Baseline Report of Clean Cooking Fuels in the East African Community (EAC) Region

SUSTAINABLE ENERGY FOR ALL

AUSTRIAN DEVELOPMENT AGENCY

Republic of Rwanda

Ministry of Infrastructure

Disclaimers

ACKNOWLEDGEMENTS

This report was produced by a number of individuals and organizations including Project Gaia; Hilary Landfried, Brady Luceno Quinn Heist, Rebecca Moreland and Harry Stokes and commissioned by the United Nations Industrial Development Organization (UNIDO). Special thanks go to the consultants hired for the project, including Uganda country consultant Richard Kiggundu, Tanzania country consultant Francis Songela, Rwanda country consultant Hellen Owala, Burundi country consultant Leonard Akwany, Kenya country consultant Vincent Okello, Ethiopia country consultants Wubshet Tadele, Desalegn Getaneh, and Dereje Petros and International Feedstock Expert, John Loke. Special thanks go to Green Social Bio ethanol, Lia Lichtenberg (UNIDO), Kolade Esan (UNIDO) and Jossy Thomas (UNIDO) for contributing and reviewing this report. Also, Jayaraj Manepalli for editing the report.

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List of Abbreviations

AfDB	Africa Development Bank
AFREA	Africa Renewable Energy Access Program
ARGeo	African Rift Geothermal Development Facility
ARTI	Appropriate Rural Technology Institute
AU	African Union
BEETA	Biomass Energy Efficient Technologies Association
BEST	Biomass Energy Strategy
BLT	Branches, Leaves and Twigs
BMZ	German Federal Ministry for Economic Cooperation and Development
BOT	Bank of Tanzania
CADESE	Capacity Development in the Energy Sector and Extractive Industries
CAMARTEC	Centre for Agricultural Mechanization and Rural Technology
CCFAT	Clean Cook stoves and Fuels Alliance of Tanzania
CEDP	Cassava Enterprise Development Project
CET	Common External Tariff
CID	Criminal Investigations Department
CIRCODU	Centre for Integrated Research and Community Development Uganda
CO_2E	Carbon Dioxide Equivalent
COMESA	Common Market for Eastern and Southern Africa
COSTECH	Commission for Science and Technology
CREEC	Centre for Research in Energy and Energy Conservation
CRGE	Climate Resilient Green Economy
DBE	Development Bank of Ethiopia
EA	East Africa
EAC	East African Community
EDPRS II	Second Economic Development and Poverty Reduction Strategy
EnDev	Energising Development
ESCAE	Ethiopian Standards and Conformity Agency
EUEI – PDF	European Union Energy Initiative Partnership Dialogue Facility
EWURA	Energy and Water Utilities Regulatory Authority
FAO	Food and Agricultural Organization of the United Nations
FDI	Foreign Direct Investment
FINCA	Foundation for International Community Assistance
FONERWA	National Climate change and environment fund
GACC	Global Alliance for Clean Cookstoves
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
GIZ	German Technical Cooperation Agency

GoT	Government of Tanzania
GTP	Growth and Transformation Plan
GVEP	Global Village Energy Project
Ha	Hectares
HAP	Household Air Pollution
HoAREC	Horn of Africa Regional Environment Center & Network
ICCO	Inter-Church Organization for Development Cooperation
ICS	Improved Cookstoves
ICT	Information and Communication Technology
IEA	International Energy Agency
IGAD	Inter-Governmental Authority on Development
IP	Investment Plan
ISTR	Institute of Scientific and Technology Research
JADF	Joint Action Development Forum
JEEP	Joint Energy & Environment Projects
km^2	Square kilometers
kWh	Kilowatt hour
LAPSSET	Lamu Port Southern Sudan Ethiopia Transport Corridor
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
m^3	cubic metre
MAFC	Ministry of Agriculture, Food Security & Cooperatives
MEM	Ministry of Energy and Minerals
MEMD	Ugandan Ministry of Energy and Mineral Development
MeS	Mkonge Energy Systems Ltd.
MINECOFIN	Ministry of Economic and Finance
MINERENA	Ministry of Natural Resources and Environmental Management Authority
MININFRA	Ministry of Infrastructure
MNRT	Ministry of Natural Resources and Tourism
MoF	Ministry of Finance
MOU	Memorandum of Understanding
MoWIE	Ministry of Water, Irrigation and Energy
MSE	Mtibwa Sugar Estate
MT	Metric Ton
MW	Megawatt
NAIVS	National Agricultural Input Voucher Scheme
NBP	National Biogas Program
NBS	National Bureau of Statistics
NEMC	National Environment Management Council
NFA	Ugandan National Forestry Association
NGO	Non-Governmental Organization

NIS	National Institute of Statistics
NTB	Non-Tariff Barrier
NUR	National University of Rwanda
OMC	Oil Marketing Companies
OSBP	One Stop Border Post
PIC	Petroleum Importation Coordinator
PoA	Program of Activities
PPP	Public–Private Partnership
PREEEP	Promotion of Renewable Energy and Energy Efficiency Program
PSI	Policy Support Instrument
REA	Rural Energy Agency
REC	Regional Economic Cooperation
RECP	Africa-EU Renewable Energy Cooperation Programme
REG	Rwanda Energy Group
RETs	Renewable Energy Technologies
RURA	Rwanda Utilities Regulation Agency
RWF	Rwandan Frank
SADC	Southern Africa Development Cooperation
SCT	Single Customs Territory
SDGs	Sustainable Development Goals
SE4ALL	Sustainable Energy for All
SLCP	Short-Lived Climate Pollutants
SMEs	Small and Medium Enterprises
SNNP	Southern Nations, Nationalities and People
SNV	Netherlands Development Organization
SPPA	Standardized Power Purchasing Agreement
TANESCO	Tanzania Electricity Supply Company Ltd.
TANWAT	Tanganyika Wattle Company (Njombe Region)
TAREA	Tanzania Renewable Energy Association
TaTEDO	Tanzania Traditional Energy Development and Environment Organization
TBS	Tanzania Bureau of Standards
TDBP	Tanzania Domestic Biogas Program
TFRA	Tanzania Fertilizer Regulatory Authority
ToR	Terms of Reference
TPC	Tanganyika Planting Company (TPC)
TPDC	Tanzania Petroleum Development Corporation
TRA	Tanzania Revenue Authority
TZS	Tanzania Shillings
UNACC	Ugandan National Alliance on Clean Cooking
UNDP	United Nations Development Programme
UNEP	United Nations Environment Program

UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USGS	United States Geological Survey
USD	United States Dollar
VAT	Valued Added Tax
WB	World Bank
WHO	World Health Organization
WWF	Worldwide Fund for Nature

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Executive Summary

Ethanol fuel production represents one of the significant opportunities for economic and social development in the East African Community (EAC) partner states. Ethanol can be produced locally using a variety of feed stocks that can be selected according to the specific local conditions and availability. Farmers can grow fuel feed stocks along with food crops to gain access to a second market and diversify their incomes. Large- and small-scale distilleries can be set up to produce ethanol, which can be sold as cooking fuel, transportation fuel, or as fuel for small scale power generation systems. Economic opportunities can be generated along the value-chain from growing crops to fuel production and sale, embracing activities from the manufacture and marketing of stoves to the distribution and retailing of fuel. Furthermore, by adopting ethanol as a household fuel, fuel energy production will move from the forest to the farmer's field, that is to say, from the cutting of wood to the growing of high yielding biomass crops that could be harvested several times in a year. More biomass can be grown and processed into a cleaner and easily combustible fuel, leading to a reduced use of firewood and charcoal production, thereby reducing the pressure on forests. Families will have healthier homes and environment with cleaner air quality.

For successful ethanol production and cookstove projects, it is necessary to have government support that fosters a regulatory environment suitable for producing, selling, distributing and regulating ethanol as a fuel. In many countries, ethanol is heavily taxed as it is classified as an alcoholic beverage in their laws, some of which continue to exist as a colonial legacy. No special tax treatment or incentives exist for ethanol as a fuel. Several of the countries included in this report have begun to adopt new policies and regulations to promote ethanol fuel production and lessen the tax burden on producers and consumers. Ethiopia is increasing production (of ethanol) over the next five years in order to use all of the waste molasses generated in its sugar industry. The Kenyan government recently passed a law that allows a tax exemption on ethanol used for cooking. Kabuye Sugar Works in Rwanda is expanding its production capacity and is including ethanol in its expansion plans. Although progress is being made to develop ethanol as an alternative clean cooking fuel, more work must be done with governments to encourage them to develop supportive tax structures for promoting ethanol as a clean cooking fuel and create standards for quality of ethanol fuel for clean cookstoves as well as for other purposes such as automotive fuel blending. This report reviews the five EAC partner states plus Ethiopia, and examines the market potential of ethanol fuel, current and projected fuel production, government policies that may affect the production and sale of ethanol for cooking and the potential for developing small-scale micro distilleries for producing ethanol.

Several types of feedstocks were reviewed, including molasses from sugarcane, damaged or unsaleable roots, tubers, and fruits, unsold produce from vegetable and fruit markets, uncollected fruit drops below mango trees (*Mangifera indica*), sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*), taro (elephant ear, *Xanthosoma*), melon (*Cucumis melo*), sugarcane (*Saccharum officinarum*) and sweet sorghum (*Sorghum bicolor*). These feedstocks were selected based on their suitability for the EAC region and current production in the countries examined. These do not represent a complete or exhaustive list of feedstocks; the list of potential feedstocks is much longer. But the feedstocks selected for examination do show the diversity of what is available. Molasses, a byproduct from sugar industry is one of the best feedstocks to use in either large- or small-scale ethanol fuel production plant. In all of the surveyed countries, molasses is currently a waste product that is either dumped or used as livestock feed, although to a lesser extent in Kenya. However, in places where sugar production exists, the quantity of molasses produced greatly exceeds the requirement for livestock feed. Many of the other feedstocks examined are best suited for small-scale ethanol production plant that could be located close to the source of the feedstock. Small-scale ethanol production is uniquely suited for the use of crops and plant materials that are wasted, do not make it to market, or are not currently utilized. This is because the small ethanol plant can be scaled to the size of the feedstock supply, can be located on a small footprint, and represents a relatively modest investment in equipment and machinery.

This report recommends a project to begin with a micro distillery in the range of 1,500 to 5,000 litres per day. While smaller projects may be feasible under the right conditions, this size, while still small, allows the operation to be monetized by a not insignificant output. A distillery of 1,500 litres per day will support cooking for up to 2,000 households. This represents a meaningful customer base and the potential for good daily revenues. Size of the plant should ultimately depend on the feedstocks available, the reliability of their supply, the market that has been developed for the fuel, the financing available, and the capacity of the project owners/operators who will be running the distillery, selling its products and managing the business.

The United Nations Industrial Development Organization commissioned this study following a successful pilot study conducted in 150 households in Zanzibar from 2014-2015. The pilot study demonstrated that ethanol produced from the Zanzibar Sugar Factory was a preferred cooking fuel to charcoal and kerosene and could be competitive in the market.

1. INTRODUCTION

Each day, three billion people cook their meals using polluting biomass fuels, including fuelwood, charcoal, dung and agricultural residues. This causes vast public health, environment and global climate change issues. According to the World Health Organization (WHO), over four million people die each year from diseases caused by Household Air Pollution (HAP) from the smoke emanating from the biomass-based cooking stoves. The reliance on biomass for cooking leads to large-scale deforestation and high opportunity costs for the women who must gather fuel for these stoves. Furthermore, biomass cookstoves emit carbon dioxide, methane, black carbon, and other Short-Lived Climate Pollutants (SLCPs) into the atmosphere hastening climate change. Residential solid fuel burning accounts for 25 per cent of black carbon emissions, 84 per cent of which are from the developing countries. Black carbon is a more potent Green House Gas (GHG) when compared to carbon dioxide and is estimated to contribute the equivalent of 25 per cent to 50 per cent of carbon dioxide warming globally (Global Alliance for Clean Cookstoves, 2015).

Providing biomass cookstoves with a cleaner alternative fuel is not only a solution to these health, social and environmental issues, but also presents an opportunity for economic growth and poverty reduction. Ethanol is a clean fuel and uniquely suited for household use. When used properly, ethanol cannot explode, burns clean and efficiently and helps reduce cooking time. Ethanol can be stored safely in a home environment when denatured with denatonium benzoate (a bittering agent) and a dye. This denaturing protocol makes the fuel unpalatable and impossible to mistake for water. By transitioning to ethanol for cooking and household energy use, families are healthier and many opportunities for employment are created throughout the stove and fuel value-chain.

There are opportunities for livelihood generation in the construction, distribution and sale of ethanol stoves. Employment can also be created in the distribution and sale of fuel. Perhaps the greatest opportunity for job creation is in the cultivation of feedstocks and their conversion into ethanol. Agriculture is the backbone of many developing countries. In Africa, agriculture employs 65 per cent of the labour force and accounts for 32 per cent of the gross domestic product (World Bank, 2015). According to the Food and Agriculture Organization of the United Nations (FAO), gross domestic product (GDP) growth in agriculture is at least two times more effective in reducing poverty compared to the growth originating in other sectors (FAO, 2015). Agriculture has an important role to play in development; it represents (1) economic activity, (2) livelihood creation, and (3) a provider of environmental services (Bogdanski, FAO, 2010). With integrated food and energy systems, agriculture can also provide crucial sources of energy through the production of ethanol (World Bank, 2015).

