooking fuel (MT)	109,091	-	-
Gap (MT)	17,523,831	2,555,686	1,111,526

As illustrated by the tables above, cane juice and cassava projections in Year 10 are equal to the gap, because no cane juice or cassava is currently allocated to ethanol processing in Kenya.

Based on the projected supply gaps, CAPEX required for feedstock production was analyzed.

Table 7: Projected CAPEX required for feedstock production under scenario 1

	Sugarcane	Cane juice	Cassava
No. of farms	2	1	1
Total CAPEX (KES)	7,583,874,006	1,106,036,928	1,616,603,387

Table 8: Projected CAPEX required for feedstock production under scenario 2

	Sugarcane	Cane juice	Cassava
No. of farms	4	1	1
Total CAPEX (KES)	12,639,790,010	1,843,394,880	2,694,338,978

Table 9: Projected CAPEX required for feedstock production under scenario 3

	Sugarcane	Cane juice	Cassava
No. of farms	8	1	1
Total CAPEX (KES)	25,279,580,020	3,686,789,759	5,338,677,956

2. Detailed methodology used to assess the required ethanol production and the projected investments over 10 years

A two-step approach was adopted (1) assessing the current level of ethanol production (2) assessing the gap based on projected ethanol production needed to meet demand.

[118] Ibid.

The current ethanol processing capacity was determined based on stakeholder interviews with ethanol processing companies in Kenya: Agro-Chemical and Food Company Limited (ACFC) and Kibos Sugar & Allied Companies (KSAIL). Below is a summary of the information collected from the stakeholders.

Table 10: Information gathered about the current production of ethanol for cooking purpose in Kenya

Type of information collected	Data	Source
Average capacity of an ethanol plant per year (L)	15,000,000	ACFC & Kibos Sugar
Average utilization rate of an ethanol plant (%)	80%	ACFC & Kibos Sugar
Percentage of ethanol used for cooking fuel (%)	5%	ACFC & Kibos Sugar

The CAPEX required for ethanol processing was estimated for each type of feedstock based on information gathered from suppliers of ethanol plants[119]. The investments required were calculated based on a 100KL per day plant producing only technical alcohol[120]. The investments required for sugar plants were calculated based on an average capacity of 90KT of sugar produced per year.

Table 11: Information gathered about the projected CAPEX for different types of ethanol plants

Type of information collected	Molasses-based plant	Cane-juice based plant	Cassava based plant	Source
CAPEX / ethanol plant (Million USD)	23	23	38	Praj industries
CAPEX / sugar plant (Million USD)	53		-	Kwale Sugar, ISGEC

3. Detailed methodology to assess the amount of ethanol distributed over 10 years

The ethanol required to be distributed was assessed along the different stages of the distribution value chain: (1) to the fuel stations, (2) within the fuel stations, (3) to the retail stores and (4) to the final consumers.

In order to estimate the projected ethanol distributed, the quantity of ethanol currently distributed was assumed negligible. The ethanol produced locally and imported were assumed to have the same distribution costs.

Data for each step of the distribution value chain was gathered from stakeholder interviews with Koko Networks. The number of additional tankers needed to be allocated to distribute ethanol over 10 years was calculated based on their capacity[121] and the estimated number of journeys per

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[119] Information collected from Praj Industries
[120] This Master Plan only studies 100KL plant ethanol plants (optimal size estimated from experts' interview). For other capacities of plant, additional studies will need to be conducted
[121] The capacity of a tanker is estimated at 30,000L (Source: Koko Networks)

year to the fuel stations[122]. Due to an excess of tankers in Kenya, no CAPEX was projected at this stage of the value chain. The number of smart depots per fuel station was estimated based on the maximum amount of ethanol distributed per fuel station[123]. The number of tankers delivering to the retail stores was calculated based on their projected capacities and the number of journeys per year[124]. The number of additional dispensers per retail store was estimated based on the saturation rate of a retail store[125].

CAPEX for ethanol distribution was estimated on a yearly basis and the total figure was determined based on a discount rate of 6.08%[126].

Data for each step of the distribution value chain was gathered from stakeholder interviews with Koko Networks. The number of additional tankers needed to be allocated to distribute ethanol over 10 years was calculated based on their capacity and the estimated number of journeys per year to the fuel stations. Due to an excess of tankers in Kenya, no CAPEX was projected at this stage of the value chain. The number of smart depots per fuel station was estimated based on the maximum amount of ethanol distributed per fuel station[127]. The number of tankers delivering to the retail stores was calculated based on their projected capacities and the number of journeys per year[128]. The number of additional dispensers per retail store was estimated based on the saturation rate of a retail store[129].

CAPEX for ethanol distribution was estimated on a yearly basis and the total figure was determined based on a discount rate of 6.08%[130].

[122] Assumption of 300 journeys per year per tanker
[123] The maximum amount of ethanol distributed per fuel station is 250,000L per month based on data collected from Vivo/Koko Networks (Source: Koko Networks)
[124] The capacity of a tanker delivering to a retail store is estimated at 4,500L (Source: Koko Networks)
[125] The saturation rate of a retail store is estimated at 5,000L/month (Source: Koko Networks)
[126] Damodaran, NYU Stern Database, capital costs per sector
[127] The maximum amount of ethanol distributed per fuel station is 250,000L per month based on data collected from Vivo/Koko Networks (Source: Koko Networks)
[128] The capacity of a tanker delivering to a retail store is estimated at 4,500L (Source: Koko Networks)
[129] The saturation rate of a retail store is estimated at 5,000L/month (Source: Koko Networks)
[130] Damodaran, NYU Stern Database, capital costs per sector

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