Improving the productivity, profits and sustainability of smallholder farmers is one of the best ways to fight rural poverty. Ethanol provides a significant opportunity for farmers by generating a second market for crops or a new market for agricultural wastes. Furthermore, locally produced fuel can provide rural communities and their urban neighbours with much needed energy for cooking, lighting, refrigeration and power generation.

It should be emphasized that there are plenty of wasted or under-utilized sugar and starch feedstocks available for ethanol production. These include molasses from the sugar industry, cassava that does not reach the food chain, agricultural co-products and by-products and other crops of interest that grow abundantly in the wild and are available for use. Some examples are prickly pear cactus, Opuntia—a nuisance plant in many localities, unharvested tree fruits and other wild plants high in sugar or starch. Other feedstocks of interest are deep-rooted plants suitable for land reclamation and wastes from rural fields or urban markets. (Gustavsson, et al., FAO, 2015). Enzymes can be selected to extract high yields of sugar to ethanol from these types of feedstocks. These feedstocks can be utilized in large- or small-scale distillation processes.

There are benefits and downsides of both large-scale (more than 5,000 litres per day) and small-scale ethanol (1,000-5,000 litres per day) production. Large-scale biofuel distilleries achieve substantial economies through advanced equipment that can convert sugar, starch, or cellulose into ethanol more efficiently; industrialized agriculture that produces more feedstock per hectare; access to inputs such as fertilizers or irrigation; and a higher degree of mechanization in the fields and factory, which reduces labour costs. However, large-scale biofuels production requires large areas of land, which can be particularly burdensome in areas of Africa where land holdings are small and divided among subsistence farmers and their families. Large distilleries also often rely on monoculture crops and the selection of certain crops that may not be suited to the region.

Approximately one third of all food produced for human consumption is lost or wasted around the world. This represents about 1.3 billion tons of food waste per year

Small-scale distilleries can take advantage of the existing waste or underutilized feedstocks that could be made available for use without the need to grow or supplement with new or larger quantities of feedstocks. Also, small-scale production can be sized to the land available, and can serve—and be owned by—a farmers' cooperative or by local landowners and business owners, because the equipment represents a manageable and financeable investment.

Small-scale processing unit, when integrated into a community provides a new and a readily accessible local market for farmers who might otherwise not have a market or have a limited market for their crops. The loss of markets has been responsible for the migration of farmers and their families to cities and the abandonment of arable lands—which may then lie fallow for a generation or more, or until market forces change. Farmland that is left fallow and uncared for, often deteriorates as a result of wind and water erosion or the introduction of invasive species, which becomes too costly and difficult to clear.

Although small-scale distillation may be ideal for rural communities and subsistence farmers, efforts must be made to make the system as efficient as possible. The cost of operating a micro distillery can quickly rise if the distillery is not located close to the feedstock source or if the feedstock is expensive. Costs can also accumulate due to inefficient boilers that utilize [purchased] fuels, or if the feedstock requires a large amount of water during the fermentation process. These added energy-input costs will affect the final price of fuel and may make the cost prohibitive for consumers.

Choosing appropriately-sized distillation equipment is imperative to ensuring the sustainability of a cookstove fuel business. The following factors should be taken into consideration when choosing between small or large-scale distillation:

(1) Selected feedstock variety – Where feedstocks are available in abundance, large-scale distillation will have an advantage through significant economy of scale. Where feedstocks are available in smaller quantities but are waste products or cheap commodities, small-scale distillation may be a valuable outlet for these resources.
(2) Feedstock price – The price of the feedstock will greatly affect the price of the final product at the end of the distillation process. Price considerations and price fluctuations of particular feedstocks should be considered in order to ensure a competitive end product.
(3) Proximity to feedstock producers – Micro distilleries must be located close to their feedstock source to keep transportation costs at a minimum. Some feedstocks also have a short time window--from the time of harvesting to the time they must be fermented.
(4) Current costs of cooking fuel – Should distilleries target the home cooking market for their ethanol supply, the cost of production and necessary mark-up for profit must still allow ethanol to be competitive with other fuels.
(5) Price of equipment – Large-scale equipment for distillation represents a higher upfront capital investment, however the payback period may be shorter depending on feedstock selected and quantity of end-product that could be sold. A cost-benefit analysis is recommended when contemplating the upfront technology costs between large and small-scale equipment.

Ethanol Myths

Ethanol is often overlooked as a clean, renewable energy source. However, it offers unique benefits as part of a renewable energy matrix due to its ease in transportation and safe handling. Many of the concerns regarding ethanol are based on old data or faulty assumptions. It is important to address these issues to demonstrate that if produced with sustainability in mind, ethanol is a choice fuel for developing markets.

Food versus Fuel:

A big misconceptions regarding biofuels is that the production of ethanol causes food prices to rise and takes food out of the mouths of the hungry (Searchinger and Heimlich, 2015). What this fails to recognize is that, if done correctly, food and fuel productions are not mutually exclusive and can be produced together (Urbanchuk, 2013). José Graziano de Silva, Director-General of the FAO said, "Given the right conditions, biofuels can be an effective means to increase food security by providing poor farmers with a sustainable and affordable energy source" (Silva, et.al, 2015).

Box. 1 Common Myths

> **COMMON MYTHS RELATED TO ETHANOL**
>
> Myth: *Ethanol causes rise in food prices and causes food shortages*
> Reality: No. If cultivation is done correctly, food and fuel production are not mutually exclusive and can be produced together. In fact, given the right conditions, biofuels can be an effective means to increase food security by providing poor farmers with a sustainable and affordable energy source
>
> Myth: *Ethanol production utilizes a large quantity of water*
> Reality: In the 1990s and early 2000s, a good deal of water was needed to produce one litre of ethanol fuel (17 litres water for 1 litre of ethanol). However, because of research, development and technological advancement, current methods have greatly reduced the amount of water used in ethanol production (2.6 litres water for 1 litre of ethanol).
>
> Myth*: Ethanol production affects water meant for agriculture*
> Reality: About 90 per cent of the land producing corn for ethanol in the United States is rain-fed and does not require irrigation. Feedstocks are varied and diverse, and thus can be chosen depending on water availability. This means that local crops can be chosen based on what grows naturally and without a need for irrigation.

Land can be used for more than one output and the technologies involved in increasing the efficiency of agricultural products is one of the best chances of ensuring both food and energy in the future. A recent FAO report on integrated food and energy systems states that, "producing food and energy side-by-side may offer one of the best formulas for boosting countries' food and energy security while simultaneously reducing poverty"(Uktina, FAO, 2011). While the primary market for farmers is food, by opening up a secondary fuel market, farmers can experience more job reliability and a greater income. By fully integrating fuel production in with food, struggling farmers gain extra income, allowing them to purchase more land, invest in machinery and purchase fertilizers. Diversifying markets for farmers ensures a stable system of food production.

The food vs. fuel debate assumes that all agricultural material used to create biofuels is fit for human consumption. Biofuels can also be made from waste products, like overripe fruits or by-products after the edible sections of the products have been removed. By using material that would otherwise be discarded, fuel can be made with no impact on food production (Christakopoulos, 2014) .

Farmers in developing markets often have access only to inefficient shipping networks and usually must go without refrigeration. About 40 per cent of food is lost in developing countries before it can reach the market (FAO, 2015). This waste can be used in efficient micro distillery systems that are located close to the farmers' fields. Currently, the cost of food is largely connected to the cost of oil. According to a World Bank Report, more than 50 per cent of food price increases are due to oil prices (Baffes and Dennis, 2013). In some inland African countries, gasoline costs three times the global average (Silva, et.al.,). By producing ethanol close to farmers' fields, the cost of transportation can be avoided and ethanol could be used for a number of purposes: cooking, transportation, generating electricity and refrigeration. Ethanol will stimulate local markets and reduce dependence on foreign oil.

Flexibility is the key to embracing both biofuels and agricultural productivity while ensuring food security and continuing sustainable development. Policymakers can address the perceived competition between food and fuel by designing ways to better control price fluctuation in agricultural products. For example, certain feedstocks could be regulated depending on varying agricultural production. When production is high, regulation could allow for ethanol production from food crops. When the crop production is low, regulations could require that ethanol be produced from waste products alone.

Malnutrition is not caused solely by lack of food. Energy poverty has a large impact on the people's ability to cook the food they desperately need. Many food products require cooking or baking and due to lack of fuel or high fuel prices, many people reduce the amount of meals they eat or go hungry (IEA, 2015).

In the 1990s and early 2000s, a good deal of water was needed to produce one litre of ethanol fuel. However, because of research, development and technological advancement, current methods have greatly reduced the amount of water used in ethanol production.

POET, the leading ethanol producer in the United States, averaged 17 litres of water per litre of ethanol in 1987 but today, their plants average 2.6 litres of water per litre. For corn ethanol, water consumption rates have dropped within the last ten years from an average of 6.8 litres/litre to 3.0 litres/litre. To put this in context, it currently requires about 34 litres of water to produce a can of vegetables, a substantially larger amount than a litre of ethanol (Schoenhorn, 2012). A 2007 National Academy of Sciences report noted, "consumptive use of water is declining as ethanol producers increasingly incorporate water recycling and develop new methods of converting feedstocks to fuels that increase energy yields while reducing water use".

Water use in crop irrigation is similarly over estimated. About 90 per cent of the land producing corn for ethanol in the United States is rain fed and does not require irrigation. This is in addition to the fact that one acre of corn gives off 4,000 gallons of water per day according to USGS, contributing to rain that eliminates the need for further irrigation. Feedstocks are varied and diverse, and thus can be chosen depending on water availability. This means that local crops can be chosen based on what grows naturally and without a need for irrigation.

Most of the information available regarding the use of water focuses on the utilization of water in industrial production of corn ethanol in the United States. However, more information is being developed regarding the use of water at micro distilleries for alternative feedstocks. Green Social Bioethanol, a micro distillery provider based in Brazil, has built small-scale 2,500 litre-per day distilleries in Guyana, Brazil, and Nigeria. According to them, 19.24 litres of water is required to produce one litre of ethanol from cassava; 4.54 litres of water is required to produce one litre of ethanol from sugarcane; and 14.46 litres of water is needed to produce one litre of ethanol from molasses.[11]
It is also possible to use supplemental feedstocks that possess a high water content to reduce the amount of water needed for dilution in the fermentation phase.

Ethanol also presents other benefits for water use and conservation. It is non-carcinogenic, nontoxic, and rapidly biodegrades when spilled, leaving groundwater and oceans free from harm, should accidents occur (Jehlik, 2011). Furthermore, using ethanol reduces climate-altering gases and thus is a solution to acid rain and desertification, which greatly threatens the planet's water supply.

Report Structure

This report explores the opportunity for both small and large-scale ethanol production for household energy use in the EAC region including Burundi, Kenya, Rwanda, Tanzania and Uganda**.** This region is particularly suited for the production and use of ethanol for cooking due to its demonstrated demand for clean fuels and strong agricultural sectors. The newest member state South Sudan is not included in the study.

[1] Bruno Mallmann, email message with Project Gaia, 1 September 2015.

The report is divided into three sections. The first section provides an overview of the opportunity for ethanol in the EAC region, presents baseline information on the current household energy market, explores current and planned government policies that may affect the production and sale of ethanol fuel, and lists current ethanol production capacities in each country.

The EAC region is particularly suited for the production and use of ethanol for cooking due to its demonstrated demand for clean fuels and existing strong agricultural sectors.

The second section provides information on the feedstocks that would be best suited for ethanol production based on the current agricultural and market forces in the region.

The final section suggest recommendations on developing distilleries and ethanol cooking programs in the EAC region. The country specific sections were researched and written by local consultants with expertise in clean energy, alternative energy, cookstoves, and related issues in their selected country. An international feedstock expert specializing in tropical agriculture was responsible for the feedstock profiles and assisted in formulating recommendations for developing successful and sustainable ethanol cooking fuel distillery programs.

2. OVERVIEW OF THE EAST AFRICA COMMUNITY (EAC) REGION

Geographically, East Africa is made up of 13 Sub-Saharan countries of Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Seychelles, Somalia, Sudan, Tanzania, Uganda, and the Republic of South Sudan. Within East Africa, there are two subgroups, including the Horn of Africa-made up of Somalia, Djibouti, Eritrea, and Ethiopia and the East African Community (EAC) comprising of Kenya, Tanzania, Uganda, Rwanda, South Sudan and Burundi.

Figure 1: Map of East African Community (EAC)

Image Courtesy: Deutsche Welle

The three original members of the EAC, Kenya, Uganda and Tanzania enjoyed co-operation under successive regional integration arrangements for many years prior to the formation of the EAC. This began with the Customs Union between Kenya and Uganda in 1917, which Tanzania, then known as Tanganyika, later joined in 1927. Thereafter, the three countries together formed the East African High Commission (1948-1961), and then the East African Common Services Organization (1961-1967). These three states finally formed the East African Community in 1967 and later the East African Co-operation (1993-2000). In 2001, Rwanda and Burundi joined the EAC as well, while South Sudan is the newest member that joined the EAC in 2017.

During the last decade, the EAC in its present form, comprising of Burundi, Kenya, Rwanda, South Sudan, Tanzania and Uganda, has become one of the most integrated regional markets in Africa, with an existing Customs Union and a Common Market. The EAC is now moving towards a Monetary Union with the Protocols for the Establishment of the EAC Monetary Union signed in 2013. This aims for the member states to progressively converge their currencies into a single currency in the Community.

The EAC as a region has also shown other remarkable achievements: it is the fastest growing region in Sub - Saharan Africa with an average GDP growth of 5.8 per cent during the last decade (EAC, 2013). Furthermore, it is one of the largest regional economic blocs in the African continent with a population of 149.7 million (2016) and a combined GDP of US$98 billion. The Foreign Direct Investments (FDI) inflow into the EAC region has tripled from US$1.3 billion in 2005 to US$3.8 billion in 2012. Therefore, the EAC partner states present ample investment opportunities in various sectors from agriculture to manufacturing, tourism, financial services, and information and communications technology (ICT).

Box 2. Why Invest in the EAC?

The EAC has a population of 149.7 million, with average annual growth rate remaining at 2.6 per cent over the last three years. This presents a significant regional market for trade and investments. There are a number of factors that distinguish the EAC as an investment opportunity when compared to other regions:

- *A growing middle class with an increasing demand for fairly sophisticated products*
- *Diversified economy offering a variety of business and investment opportunities*
- *Business-friendly environment*
- *Stable economic and political environment*
- *Harmonized tariff structure within the EAC*
- *Great market access to Africa, the Middle East and Asia, and a preferential market access to the United States, the European Union and some other developed countries*
- *English as an official business language*
- *A relatively large pool of educated and skilled workers*

Box 3. Impact of economic integration of the EAC

- *Establishment of the East African Community Customs Union*
- *Establishment of the East African Community Common Market*
- *Convertibility of the currencies of Kenya, Tanzania and Uganda*
- *Capital markets development and cross-listing of stocks*
- *Joint infrastructure development projects (e.g. Arusha-Namanga-Athi River Road)*
- *Harmonization of the EAC axle load (vehicle weight) limit*
- *Harmonization of standards for goods produced in East Africa*
- *Reduction of national trade barriers*
- *Implementation of preferential tariff discounts*
- *Free movement of goods*

- *Harmonizing the operations of Ministries of Finance and Central Banks during national budget preparation and presentation*
- *Mutual recognition of health certificates issued by national bodies for goods traded in EAC*

Besides the economic cooperation block, there are a number of other significant integrational initiatives that have already succeeded, further unifying the region. These include initiatives to increase the mobility of the labour force (such as the operationalization of the East African passport, which grants the holder a six month multiple-entry visa in the region, and the harmonization of procedures for granting work permits), political, defence and security pacts (such as establishment of a forum for Chiefs of Police, Directors of Criminal Investigations Departments (CID), and Directors of Operations and Intelligence, which allow them to coordinate peace and security matters, carry out joint patrols, share criminal intelligence and conduct joint surveillance to combat cross-border crime), and the establishment of key regional institutions such as the East African Legislative Assembly and the East African Science and Technology Commission.

Box 4. African Development Bank's priority areas in the EAC

The African Development Bank's (ADB) targeting on a number of key improvements in regional transport and trade infrastructure—which further enhances economic opportunity in the EAC.

- *Addressing equipment shortages in the regional railway system*
- *Improving regional seaports in Mombasa and Dar es Salaam*
- *Improving water and air transportation to island countries*
- *Design and construction of One Stop Border Posts (OSBPs) along the transport corridors to help reduce waiting time at the borders and lower transport cost*
- *Construction of regional interconnectors that will focus on missing links in the transportation system to enhance regional connectivity. Together with the ongoing projects (Ethiopia-Djibouti, Ethiopia-Sudan and Kenya-Uganda-Rwanda) and the Sudan-Eritrea Interconnector project scheduled to open by 2015, all countries in Eastern Africa will be interconnected except Somalia.*
- *Increased green energy generation that will include hydropower, wind, solar, and geothermal energy*

Green Energy:

The prospects for green energy generation are especially encouraging. The East Africa region has more than 15,000MW of geothermal power potential, located primarily in the Rift Valley areas. The untapped energy potential for the latter is estimated at more than 7,000 MW of electric power.

Geothermal prospects abound in Djibouti, Ethiopia, Kenya, Rwanda, Tanzania and Uganda. It is currently under-exploited due to a number of challenges, including:

- Lack of an enabling policy, legal and regulatory framework that would attract investment into the region
- Colossal start-up investment outlays for geothermal exploration and development, and
- Risks inherent with resource exploration and power development projects]]

The African Rift Geothermal Facility (ARGeo) was established by the United Nations Environmental Program (UNEP), The Global Environmental Facility (GEF), the African Development Bank (ADB), several African countries, and international aid agencies to promote development of geothermal resources in the region.

Environmental richness:
East Africa is well-endowed with a variety of ecosystems that are of great economic value and also provides habitat for a wide range of species.

The Kenyan coastline is characterized by a rich diversity of flora and fauna, including fish, coral reefs, and mangrove forests. The range lands are composed of a number of different habitats ranging from open grasslands to closed woody and/or bushy vegetation with varying amounts and composition of grass cover.

Rwanda's location at the heart of the Albertine Rift Eco-Region in the western arm of Africa's Rift Valley makes it one of Africa's most biologically diverse regions. It is home to some 40 per cent of the continent's mammal species (402 species), a huge diversity of birds (1,061 species), reptiles and amphibians (293 species), and higher plants (5,793 species).

Burundi has 13 protected areas covering 100,000 hectares of land. About 172,000 hectares (or 6.7 per cent) of Burundi is forested. These ecosystems harbour 2,500 higher plant species, 145 bird species, 107 mammal species, 79 reptile species, 18 amphibian species, and 5 fish species.

Tanzania has a diverse spectrum of fauna and flora, including a wide variety of endemic species and sub-species. The biological abundance of this region includes primates (20 species and 4 endemic), antelopes (34 species and 2 endemic), fish (with many endemic in Lakes Victoria, Tanganyika, and Nyasa, as well as other small lakes and rivers), reptiles (290 species and 75 endemic), amphibians (40 endemic), and plants (around 11,000 species including many endemic).

Uganda also has a rich array of natural resources which include water and wetlands, biodiversity, fisheries, forestry, land resources, wildlife, and minerals, among others. The country has more than 5,000 plant species along with 345 mammals, 1,015 birds, 165 reptiles, and 43 amphibians.

Water Resources:

The distribution of water varies significantly within the region. The region has four major aridity zones: moist sub-humid mainly in Uganda, Rwanda and parts of Burundi, dry sub-humid (parts of Uganda, western Tanzania), semi-arid (parts of Tanzania) and arid, most of Kenya. The western component of East Africa, including Burundi, Rwanda and Uganda, are considered rain surplus, while large parts of Kenya have a very large water deficit.

The three most notable water bodies and systems of relevance to the EAC include:

(1) Lake Tanganyika - the greatest single reservoir of fresh water on the continent and second deepest in the world.
(2) The Nile River Basin - source of the Nile, the longest river in the world
(3) Lake Victoria - Africa's largest lake and the world's second-largest freshwater lake

Economic Significance of Lake Victoria

Lake Victoria is the focus of new attention following the declaration by the East African Community Heads of State that a joint program be developed for the overall management and rational utilization of the shared resources of the Lake. The EAC has designated Lake Victoria and its basin as an "area of common economic interest" and a "regional economic growth zone" to be jointly developed by the Partner States. With a surface area of 68,800 km^2 and an adjoining catchment of 184,000 km^2, it is the world's second largest body of fresh water, and the largest in the developing world. It is the most significant and single largest environmental determinant in the EAC region.

Kenya, Tanzania and Uganda control 6, 49, and 45 per cent of the lake surface area respectively. The gross economic product of the lake catchment is in the order of \$3-\$4 billion annually, and supports an estimated population of 25 million people at incomes in the range of \$90 and \$270 per capita per annum.
The lake catchment area thus provides for the livelihood of about one third of the combined populations of the three countries, and about the same proportion of the combined gross domestic product. With the exception of Kampala, the lake catchment economy is principally an agricultural one, with a number of cash crops (including exports of fish) and a high level of subsistence fishing and agriculture.

In Kenya and Uganda, the coffee and tea plantations in the catchment area are a significant part of their major agricultural imports. Although it is not possible to precisely and unequivocally estimate the monetary value of the lake in sustaining the regional economy, its vital importance can be understood when one considers that any deterioration of Lake

Victoria that leads to a five per cent reduction in productivity of the region would result in consequent losses in the order of $150 million annually.

Crucial regional issues

It is clear that the region has significant volume of water and that it could be enhanced by the preservation and restoration of the region's water towers. However, to achieve water security, there is a need to address important policy issues regionally, including:

- Though water resources are available, they are not evenly distributed nationally and regionally
- Access to water is critical; water storage and transportation is currently not sufficiently developed to deal with the scale of regional water availability, shortcomings are further emphasized during natural disasters such as drought
- Water quality is declining significantly, mainly as a result of human activity in both the catchment areas and river basins
- Sedimentation and siltation are exacerbated by increasing deforestation; pollution occurs as a result of untreated industrial, domestic wastewater and solid waste as well as boat discharges; high levels of eutrophication and anoxia occur as a result of agricultural run-off and domestic wastewater and solid waste discharge
- Lake Victoria is relatively shallow with high rates of evaporation and almost completely reliant on rainfall thus pollution can be concentrated within the lake
- Lake Tanganyika is already anoxic beyond a depth of 35m and most importantly as a closed basin, water and pollution are long-lived; it takes approximately 7,000 years for water to be flushed from the lake

The main challenges to achieving water security are, therefore:

- The destruction of the ecosystems underpinning the region's water towers
- The lack of physical infrastructure to store and transport water from areas of high availability to those of low availability
- High population density that continues to increase above the continent's average
- Poor waste management
- High rates of evaporation particularly of Lake Victoria
- Lack of systematic knowledge, data and monitoring of groundwater aquifers

EAC Economy: Customs Unions and Common Markets

East Africa has the largest number of Regional Economic Cooperation (RECs) and intergovernmental regional bodies in Africa (Africa Development Bank, 2011). The EAC entered into a full-fledged Customs Union in January 2010 and commenced the implementation of the Common Market in July 2010. It provides for "Four Freedoms", namely the free movement of goods, labour, services, and capital, which will significantly boost trade and investments, make the region more productive and prosperous, and simply enable the free movement of people, capital and services, and abolish import duties. The eight other countries in East Africa are members of six of the eight RECs recognized by the African Union (AU), with most of them belonging to one or more of the 24 regional intergovernmental organizations, notably the Indian Ocean Commission (IOC) and the Inter-Governmental Authority on Development (IGAD), that also have a strong influence on the regional integration process. This multiple membership feature is counterproductive and often results in duplication of resources and conflicting goals and policies. The Common Market for Eastern and Southern Africa (COMESA) and Southern African Development Community (SADC) have formed a Tripartite Arrangement with the EAC in a bold attempt aimed at addressing this multiple membership issue.

The total aggregate output (at current prices) for the EAC amounted to $110.3 billion in 2013, compared to $99.3 billion in 2012. The per capita GDP for the region in 2013 ranged from $294.20 in Burundi to $1,055.20 in Kenya. The dominant sector in the EAC in 2013 was agriculture, followed by wholesale and retail trade and manufacturing. In 2015, the total exports from the intra-EAC trade amounted to $3,207.4 million while the total imports amounted to $1,533.1 million, thus giving an intra-trade surplus of $1,677.5 million. Tanzania, Kenya and Uganda recorded overall intra-trade surplus balance while Burundi and Rwanda recorded an overall intra trade deficit for the year.

Table 1. EAC member country population and GDP figures (2015)

State	Population (Millions)	GDP (US$ Billion)	GDP Growth %	Inflation %	Total area (1,000 km)^2
Burundi	10.0	2.718	4.5	8.0	25.0
Tanzania	48.8	33.23	7.0	7.9	886.3
Uganda	35.5	21.48	5.8	5.5	200.5
Rwanda	11.2	7.452	4.6	4.2	24.2
Kenya	44.2	44.10	4.7	5.7	580.7
EAC Total*	**149.7**	**108.98**	**5.32**	**6.26**	**1716.7**

Source: East African Community Facts and Figures (2016) Report, EAC Secretariat (*excluding South Sudan)

The EAC integration stands as the single most significant opportunity cluster for the region, giving all partner states immediate access to a market of approximately 154 million people. This integration is only likely to increase as the member states show renewed political commitment on a number of key projects, including:

- Implementation of the Single Customs Territory (SCT), which removed multiple weighbridges, police, and customs checks along the Mombasa-Kampala-Kigali route and introduced computerized clearance and electronic tracking.

- Joint infrastructure projects such as oil-pipeline and railway networks, which will reduce high transport costs and increase export competitiveness. The $24 billion Lamu Port Southern Sudan Ethiopia Transport Corridor (LAPSSET) infrastructure mega project is the single most valuable investment project in the region, with a value that is a fifth of the combined EAC GDPs in 2013, initiated primarily for the extraction and movement of oil from newly discovered deposits in Northern Kenya and Uganda, and to offer an alternative transit route for Southern Sudanese oil exports.

- Increasing mutual recognition of standards in goods and services.

- Elimination of Non-Tariff Barriers (NTBs) through bilateral engagements and the EAC Time bound program. This is an internal EAC mechanism for the removal of barriers such as:
    - Delays in transit bonds cancellation, now targeted to be done within 24 hours
    - Numerous institutions involved in testing goods
    - Existence of several weighbridge stations in the Central and Northern Corridors
    - Ugandan restriction of beef & beef products from Kenya
    - Several Police roadblocks along Northern and Central Corridors, estimated at 36 between Mombasa-Kigali and 30 between Dar Es Salaam to Rusumo border
    - Lengthy procedures for issuing work permits that vary across the EAC Partner States

Agriculture:

The agricultural sector accounts for about 34 per cent of the GDP in Burundi, 29 per cent in Kenya, 32 per cent in Rwanda, 25 per cent in Tanzania and 23 per cent in Uganda (2014), although agriculture's percent contribution to these economies is slowly declining. Since agriculture employs over 80 per cent of the rural population in the EAC -- the majority of whom are poor -- development of the agriculture sector presents a great opportunity for poverty reduction in a sustainable manner. Agriculture also contributes to foreign exchange earnings, employment and provides raw materials for agro-based industries (Ssekalo, 2015).

The agricultural sector is dominated by smallholder mixed farming of livestock, food crops, cash crops, fishing, and aquaculture. The major food crops are maize, rice, potatoes, bananas, cassava, beans, vegetables, sugar, wheat, sorghum, millet, and pulses. Some of these are also sold and could be regarded as cash crops. Cash crops include tea, cotton, coffee, pyrethrum, sugar cane, sisal, horticultural crops, oil-crops, cloves, tobacco, coconut, and cashew nuts.

The livestock sub-sector consists of cattle, sheep, goats, and camels, mainly for meat and milk production; pigs and poultry for white meat and eggs, respectively; and animal hides and skins for export and industrial processing. Aquaculture products include both fresh water fish from rivers, dams and lakes, and marine fish from the Indian Ocean. Forestry products include fruits, honey, herbal medicine, timber, and wood for fuel.

The adverse impacts of climate change aggravated by rising average global temperatures are a threat to the livelihoods of people in almost all sectors of the economies of the EAC region. Severe droughts, floods, and extreme weather events associated with climatic variability are occurring with greater frequency and intensity in the region. The dependence on agriculture in the EAC region, particularly rain-fed agriculture, makes agricultural production highly vulnerable to climatic variability and climate change.

Owing to the above challenges, the EAC has developed a Climate Change Policy, Climate Change Strategy and Climate Change Master Plan. The overall aim of the Policy is to contribute to sustainable development in the region through harmonized and coordinated climate change adaptation and mitigation strategies, programs and actions. The Climate Change Strategy and Master plan are tools to guide and monitor the implementation of the EAC Climate Change Policy.

3. COUNTRY REPORTS

This section provides baseline reports on energy and cooking in the five EAC countries. Each report outlines the demographics and basic information of the selected country. The reports include an overview of the fuels and stoves currently used for cooking, whether ethanol is currently available, and if ethanol is produced locally. Each report also details government laws, policies, and taxation schemes that may affect the production, distribution, and sale of ethanol.

3.1. Burundi

Country and Demographic Information

Burundi is a small landlocked African Country with territorial total area of 27,834 sq. km out of which the land area is: 25,680 sq. km and water occupies 2,150 sq. km. Burundi is administratively divided into 18 provinces and further into 117 Communes and 2639 Collines. The population is 10.5 million with a density of 410 people per square kilometre, making it one of the high density countries in Africa. Approximately 90 percent of the population live in rural areas with agriculture as their main economic activity. The population of Burundi has an annual growth rate of 3.1 per cent. Additionally, young people dominate the population, that is, 7 out of 10 Burundians are under the age of 15. Burundi is composed of three ethnic groups--Hutu 83 per cent, Tutsi (14 per cent) and Twa (3 per cent). The official languages are Kirundi and French.

Burundi has experienced decades of political instability, conflicts and civil strife. This is due to ethnic and political rivalry between majority Hutu and minority Tutsi who control political and economic power. The war lasted for 12 years from 1993 to 2005 claiming 300,000 lives and displacing approximately 1,200,000 people or 16 per cent of the population. The ongoing political instability in Burundi due to the disputed extension of presidential term is an indicator of Burundi's precarious state of affairs. The dispute is likely to diminish the gains of Arusha Peace and National Reconciliation Accord signed in 2000 and the Government of Burundi's endeavour in consolidation of peace, national reconciliation and economic reform.

There is widespread poverty in Burundi. This is illustrated by 90 per cent to 95 per cent of the population living on less than US$2 per day, especially in rural areas. The economic growth has been dynamic as characterized by negative GDP for several years, 5.9 per cent in 2006, 3.9 per cent in 2010, and associated per capita GDP of US$210 in 1990 and US$110 in 2002. Likewise, the per capita Gross National Income (GNI) in 2010 was US$170, about half its pre-war level some 20 years ago. Additionally, Burundi is ranked 185th out of 187th

countries on the 2011 United Nations Development Programme's Human Development Index (HDI), and eight out of ten Burundians live below the poverty line. The critical food insecurity situation in Burundi captures vividly the poverty situation in the country; 70 per cent of the population is living in food insecurity and 35 per cent of children under five are suffering from moderate to severe underweight (Vinck, et.al., 2008).

In terms of land-use, agricultural land is 73.3 per cent out of which arable land is 38.9 per cent; permanent crops 15.6 per cent; permanent pasture 18.8 per cent, forest 6.6 per cent and others 20.1 per cent (Niyongabo, 2008). Burundi experiences two rainy seasons; a long rainy season in February-May and short rainy season in September-November. Additionally, it has very short rainy season in January. The rainfall ranges from 2,000 mm in higher altitudes to 1,000 mm in low-lying areas. The average temperature is 16 ^{o}C-23^{o} C.

The economy is predominantly agricultural, accounting for just over 40 per cent of GDP and employs more than 90 per cent of the population. Other economy contributors include light industries and trade, and additionally, the Government budget is heavily funded by donor financial support. The main staple crops are bananas, cassava, sweet potatoes, and beans. Bananas alone accounted for 29 per cent of total cultivated area and 44 per cent of the total value of crop production between 2006 and 2008. Cash Crops include coffee, tea and palm oil. The livestock subsector is faced with low productivity, and the industrial sector is poorly developed and other negatively impacting issues such as limited access to external economies, overpopulation, and land scarcity exacerbates Burundi socio-economic situation (USAID, 2016).

Smallholder farmers with an average of 0.8 hectares or two acres dominate the agricultural landscape. This demonstrates the fact that securing 100 hectares or 400 acres for feedstock production will necessitate bundling of the farmers through existing farmers' cooperative initiatives. Environmental degradation and specifically land degradation is a key feature of agricultural landscape due to soil erosion from poor agricultural practices, lack of fertilizer, irregular rainfall, and shortened fallow periods leading to negative impact on soil fertility (Hobbs and Knausenberger, 2003).

Poverty and food insecurity in rural areas are the result of high population pressure on over cultivated, eroded land supporting farms of an average size of 0.5 Ha or less, insecurity and displacement, recurrent drought or climatic constraints, scarcity or poor quality of agricultural implements and technology, extension services, and limited market incentives, low productivity of labor, low cash incomes from subsistence agriculture or limited non-agricultural activities, inadequate basic health and education services and safe drinking water, and high rates of illiteracy (Curtis and Adama, 2013).

Burundi is characterized by a poor transport system and network. The total road length is

12,322 km, out of which 1,286 km is paved and 11,036 km (2004) unpaved (USAID, 2012). The country has an interesting landscape with an altitude that ranges from 772 meters (Bujumbura) to 2,670 meters (Mont Heha). The average altitude of the country is 1,700 meters. The terrain is full of mountain range, hills, plateaus and minimal plains such as Imbo and Meso plains in Western and Eastern side respectively. Large parts of Burundi's landscape are mountainous with elevations between 770 m and up to 2,670 m; the terrain drops to a flat plateau in east. Highest point is Mount Heha (2,670 m) within the Burundi Highlands mountain range.

East Africa's dominant energy source is biomass, and Burundi is no exception. Wood and peat account for 94 per cent of energy consumption in Burundi. Access to electricity for the Burundian population is very low (10 per cent) compared with other countries in the East African Community. According to the Government of Burundi statistics (2012), the 2011 consumption level was 200 GWh, out of which 70 GWh was utilized by industrial and commercial activities, 84 GWh for households and 46 GWh for other consumers. However, Burundi's hydroelectric potential is 1,700 MW, of which 300 MW are sites of more than 1 MW. Currently, only 32 MW are developed.

Burundi actual and projected main energy sectors include urban, industrial, transport, fishing, commercial, agricultural, health, education, and tourism. The potential energy sources include hydropower, solar, wind, geothermal, biomass, and imported petroleum fuels. In relation to biomass, peat offers an alternative to increasingly scarce firewood and charcoal as a domestic energy source. The annual deforestation rate stands at 9 per cent, and national forest cover is below 6 percent. Burundi possesses a peat potential estimated at 600 million tons. The exploitable potential would be around [47 to 58 million tons]. The government is promoting peat production. Burundi has immense forest and agricultural resources that can be converted into energy. In addition, as an agricultural country, Burundi generates a lot of agricultural residues, which can be converted into energy as well.

Baseline Energy Information

The energy sector in Burundi should be [appraised] in the context of its political instability and war leading to neglect and inadequate investment in energy sector. There were climate constraints, such as recurrent drought hampering the full potential of hydropower, low consumption and purchasing power leading to highly subsidized electricity. The landlocked nature of the country, 2000km route to transport petroleum products from Kenya or Tanzania coast, poor infrastructure leading to low penetration in rural areas, and weak private sector participation. However, population increase, potential of nickel extractive manufacturing, modest increase in need for energy in urbanizing zones, industries, transportation, fishing, commercial and agricultural activities, health, education and tourism is up surging the demand for reliable and affordable energy sources.

Burundi has some of the lowest energy access rates in the world-only 7 per cent of the population has access to electricity sources. Only 2.1 per cent of the population has access to clean fuels and technologies for cooking (World Bank, 2014). Energy usage is primarily for heating, lighting, commercial, agricultural, and industrial purposes. Traditional biomass such as wood, solid wastes, charcoal and bagasse provide 96 per cent of energy needs in Burundi. Biomass energy is composed of 70.8 per cent fuel wood, 18.35 per cent agricultural residues, 5.82per cent charcoal, and 0.978 per cent bagasse. Additionally, other energy sources participating in energy balance are 2.5 per cent petroleum products (crude oil, liquefied petroleum gas), 2.5 per cent flowing water (hydropower), 0.04 per cent peat, and 0.01 per cent solar radiation and biogas. Per capita, consumption of commercial energy is only 219 kg oil equivalent per year, one of the lowest in the world. About 77 per cent of Burundi's supply of commercial energy is imported (petroleum products and electricity), the other 23 per cent being domestically produced in the form of hydroelectric power and peat (Hakizimana, 2008). The challenges of energy sector in Burundi include:

- Investment costs are very high and difficult to mobilize
- The lack of new investment--for instance, the last hydropower investment was in 1988
- The cessation of activities of some industrial potential are energy-consuming
- Deforestation and destruction of ecosystems in certain areas of the country
- The destruction or the abandoning of solar energy and biogas infrastructure during the civilian war
- Drought during the recent period
- A strong deficit in electricity
- Low involvement of the private sector
- Over-exploitation of traditional energy resources and the low rate of regeneration of natural forests
- No access to the ocean (all petroleum products are imported)
- High prices of oil products and lack of strategies to reduce the price
- Lack of measures to promote renewable energy among others.

Fuelwood

Fuelwood dominates energy consumption in Burundi, and its uses include lighting, cooking, water heating, household heating and home enterprises. Ninety-six per cent of households use wood, farm residues, and charcoal. Biomass and farm residues are mainly used in rural areas with 94 per cent of the households as compared to 2 per cent of the urban households. The demand for fuel wood and other biomass is estimated at over 6 million tons. For instance, in 2007 the total firewood biomass supply from all sources was estimated to be 6,400,000m. Fuel wood in the rural areas is collected freely from farms and rangelands; only a small percentage is commercially traded. Urban average fuel wood consumption is 1.2kg per person per day while the national figure stands at 1.5kg. The average annual per capita consumption was approximately 741 kg and 691 kg for rural and urban households respectively. In urban areas, especially Bujumbura and its surroundings, firewood costs US$ 0.46 – US$0.50 per kg. In urban areas, it is the lowest income households who depend on firewood the most. Recent trends have shown that the per capita consumption dropped, the main reason being that wood resources have become scarcer. Sustainability is a critical question in wood consumption in Burundi. This is illustrated by potential wood consumption forecast requirement production of 180,000 hectares versus current forest coverage at 174,000 hectares. This necessitates reduction of consumption through diversification of energy mix and afforestation and reforestation initiatives.

Charcoal

The total charcoal consumption in 2007 was 382,110 tonnes. This translates to consumption of 0.3 to 0.437 kg/person/year for charcoal in urban areas. Charcoal consumption is imperative to 10 per cent of the population in urban areas and peripheral zones. The usage stands at 30.2 per cent urban, 7.7 per cent rural, and 13.3 per cent national. The cost of charcoal is at US$10 to US$15 per sack. However it varies depending on the production zone, season and the location of demand. Charcoal production is commercial and raw materials are extracted from rangelands and trust lands. The irony is that production of charcoal is illegal in Burundi despite its trading in the market and consumption. This illegality has resulted into use of traditional and inefficient technologies such as kilns. Domestic cooking and meat eateries for “nyama choma” influence the demand for charcoal in urban areas. Charcoal is not only a fuel for the low-income urban dwellers; 83 per cent of high-income groups regularly use charcoal as well.

Crop Residue/Animal Dung

Burundi has immense forest and agricultural resources that can be converted into energy. Additionally, Burundi generates a lot of farm residues from its agriculture-dominated economy and this can be converted into energy. Farm residue is mainly used for cooking, water heating, ironing, lighting, and home businesses. Rural households also use wood waste comprising of wood shavings, sawdust, timber rejects, and off-cuts.

Peat

Burundi possesses a peat potential estimated at 600 million tonnes. The exploitable potential would be around 47 million to 58 million tons. The National Office of Peat (ONATOUR) is responsible for the promotion of peat. The current customers include schools, hospitals, barracks, and prisons. The penetration of peat is hampered by its unpleasant odour, harmful combustion fumes, high installation cost, and the poor technology available for its use at a household level.

Biogas

Biogas' potential, as implied in 700,000 herds of livestock, is under exploited. This is illustrated by 320-1100 units or systems installed in 1993. About 70 per cent of them are not in working condition (Hakizimana, 2008). The major cause was the civil war. The notable biogas technology promotion efforts were undertaken in the 1980s by German Technical Cooperation Agency (GTZ, now GIZ), Belgian Cooperation, Belgian Technical Cooperation (BTC), French Technical Cooperation (FTC), Chinese Cooperation, and Ministry of Energy and Mines (MWEM). The mean daily consumption of biogas works out to be 0.6 m^3, which translates to an annual per capita of 219 m^3 of biogas.

Fuel Briquette

Numerous enterprises, such as Bioenergy Burundi, are converting biomass waste into a comparatively high quality energy source known as the briquette. The available briquettes are sold at an estimated low amount of BIF 259 per Kilogram while a machine of grinding produces 500 tons per month and three tons an hour.

Electricity

Access to electricity for the Burundian population is very low (10 per cent) compared to other countries in the East African Community or Sub-Saharan Africa (Pachauri, 2012). However, Burundi's hydroelectric potential is 1,700 MW, of which, 300 MW are sites of more than 1 MW. Currently, only 32 MW are developed. Hydropower dominates Burundi's electricity power supply. Power utility, REGIDESO, also owns a 5.5 MW thermal power plant in Bujumbura, which has been mostly idle since its acquisition in 1995. Often used minimally and as a backup, it was reactivated into regular use in 2009. Electricity in Burundi is among the least developed in the world.

The production cost of electricity is lowest in the East Africa region. This stands at US$0.04 /kWh, US$0.3/kWh and US$0.48/kWh for hydropower plants, thermal power and diesel generators respectively. The average production costs for the energy mix are consequently estimated at 0.062 USD/kWh for 2012. To facilitate cost recovery and boost private investment, price increases were affected in 2011 and 2012. The households that constituted the greatest consumers (> 300 kWh/month) saw their energy bills multiply by three times, increasing from US$0.06/kWh to US$0.18/kWh[3].The potential for increased electrical consumption is substantial; the average household consumption is quite low, around 23 kWh/year per household, compared to the African average of 150kWh/year. It is a national and regional objective to close this gap as soon as possible through the opening of national energy market for private investment, associated enabling environment, and cooperation with other countries in East Africa for regional energy infrastructure projects.

Solar Energy

Solar is increasingly being exploited in Burundi for off-grid rural electrification. This is a donor driven initiative as opposed to the market driven one, as indicated by players such as Japan International Cooperation Agency (JICA), United Nations Development Programme (UNDP), European Union (EU), and the government of Burundi. Photovoltaic solar energy or small hybrid thermal-photovoltaic power plants are preferred for the electrification of remote centres.

Wind Power

Wind power is more or less completely unexploited in Burundi. Only two mechanical wind machines have been installed in the last few decades on the Imbo plain to pump water. Hence, more studies are needed to determine wind energy resources.

Geothermal Energy

Geothermal resources exist in the West Rift Valley. However, more studies are needed to map the commercial viability of geothermal energy.

Kerosene

Kerosene is imported from the Middle East via Kenya and Tanzania. It is a part of the petroleum products consumed in Burundi for lighting and cooking. Kerosene dominates in urban areas such as Bujumbura. The widespread use of kerosene is limited by poor delivery infrastructure and high import and transport cost since Burundi is a landlocked country.

LPG

This is an alternative fuel for cooking in both urban and rural areas. Low penetration of LPG in rural and low-income areas is associated with the high cost of LPG itself, the cost and the availability of appliances, and the poor infrastructure for delivery.

Biofuels

There is no experience of biofuels in Burundi. There is a potential for biofuels in Burundi as implied through the availability of first and second generation biofuel feedstocks such as crops, plants and wastes. This is augmented by the presence of the sugar factory Société Sucrière du Moso (SOSUMO) in Rutana. The sugar factory capitalizes on the use of bagasse for electricity through cogeneration technology. This electricity is only used in the factory and its buildings, but not connected to the national grid of National Electricity and Water Utility (REGIDESO). However, the biofuel domain and a strategic framework are not yet developed to tap into this **energy** niche. The country's sugar belt in eastern Burundi holds promise in sizeable production of this fuel. It is imperative to note that the region has been mobilized by the private sector to implement a Vanilla-Jatropha Development Project. This is likely to establish out grower farming activities of the Jatropha crop with the aim of producing biodiesel. Nothing substantial has resulted from this self-mobilization.

Table 2. Gross Energy Supply in Burundi

Sl. No.	Type of Energy	Quantity (tons)	Toe	Per cent
1	Biomass			
1.1	Fuel Wood	6,400,000m	1,216,000	70.8
1.2	Agricultural Residues	900,000	315,000	18.35
1.3	Charcoal	346,617	100,000	5.82
1.4	Bagasse	48,000	16,800	0.978
2	**Petroleum Products**	40,500	42,000	2.5
3	**Hydroelectricity**	180 GWh	45,580	2.5
4	**Peat**	8,000	2.276	0.04
5	**Solar and Biogas**	n.a.	n.a.	0.01
	TOTAL			100

Source: Godefroy Hakizimana, Burundi Country Baseline Report and Workplan 2008.

Current Initiatives for Clean Cooking

Cooking in Burundi is heavily dominated by fuelwood, charcoal, and peat in the order of prominence. This results in Household Air Pollution, environmental degradation, and a lot of time spent especially by women and girls to collect fuel wood due to overdependence on it and its increasing scarcity. The amount of time spent collecting fuelwood varies from thirty minutes to two hours a day. The consumption of other cooking energy sources such as kerosene and LPG are marginal due to high cost and difficulty in supply delivery.

Multiple projects have promoted clean cooking in the biomass sub-sector from the 1980s through Improved Cook Stoves (ICS). Development partners, donors, civil society and the Government drive these projects (Johnson et. al., 2015). These ICS initiatives for firewood and charcoal include the Rural Cookstoves Project and the International Development Association's (IDA) Urban Development Project (DUB). These projects have targeted urban areas such as Bujumbura and have not reached the critical mass in the rural areas. The challenges for penetration of ICS include:

- Traditional stoves being more profitable to artisans than improved cook stoves
- The strong tradition of not cooking with stoves, but with open three-stone fires
- The affordability of improved cook stoves and availability of incentives such as subsidized stoves
- Poor social marketing of ICS

Biogas energy for clean cooking has been promoted as well and despite the obvious potential and installations of over 1,100 units, over 70 per cent of the digesters are not in use. The poor penetration is attributed to the civil war of 1993-2005, poor usage capacity, frequent repair and construction, poor development of milk or livestock industry, and high installation cost (Hakizimana, 2008).

The promotion of clean cooking with peat as energy through ICS has targeted institutions such as schools, barracks, prisons, and hospitals. Other clean cooking includes Bioenergy Burundi and Biofuel Moso. The Biofuel Moso is done in partnership with Burundi Quality Stoves and involves manufacturing biomass briquettes from agricultural waste such as peanut shells, coffee husk, rice husk, cocoa husk and bagasse from sugar cane. This project is mostly in Bujumbura but is projected to cover the entire country. This environmental friendly alternative for charcoal and firewood is produced at a capacity of 3,000 kg/hr. and marketed to community consumers (restaurants, households, schools, police camps etc.). Burundi Quality Stoves has equally applied for CDM carbon financing for the Improved Cook Stoves Project for reduction of 217,458 metric tonnes of CO2 equivalent per annum.(Poa, 9634, UNFCC 2015)

Government Regulations for Ethanol Fuel

The Ministry Water, Energy, and Mines (MWEM) is responsible for policy and regulation of the energy and water sectors in Burundi. The Centre d'Etudes Burundais des Energies Alternatives (CEBEA; The Burundian Centre for Studies of Alternative Energies) is responsible for research on alternative energy sources such as solar, wind and biomass. Multiple sectoral policies and regulatory regimes such as agriculture, sugar, trade and industry governs production of biofuels in Burundi. This multiplicity of governance regimes is open to interpretation by regulatory bodies such Energy Regulatory Commission (ERC) of Burundi. This necessitates the need for a specific national policy, strategy, and plan for biofuel production and development in Burundi. The biofuel sub-sector framework will address issues such as land tenure system and property rights, land use planning, secondary processing of primary fuel, cost of the product, consumer education, and gender issues. The government of Burundi is currently planning a biofuel policy.

The following laws, policies, strategies and plans may directly or indirectly impact on ethanol production:

- National Energy Policy
- Energy Implementation Strategy and Investment Plan
- Law 01/014
- The Growth and Poverty Reduction Strategic Framework
- National Agricultural Strategy (*Stratégie Agricole Nationale*) for 2008-15

Table 3. National Plan for Agricultural Investment (*Plan National d'Investissement Agricole)* for 2012-17

No	Enabling Institutional Instrument	Impact on Biofuel Sub-Sector
1.	National Energy Policy 1998	The policy aims to facilitate supply and demand for energy for the Burundian population and transformation of energy sector through increased capacity for production, modern energy to be accessible to the vast majority of the population and energy sector to be efficient, transparent and equitable in order to optimize the use of financial and human resources
2.	Energy Implementation Strategy and Investment Plan	Captures the road map to actualization of National Energy Policy and outlines the role of private sector and other stakeholders in the energy sector
3.	Document on Investment opportunities in renewable energy Burundi	Outlines the Prioritized Renewable Energy Investment Opportunities in Burundi
4.	Law No. 1/014	Domain of liberalizing and regulating public electricity. Outlines principles, forms and conditions for private sector intervention in the sector.
5.	Poverty Reduction Strategy Paper II	Details Burundi's macroeconomic, structural, and social policies in support of growth and poverty reduction, as well as associated external financing needs and major sources of financing. An excellent reference point for facilitative biofuel sector initiatives, though inclined towards hydroelectricity and household inaccessible renewable energy alternatives such as solar, biogas, geothermal, peat, and micro-hydro plants
6.	National Agricultural Strategy (*Stratégie Agricole Nationale*) for 2008-15	Captures Government Priority Areas in Agricultural Sector critical for Biofuel Raw Materials or Feedstocks
7.	National Plan for Agricultural Investment (*Plan National d'Investissement Agricole)* for 2012-17	Captures Priority Opportunities for Investment in Agricultural Sector and role of Private Sector and other Stakeholders

No	Enabling Institutional Instrument	Impact on Biofuel Sub-Sector
8.	Ministry of Energy and Mines	Developing policy and strategic interventions in energy sector; enabling environment
9.	Energy Regulatory Commission (ERC)	Entire energy sector regulation
10.	Universities, Burundian Centre of Alternative Energies(CEBEA), Forest Department, National Office of Peat (ONATOUR).	Accessibility to modern energy or cooking technologies through research and training
11.	Vision Burundi 2025	The goal of the vision is to put Burundi on the path toward sustainable development, increase the economic growth rate, and reduce poverty by half, or from 67 per cent to about 33 per cent by 2025. Inclined towards Hydroelectricity and promoting new and renewable energies – such as solar, biogas, geothermal, peat, and micro-hydro plants – is justified by the need to rationalize firewood consumption and yet none is really geared towards solving household energy problem.
12	The Investment Promotion Agency	Create an enabling environment for private investment, thus application for Biofuel Sub-sector. Likewise, additional associated Laws such as Law No. 1/23, Law No. 1/09 Law No. 1/24 linked to tax benefits, rule of law for business and ease in establishing business and related security.

Regional policies, strategies, and plans are also critical since Burundi belongs to the six regional communities: (1) the East African Community (EAC); (2) the Nile Basin Initiative (NBI); (3) the Economic Community of the Great Lakes Countries (CEPGL); (4) the Common Market for Eastern and Southern Africa; (5) the Economic Community of Central African States (CEEAC), and (6) the International Conference on the Great Lakes Countries (CIRGL). The objectives of these different communities are complementary and interdependent. Burundi has taken the necessary steps so that programs agreed upon in each organization can be carried out in accordance with the principles expressed by the member states. These regional bodies have direct or indirect energy related agenda and regional approach to trade and investment (USAID, 2015). For instance, the EAC Strategy on Scaling-up Access to Modern Energy Services which promotes joint EAC countries energy investment and national initiatives to improve the energy security.

Additionally, donor interest matters in energy sector and biofuel production in Burundi. They play a critical role, funding nearly half of Burundi's national budget and half its agriculture budget in recent years. The involvement of private sector is equally critical.

Overview of Ethanol Production in the Country

Currently, there is no ethanol fuel production in Burundi, except artisanal processing of local alcoholic drinks for consumption from local crops such as sorghum (Habindayyi, 2009). Burundi has potential to produce ethanol through three sources: crops, wastes, and other plants. Therefore, it is appropriate to explore the potential for ethanol production.

Burundi is administratively divided into 18 provinces and further into 117 Communes and 2639 Collines. The provinces, which are located in the region of smallholder farmers, will suffice in ethanol production. However, bundling of farmers into strong producers' cooperatives will be desirable to secure the minimum 100 hectares for micro-distilleries. Confédération des Associations des Producteurs Agricoles pour le Développement or the Confederation of Associations of Agricultural Producers Development, which is an association of over 50 farmers cooperatives, would be a great entry point. In the region of plains, such as Imbo and Moso the population densities are comparatively low, so holding acreage is 2-5 hectares, hence suitable for bioethanol feedstock farming. Other sugar belt regions within the Agricultural Ecological Zones (AEZ) of the country such as Buragane and Bugesera would be suitable as well.

The table below provides production level of crops and is indicative of existing gaps to actualize ethanol production from 1st and 2nd generation feedstocks.

Table 4. Crop Production 2006-2009

Food crops (million tons)	**2006**	**2007**	**2008**	**2009**
Grains	282	290	290	298
Legumes	238	239	221	239
Roots and tubers	1,458	1,518	1,575	1,548
Bananas and Plantains	1,663	1,709	1,760	1,806
Income Crops (in tons)				
Coffee	29,951	8,210	24,700	6,814
Tea	6,338	6,475	6,728	6,729
Cotton	1,750	2,870	2,887	2,547
Non-Traditional crops	-	246	763	727

Source: IMF 2015

The only sugar factory in Burundi, La Société Sucrière du Moso (SOSUMO) has a potential facility for ethanol production and associated raw or waste materials such as molasses. The factory is situated in the Rutana Province in the southeast of Burundi, produced 23,149 metric tonnes of sugar in 2013, and had a successful production rate of 217,624 tonnes. It is situated in Moso at Gihofi village, which is about 180 kilometres from Bujumbura. The company covers an area of 5,800 hectares. The cane cultivated by SOSUMO is rich, about 14 per cent of sugar and has a fibre of 12.5 per cent. The company is aiming to:

- Increase sugarcane production by irrigating some plots
- Progressively replace the old equipment
- Make various improvements to produce 35,000 tonnes from the current 33,000 tonnes within three years
- Transform the molasses into carburizing, pharmaceutical, and consumable alcohol

A feasibility study was conducted by The World Bank and undertaken by a consultant, Sofreco, in 2003-2004 for factory rehabilitation, the expansion of the sugar plant, and construction of an ethanol distillery from waste molasses. The ethanol distillery was designed to produce both power and potable alcohol, and the plans included an increase in capacity from 22,000 tonnes to 35,000 tonnes of sugar annually with a production of ethanol of 1,500,000 liters per year (Hakizimana, 2008). However, these plans are yet to be implemented. The only alcohol and soft drink company is Brarudi Brewery. It is owned by the government (40 per cent) and Heineken International Netherlands (60 per cent) and could be a source of ethanol.

Conclusion and Recommendations

The energy sector in Burundi is one of the least developed in the world. It relies heavily on fuelwood and charcoal. The overall low consumption of energy in Burundi has exacerbated poverty and stalled development. This has negative consequences on the economic growth, environmental sustainability, health, and social welfare of Burundians. The ongoing political stability processes, economic reform, international donor and development partners input, and regional integration is catalyzing an increase in demand for reliable and affordable energy sources. This demand is marked in sectors such as urbanizing hubs, industries, transportation, fishing, commerce, agricultural activities, health, education, and tourism. This necessitates energy sector reforms in terms of refurbishment of infrastructure, improving efficiency, cost recovery mechanisms, diversification of energy sources, enabling private sector investment, and energy resources studies for potential and feasibility mapping. Additionally, reduction in the use of fossil fuels due to over 2000 km transport difficulty from the coast of Kenya and Tanzania is recommended by the EAC.

Biofuel in terms of bioethanol, biodiesel, and biogas have potential in Burundi despite their current lack of exploitation. This is confirmed by the availability of first and second generation feedstocks and wastes for biofuel production. However, this potential must be considered with population increase, high population density, land tenure system and scarcity, food crops, food security, biodiversity conservation, poor infrastructure, low consumption or purchasing power, and low local capacity. Biofuel production must also integrate gender issues as illustrated through the fact that most important actors in smallholder farming are women, who account for 55 per cent of the workforce and do 70 per cent of farm work. Yet women have few rights; under customary law, they are not allowed to own land or livestock (Curtis and Adama, 2015).

The commercialization of the biofuel industry in Africa is bottlenecked by both technological and non-technological factors, including policy, institutional and legal hurdles, financial limitation, technical and infrastructural hurdles, information hurdles, especially from demand side and capacity hurdles (Amigun, Sigamoney and Blottnitz, 2008). Burundi is no exception to this and may be worse off in these technological and non-technological barriers. Biofuels can be promoted in Burundi to replace imported fossil fuel associated with high costs and a skewed balance of payment deficit with renewable fuel that has potential to off ottnitz, 2010). Therefore, biofuel production must be built upon the following:

- Gendered biofuel production in terms of sensitivity and responsiveness; this recognizes that Burundi is a patriarchal society and that land is owned by men under customary law. This necessitates factoring in power dynamics and resultant decision-making in allocation of land for biofuel production, access to loans for agricultural investment, and sharing income from biofuel for women. The National Gender Policy equally advocates for increasing accessibility to factors of production and participation in decision-making.

- Smallholder farmers' bundling into strong cooperatives as opposed to current weak associations for economies of scale and production of adequate feedstock for micro-distilleries or large-scale distilleries.

- Enabling the requisite sustainable biofuel production legal, institutional, and policy framework.

- Transformation of poor private property rights and land ownership, which is an obstacle to secure loans for biofuel production.

- Accessibility to financial services for farmers to invest in biofuel production and distilleries.

- Climate change constraints such as recurrent drought and associated water footprint.

- Infrastructural constraints along the biofuel value chain cycle. This is because Burundi is greatly underdeveloped and is poor in infrastructural provisions such as transportation network, electricity, and communication critical for biofuel value chain development.

- Widespread poverty and national average income of US$140 per year hampering investment capacity in biofuel production.

- Working with smallholder farmers must be supported by extension services, rural credit, agricultural research, and input subsidies.

- better opportunities for rural employment, alternative markets for agricultural commodities, and economic returns from ethanol industry in terms of profits (Amigun et.al., 2008)

3.2. Kenya

Country and Demographic Information

Kenya has a total population of 48.5 million, of which 41.3 per cent are under the age of 14 years, making it a country with a median age of 19 years old. The total fertility rate per woman is 4.4 children, and the national live births ratio per thousand is 1,549. The number of deaths is 366.1 persons per thousand (WHO, 2015).

About 25.6 per cent of the total population lives in urban areas while the remaining 74.4 per cent live in rural areas. The population growth rate is 2.6 per cent (World Bank, 2016). About 50 per cent of the population was living below the poverty line in 2009.

There are over 70 distinct ethnic groups in Kenya, ranging in size from about seven million Kikuyu to about 500 El Molo who live on the shore of Lake Turkana. Kenya's ethnic groups can be divided into three broad linguistic groups: (1) *Bantu* (Kikuyu, Meru, Gusii, Embu, Akamba, Lyhya, Swahili and Mijikenka), (2) *Nilotic* (Luo, Masai, Turkana, Samburu, and the Kalenjin) and (3) *Cushite* (Somali, El Molo, Boran, Burji, Dassenich, Gabbra, Orma, Sakuye, Boni, Wata, Yaaka, Daholo, Rendille, and Galla). (Kurian, 1987) No ethnic group constitutes a majority of Kenya's citizens; the largest ethnic group, the Kikuyu, make up only 20 per cent of the nation's total population. The five largest - Kikuyu, Luo, Luhya, Kamba and Kalenjin account for 70 per cent. About 97.58 per cent of Kenya's citizens are affiliated with its 32 major indigenous groups.

The informal sector had the largest share of employment accounting for 82.7 per cent of the total jobs. The Kenyan economy is primarily agriculture based, with farming and fishing contributing 30 per cent of the total GDP for 2014. Other significant GDP contributors are manufacturing, whose share edged downwards to 10 per cent from 10.7 per cent in 2013. Taxes on products, wholesale and retail trade, transport and storage, real estate, finance, and insurance also ranked high in terms of their contribution to GDP.

The agriculture sector could be a key factor in poverty reduction if improvements were made to increase productivity, add value, expand marketing, and create better linkages to other sectors. Performance of the agriculture sector is heavily dependent on rainfall and the lack of rain adversely affects the agriculture output in a particular year.

Kenya’s annual GDP growth rate has been witnessing steady growth over the years—from 0.2 per cent in 2008 to 5.8 per cent in 2016. The major drivers of the economy were agriculture, forestry and fishing, construction, wholesale and retail trade, education, and finance and insurance. The demand side was mainly driven by a resilient private final consumption and a robust growth in fixed assets. Investment in fixed assets expanded rapidly on account of a vibrant growth in the real estate sector, the on-going mega infrastructure projects, and increased investments in air transport equipment. There was an increase of 7.0 per cent in exports of goods and services.

Policy & Employment: The Ministry of Gender, Children and Social Development, created in 2008, deals with issues of gender equality and women's empowerment. Women make up 70 per cent of the agriculture labour force. They are also involved in the informal sector and make up almost half of Micro, Small, and Medium Enterprises (MSMEs). Men are dominant in the formal and modern sector and are more likely to migrate to urban areas in search of work while the women look after the rural home, arising from the traditional patriarchal land tenure and family systems. Whereas the new constitution promulgated in 2010 gives new broad rights to women insofar as property ownership, inheritance, and access is concerned, it might be a bit early to assess the real impacts of these legal provisions within the national development fabric.

Cultural Background: The Kenyan society follows a patriarchal nature particularly in traditional rural areas where men take on the role of community leaders. In rural areas women are primarily responsible for domestic tasks, raising children, collecting water and fuel, and caring for family members and others in the community. Inheritance traditions mean that women only hold around 1 per cent of title deeds in the country limiting their economic progress. A new constitution now levels the field at the legal framework level but the gains are yet to be measured.

Role of Gender: Although women are involved in household purchasing decisions men have more purchasing power. Around 71 per cent of households are male headed and 29 per cent female headed. Women's groups have played an important role in the cook stove sector in Kenya in production and sales. Women are mainly involved in liner production and stove assembly whereas men dominate metal work. Women are integral to any consumer awareness and education campaign as the primary users of cook stoves. Women often have less access to finance and own less collateral, hence finding it difficult to secure a loan for business expansion. The role of looking after the home often restricts the ability of women to travel long distances and limits them to local activities.

Fixed Minimum Wages: The wages payable as minimum wages in the manufacturing, services, agricultural, and other applicable sectors in Kenya are categorized into several occupations and grades, then determined by regions, then by minimum wage per hour, per day and per month. The main regions are cities such as Nairobi, Mombasa and Kisumu, then municipalities such as Mavoko Town Council, Riuru Town Council, Limuru Town Council, and then all other areas that are neither cities nor municipalities nor town councils. On an average, farm workers have lower education and income than non-farm workers.
The minimum wages are paid as follows;

(1) KES 97.90 per hour (US $0.99); KES 527.10 (US $5.38) per day and KES 10,954.70 (US $111.78) per month for cities;
(2) KES 89.50 (US $0.92) per hour; KES 484.30 (US $4.94) per day and KES 10,107.10 (US $103.13) per month for municipalities;
(3) KES 54.70 (US $0.56) per hour; KES 296.20 (US $3.02) per day and KES 5,844.20 (US $59.63) per month all other areas that are neither cities nor municipalities nor town councils.

The general working hours are 52 per week, but the normal working hours usually consist of 45 hours of work per week, that is Monday to Friday, 8 hours each, and 5 hours on Saturday.

The agricultural and allied industry sector categorizes its workers into three main groups; unskilled, semi-skilled or skilled workers, with corresponding levels of wages. The lowest minimum wages are for the unskilled workers. The minimum wages as paid in the agricultural sector are set per day and per month, as follows;

(1) KES 228.30 (US $2.33) per day and KES 5,436.90 (US $55.49) per month for unskilled workers;
(2) Between KES 236.30 (US $2.41) and KES 337.70 (US $3.45) per day for the lower cadres of the semi-skilled to skilled cadres, and a monthly wage of between KES 6,278.80 (US $66.11) for stockmen, herdsmen, and watchmen, and KES 7,966.80 (US $81.30) per month for lorry and car drivers.

Agriculture: Out of the 40 Key Economic and Social Indicators 2010 – 2014 identified in the Economic Survey for 2015, seven are primary agricultural products (sugarcane 6,477.7 Ktons, milk 541.3 Ktons, tea 445.1 Ktons, maize 338.4 Ktons, fresh horticultural produce 220.2 Ktons, wheat 218.0 Ktons, and coffee 42.5 Ktons.)

Sugar-cane production in tons was 5,695.1 in 2010; declined to 5,307.3 in 2011; grew to 5,824.0 in 2012, again to 6,673.7 in 2013 and then declined again to 6,477.7 in 2014.
Only 9.8 per cent of the land in Kenya is considered arable

Table 5. World Bank Indicators-Kenya Land use

Item	**Value**
Agricultural land (sq. km)	266,710.0
Agricultural land (% of land area)	48.5
Arable land (hectares)	4,891,000.0
Arable land (hectares per person)	0.2
Arable land (% of land area)	8.6
Permanent cropland (% of land area)	0.8
Forest area (sq. km)	35,820.0

Item	Value
Forest area (% of land area)	7.8

Note: Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded.
Source: World Bank, 2015

Key Population Health Indicators

Malaria and pneumonia continued to be the leading causes of death each accounting for 11.6 per cent and 10.9 per cent of all reported deaths respectively, in 2014. Cancer and HIV/AIDS were ranked third and fourth with 14,175 and 12,235 death cases respectively, in 2014. Malaria and respiratory diseases continued to be the leading causes of illness accounting for 58.8 per cent of the total in 2014.

Table 6. Household Air Pollution (HAP) Impact in Kenya

Group	Numbers Exposed
1. Households using traditional open fires in built kitchens	9.9 million
2. Female cooks	2.48 million
3. Institutional cooks and kitchen helpers	100,000
4. Secondary students age 13-19 who study with Kerosene	3.3 million
5. Population directly affected by HAP	14.9 million

Source: Global Alliance for Clean Cookstoves, 2012

The population directly affected by Household Air Pollution (HAP) is 14.9 million. Of these, the households using traditional open fires in built kitchens are 9.9 million. Female cooks affected are 2.48 million while institutional cooks and kitchen helpers are 100,000. Secondary students age 13 years to 19 years who study with a kerosene tin lamp are 3.3 million.

The use of biomass with basic cooking devices combined with unsuitable cooking spaces is the main cause of HAP in Kenya. Low-grade biomass and agricultural residue used as cooking fuel increases the exposure. Three-stone wood fires and traditional cook stoves at both the residential and institutional level are the primary cause of household air pollution in rural homes. Traditional charcoal stoves burning poor quality charcoal cause exposure to carbon monoxide. Women keep small children near them during the preparation of meals. Most kitchens are in a separate hut or makeshift shelter, and are poorly ventilated. Use of poor quality kerosene lanterns that generate a lot of soot is widespread in the rural areas.

Cook stove programs need to educate people on best cooking practices as well as encouraging cleaner technologies.

Female cooks and children are the main groups exposed to HAP, which is linked to acute respiratory infections responsible for 14,300 deaths each year.

Awareness of Acute Respiratory Infections (ARI) is low. Only 46 per cent of children with ARI symptoms are taken to a health centre, yet they are the second largest cause of death. 26 per cent of all deaths reported in hospitals are attributed to ARI. Health impacts of HAP include acute respiratory infections, eye problems, and severe headaches. HAP exacerbates the condition of HIV/AIDS patients as it breaks down immunity. Another 8 per cent of children under age five show symptoms of ARI at any given time.

Baseline Energy Information

Only thirty-six per cent of the population has access to electricity while only 6.2 per cent of the total population has access to clean fuels and technologies for cooking (World Bank, 2016). Overall, 68 per cent of all energy needs in Kenya are met by traditional biomass, comprising mainly woodfuel and charcoal. The balance of 32 per cent is met by fossil fuels (crude oil, liquefied petroleum gas), geothermal power, flowing water (hydropower), wind, and solar radiation (Ngigi, 2015).

Traditional biomass-based fuels for cooking and heating are currently the most important source of primary energy in Kenya with woodfuel consumption accounting for 68.3 per cent of total consumption (rural—87.5 per cent; urban—10 per cent). The total sustainable biomass supply from all sources is estimated at 15 million tons. Firewood comes from three main areas: rangelands (25 per cent), government forests (28 per cent), and small farmlands (47 per cent). The role of agroforestry on small farms in providing firewood has increased while showing a decline in the other categories.

Total installed capacity for electricity generation expanded by 4.7 per cent from 1,717.8 MW in 2013 to 1,798.3 MW in 2014 mainly due to increased geothermal capacity. Total electricity generation expanded by 8.2 per cent to 9,138.7 GWh in 2014. Hydro and geothermal power accounted for the bulk of power with a total share of 71.0 per cent during the period. Domestic demand for electricity registered a growth of 3.8 per cent to 7,768.6 GWh in 2014 from 6,928.1 GWh in 2013. Renewable electricity sources account for 69.5 per cent of the total electricity output, compared to just 10.1 per cent in the USA.

The sale of petroleum fuels by consumer category between 2010 to 2014 was dominated by road transport (2,791.0 Kilotons and 71 per cent), aviation (530.4 Kilotons and 13 per cent), industrial, commercial and others (451.2 Kilotons and 11 per cent), power generation (98.9 Kilotons and 2 per cent) and agriculture (36.4 Kilotons and 1 per cent).

Main Energy Sectors

The electricity sector grew by 6.8 per cent compared to a growth of 9.8 per cent in 2013. The performance was determined by a number of factors among them: suppressed long rains that led to a contraction of 19.5 per cent in hydro generation. On the contrary, there was an increase of 63.8 per cent in geothermal power generation, primarily due to expanded installed capacity. In addition, thermal electricity production increased significantly by 19.6 per cent during the review period. This culminated in an overall increase of 8.2 per cent in electricity generation in 2014 compared to an increase of 7.6 per cent in 2013. The resulting energy mix led to a higher gross value added due to replacement of the more expensive thermal power and hydro with cheaper and more reliable geothermal energy. Total installed electricity generating capacity expanded from 1,717.8 MW in 2013 to 1,798.6 MW in 2014, representing a 4.7 per cent increase. The installation of additional capacity led to the stabilization of power supply as well as a drop in electricity prices though the cost of power remained relatively high compared to economies with more efficient technology of electricity generation. The sector also maintained its power diversification drive by increasing investments in solar and wind sources. On an average, electricity prices might fall slightly in the coming years due to increasing share of geothermal electricity generation.

Current Energy Related Problems and Issues

There is a steadily increasing demand for electrical energy in the country. Kenya's development plan under Vision 2030 anticipates rapid increase in energy demand arising from economic & social activities that are expected to be undertaken. Peak electricity demand is expected to rise from 1,350 MW in 2013, to 5,359 MW by 2017. To meet this demand, new generation capacity of 5,000 MW needs to be developed by 2016. It is anticipated that peak demand will be 18,000 MW in 2030 against installed capacity of 24,000 MW.

The bulk of this generation capacity is expected to come from fossil fuel sources, geothermal, nuclear, wind, and solar. There is however an opportunity for bioenergy to contribute significantly towards meeting this demand. According to the Ministry of Energy Survey carried out in 2007, the Kenyan sugar industry has potential to generate up to 200 MW of electricity for export, from biomass cogeneration. This will also help factories drive down the costs of sugar production (Magenya, 2014). Government priorities in energy focus on expansion of the grid and expanding sources of electricity generation.

Kenya recently commissioned a geothermal power plant, which propelled the country to the top of the green power using countries, producing 51 per cent of the national energy generation. The 280 MW plant required massive investments and inter-sectoral collaborations to ensure its successful commissioning. This is a pointer to marked need for the types of massive investments needed in order to set up the basic infrastructures for clean energy access at the macro levels, and also at the micro levels.

The Kenya Power and Lighting Company (KPLC) has introduced initiatives to try to address the issues of cost and access, including providing subsidized energy and community based energy, whereby a community requests supply and is connected when 25 per cent of that community has paid according to KPLC's quote. Another initiative that is a proven hit among rural residents is the Stimaloan (which means "electricity loan" in Swahili), developed in partnership with the French Development Agency (AFD), which offers flexible microfinance to make electricity connection possible. Bill delivery and payments are managed through mobile phone.

Despite the massive investments in Kenya, it is unlikely that there will be a massive transition from traditional cooking technologies and fuels towards the use of electricity, due to the current cost regimes for the source of clean energy. Although there had been an increase of geothermal generated electricity in Kenya recently, the cost of electricity is yet to reduce to the extent that mirrors the recent developments. This is due to the fact that 40 per cent of the cost of one unit of electricity is in the form of taxes and does not form part of the production costs. There are myriad taxes levied on the electricity, as follows:

Table 7. Real cost of electricity

1.	*Fuel Cost Charge (FCC)*	Variable rate per kWh, published monthly by KPLC in the Kenya Gazette (but not on their website). It is reflective of the cost (to KPLC) of generating electricity during the previous month. It varies monthly.
2.	*Foreign Exchange Rate Fluctuation Adjustment (FERFA)*	Variable rate per kWh, published monthly by KPLC. This includes the sum of the foreign currency costs incurred by KenGen, sum of the foreign currency costs incurred by KPLC other than those costs relating to Electric Power Producer, and the sum of the foreign currency costs incurred by KenGen. It varies monthly.
3.	*Inflation Adjustment (IA) - Variable rate per kWh*	Published monthly by KPLC. Factors include the Underlying Consumer Price Index as posted by Kenya National Bureau of Statistics and the Consumer Prices Index for all urban consumers (CPI - U) for the US city average for all items 1982 - 84 as published by the United States Department of Labour Statistics. It is not clear why the cost of Kenyan electricity

		depends on how much the population of the USA is spending. It varies monthly.
4.	Water Resources Management Authority (*WARMA) Levy*	5 cents per kWh.
5.	Energy Regulatory Commission (*ERC) Levy*	3 cents per kWh.
6.	Rural Electrification Authority (*REA) Levy*	5% of the base rate
7.	*VAT*	16% on everything except the WARMA, ERC and REA levies and Inflation Adjustment. (Prior to 2 September 2013, consumption less than 200 kWh was excluded from VAT, and VAT was charged at 12%).

The use of diesel generators for thermal power generation has also meant that the price of electricity fluctuates with movements in international oil prices.

Fuel Options for Household Fuels in Urban and Rural Markets

Biomass is the primary fuel used by the population. Whilst cost is a significant factor affecting fuel purchase, availability and minimum quantity sold are also important, along with social and cultural factors.

The charcoal market is the most variable in terms of supply and costs, by as much as 50 per cent.[2] The units for retailing fuels such as charcoal have been further reduced, such that there are intermediary units between the 30kg to 40 kg sack and the 2 kg tin, with options for troughs at 10 kg, half sacks at 25 kg and larger 5 kg tins. The cost per unit falls as the units increase in weight, such that the 2 kg unit is US $0.5 while the sack is US $10 but for which only 75 per cent of the sack is usable coal. The rest is chardust, usually recycled for making briquettes. In a number of the urban areas such as Kisumu and Nairobi the briquettes are significant sources of energy for cooking, and are also cheaper.

The majority of rural households use firewood for cooking, whilst urban areas households use mainly kerosene and charcoal. Firewood is used by 89 per cent of rural households and 6.4 per cent of urban households; mainly in three stone fires, rural improved stoves, and ceramic stoves, such as the upesi (maendeleo) stove. Many households use multiple fuels depending on the type of food being cooked and the time of day. Many households in rural areas can collect firewood for free, although it is becoming increasingly unavailable. The price of fuel is higher in urban centres and is subject to seasonal fluctuations. Access to

[2] Authors own sources, determined during "Initial Assessment of Household Energy, Cooking Practices and Clean Energy Issues in selected settlements in urban and rural Kisumu County" literature review.

modern fuels in Kenya is higher than in other parts of East Africa especially in urban areas where 58.4 per cent of the population have access to modern fuels. LPG usage is low in rural areas. A small proportion of the urban population uses it and initiatives are being trialed to increase its use among urban, low-income households. Use of wood and kerosene tends to decline with rise in income whilst use of LPG, electricity, and biogas increases with income. Recycled biomass briquettes have been promoted, but their use is very low and they struggle to compete with charcoal in the market. Many middlemen exist in the fuel supply chain each adding their mark-up and increasing the price to the end user.

Despite the frequency of kerosene as an urban fuel for cooking and lighting, there are no stand-out stove designs for the kerosene cookers, and most of what is available in the supermarkets and stores range from US $2 to US $12, depending on their size. Most of the brands available are imported from China and India, though there are a few locally manufactured brands.

Table 8. Fuel cost per week using traditional cooking methods

Fuel	**Purchase Unit**	**Usage**	**Cost (KES/$)**	**Cost per week ($)**
Wood (urban)	Bundle (20 kg)	2 days	210 KES/$2.50	$0.75
Charcoal	1 bag (30 kg)	3 weeks	1,200 KES/$14.30	$4.80
LPG	13 kg	30 days	3,000 KES/$35.70	$8.33
Kerosene	1 litre	2 days	100 KES/$1.20	$4.20

Source: Global Village Energy Partnership International, Kenya Market Assessment: Sector Mapping.

Fuelwood

Nearly 400,000 households relied on fuelwood for lighting as of 2009. Apart from households, there are other bulk users of firewood including learning institutions, prisons, industries such as tobacco, tea curing and fish smoking, and small and medium enterprises such as restaurants and camping sites. In the tea industry, over 70 per cent of small-scale factories have boilers that can use both furnace oil and firewood in curing tea. Most of them use wood-fired steam boilers to generate heat in order to reduce the cost of tea production. Meanwhile, it is estimated that a student in secondary school consumes an average of 0.524 kg daily of firewood irrespective of the combustion device used for cooking, school type, and number or types of meals cooked (Stockholm Environmental Institute, 2014).

These examples show that it is time to acknowledge the important role that firewood plays in meeting the energy needs in Kenya, and not simply view it in terms of negative environmental impact. Indeed, shifting from firewood to charcoal or kerosene does not automatically lead to positive impacts as historically presumed. Recent studies show that charcoal production has a worse impact on the environment compared to firewood collection as trees and shrubs are cut down in the former, while in the latter, pruning, deadwood, and forest respectively are the main sources. Kerosene, on the other hand, is unaffordable for the majority of poor households and fails to provide the highly appreciated space heating that allows families to sit around the fire and socialize, especially in the evenings. Concerted effort across sectors is required to understand and regulate the sourcing and use of firewood in a way that minimizes its negative impacts on environment and health. Firewood is becoming increasingly commercialized, thereby creating an opportunity for regulating this sector in ways that have not been available previously.

With a current enrolment rate of about 1.5 million, the Home grown School Feeding Program (HGSFP), introduced in 2009 by the World Food Program and the Government of Kenya, will contribute greatly to demand for firewood in Kenya. For a nine-month school term, this program projects 405 million meals cooked over a year's period, and 4.05 billion meals over a ten-year period. Calculating a mature tree weight at 432 kg for a 20-foot pine tree, with smaller diameter of 12 inches and larger diameter at 18 inches, cooking that number of meals over a period of ten years will require an estimated 2,122,200 trees.

Charcoal

In Kenya, charcoal production is still considered an illegal activity despite the existence of a loosely implemented legal framework for the production, distribution and movement of the fuel.[3] Consequently, charcoal is produced in an uncoordinated fashion and using very low-efficiency technologies. This often leads to massive waste of the biomass feedstock, hence accelerating the rate of deforestation. Furthermore, there are health hazards associated with the use of charcoal. When charcoal is burnt, it produces carbon monoxide.

If charcoal is used in a room that is not well ventilated, it could lead to accumulation of high concentrations of carbon monoxide. Carbon monoxide is a poisonous gas that can lead to death if it gets into the blood circulation system in large quantities. Usually, charcoal is relatively low-cost and affordable. But because the poor buy it in small quantities, it ends up being more expensive in the long run when compared to buying it in bulk, e.g., as a 36 kg sack of charcoal. An analysis of the expenditure on charcoal, shown below, demonstrates that buying charcoal in small quantities can be about four times more expensive than buying it in bulk.

[3] The Energy Act and Policy, the Forest Act and Draft Forest Policy recognize charcoal as an important source of energy and make provisions for its sustainable production, commercialization and utilization. In addition, the Ministry of Forestry and Wildlife has developed and gazette subsidiary charcoal legislation to ensure these policies are acted upon. Despite all efforts made so far, the provisions of these policies and legislation are not known to the key value chain actors. The result is that all actors continue to operate just as they did before the policies and legislation were enacted

Table 9. Cost of fuel in Kisumu market

Cost of charcoal in bulk (36 kg sack) = $5.00 per sack
Hence, unit cost of charcoal in bulk = $ 0.14 per kg
Retail cost of charcoal in 0.4 kg tins = $ 0.55 per kg

Based on Vincent Okello's primary research

Charcoal is used by 82 per cent of urban and 34 per cent of rural households in Kenya. The charcoal industry employs over 700,000 people who support over two million dependents. Despite charcoal being an important energy source, its production and transportation still faces numerous challenges, and its true value is not captured in the national economic statistics. The charcoal industry has continued to have a low profile, and this has made it difficult to access funds for investing in product development, a crucial first step towards commercialization (FAO, 2009).

Electricity

1,989,740 households were reported as having electricity during the 2009 census, which was 22.7 per cent of the total national number of households.

Electricity contributes only 9 per cent of the total energy needs in Kenya, after biomass (68 per cent) and petroleum (22 per cent). It is costly in Kenya due to the high costs of generation, currently estimated at US $11.30. Commercial/industrial tariff is at US $0.14 and domestic tariff is at US $0.20. There is a low supply and it is difficult for the country to meet its energy demand. There is a lack of major investments in the sector by the private sector. The electricity is not affordable. There are high power losses along the weak transmission and distribution networks, frequent power outages, and low voltages contributing to high tariffs and low connectivity rates. There is also vandalism and theft of transformers and power cables escalating the cost of maintaining electricity connections. It is used primarily for lighting in the urban areas and does not feature significantly as a household energy source for cooking in the rural areas.

Kerosene

In the 2009 National Census, 2,670,387 (30.5 per cent) and 3,373,126 (38.5 per cent) reported use of kerosene lanterns and tin lamps respectively, though the figure does not indicate whether the households owned both. Kerosene is notoriously unsafe to use and store in poor households. Even though it is a popular fuel for both cooking and lighting among poor households, it produces noxious fumes during combustion, offers poor quality light when used in a lantern. It also causes frequent accidents through explosions after gas build up during use, is frequently ingested by small children who mistake it for water, and adds a 'kerosene smell' to food during cooking as well as to the fabrics and household goods in homes that use it.

Kerosene is also a lucrative retail trade good, and its highly developed supply chain means that the litre that is purchased for just below US $0.65 at the pump, ends up costing double the amount by the time it is distributed in smaller quantities of 0.2 litres among poor households. Kenya does not subsidize kerosene, but removed the value added tax (VAT) of 16 per cent from the pump prices in May 2011. Kerosene is often regarded as a “poor man’s fuel” and is used by approximately 92 per cent of all households (rural 94 per cent; urban 89 per cent).

Liquid Petroleum Gas (LPG)

Kenya consumes about 2.1 kg per capita of LPG. The demand for LPG in the country has risen from 78,000 tons in 2008 to the current level of 100,000 tons. Less than half a percent of the households surveyed in the 2009 national census have an LPG lantern or use it for lighting purposes. It is relatively costly, retailed in bottles of 6 kg, 12 kg, and 13kg for domestic use, at KES 1300 and KES 2700 per bottle respectively. There are no LPG subsidies in play in Kenya at the moment.

LPG is used today by 0.6 million urban households (25 per cent of households) and 0.1 million rural households (1 per cent of households) at an average price of US $2.50/kg (which is significantly higher than regional averages).

Pima Gas is an LPG initiative promoted by Premier Gas, aimed to overcome these issues by offering a 1 kg gas cylinder and refills for as little as 50 KES (US $0.60). The scheme has started rolling out in Nairobi with dispensers located in low-income areas around the city, achieving 1,500 users in the first month. Initiatives were done on a trial basis in the LPG sector to target low income households by reducing the upfront cost of LPG hardware and refilling costs. Valve incompatibility across gas bottles from different retailers locked in customers to specific brands, but after the Kenyan government made it a law to ensure compatible valves, it opened up the market to new customers and increased uptake.

Biofuels: Ethanol, Plant Oils, and Biodiesel

A range of biofuels and feedstock products received a lot of attention that has since diminished in the light of market and technical realities. Jatropha was intensely promoted as a ‘poster’ crop in the arid and semi-arid lands (ASAL) in Kenya, but the efforts to actually develop the feedstock as a household fuel seemed to have reduced considerably.

In 2006, an Energy Act was passed which mandated the government to pursue and facilitate the production of biofuels. An official Kenyan government strategy paper followed this on biodiesel in 2008, which specifically focuses on growing jatropha.

“Jatropha is just not viable in Kenya,” says Violet Mogaka, a researcher with the World Agroforestry Centre, and lead author of a study recently published in Energy for Sustainable Development. “Jatropha should be abandoned in Kenya until improved seed material and locally-adapted knowledge about its cultivation becomes available, and until it becomes economically competitive.” (Langford, 2015)

The project “Piloting Bioethanol as an Alternative Cooking Fuel in Western Kenya” sought to pilot an ethanol stove and fuel market system in the Kisumu area. The overarching objective of the pilot project was to test the viability of ethanol as a clean, affordable, and easily accessible household fuel and to stimulate demand for it in households in the target area and ultimately, elsewhere in Kenya (UNDP, 2015). The success of the pilot was a demonstration of the viability of both fuel and stove technology, with overwhelming user acceptance and determination of possible value chains. The ethanol was locally sourced and the stove promoted was the Dometic CLEANCOOK Stove. This success was closely followed by Safi International’s rollout in Kibera informal settlement of its Safi eCooker, in imitation of the CLEANCOOK’s successes in Kisumu (Safi International, 2015).

Current Initiatives to Promote Clean Cooking

Programs have also been implemented with the involvement of civil society organizations. Some have been run jointly with the Kenyan government, for example the UN Development Program’s Development and Implementation of a Standards and Labelling Program in Kenya and Access to Clean Energy Services in Kenya. Some of the private initiatives implemented include the Africa Biogas Partnership Program (ABPP) run by SN/Hivos of the Netherlands and Kenya National Federation of Agricultural Producers (KENFAP), Lighting Africa, a joint International Finance Corporation (IFC) and World Bank program, and various initiatives by key private sector players such as the Global Village Energy Partnership (GVEP) and the Renewable Energy and Energy Efficiency Partnership (REEEP).

Currently the Global Alliance for Clean Cookstoves (GACC) stands as the largest initiative in the region to promote both clean cook stoves and fuels. Under the mantra “Cooking shouldn’t kill,” it has mobilized global resources from international donors, governments, and private investment to stimulate the uptake, development, distribution, and market development of improved cook stoves and fuels. In Kenya, it targets the distribution of the interventions to at least one million homes. Almost all other players in the region have tagged onto the GACC’s campaign, currently locally managed by the Clean Cookstoves Association of Kenya (CCAK), and supporting local institutions such as the Improved Stoves Association of Kenya (ISAK).

The cook stove value chain in Kenya is fragmented with several options for production and distribution existing. Components are often made separately and assembled by other businesses. Several middlemen exist in the value chain before stoves are sold through markets and retailers. Cook stove and fuel adoption or choice is influenced by 12 main variables that influence purchase:

(1) Age
(2) Gender
(3) Head of household
(4) Home ownership
(5) Family size
(6) Geographic location
(7) Fuel used in cooking
(8) Employment (income quintiles)
(9) Fuel access
(10) Education level
(11) Fuel cost
(12) Willingness to pay

Improved cook stove adoption and fuel choices are significantly influenced by socio-economic status and demographic profile of households, energy choices and uses, and energy costs and expenditures. The Kenya Consumer Segmentation study found that most of the segments indicated high willingness to purchase new improved cook stoves (ICS), as shown by selected segments in the table below.

Map 2. Kenya Consumer segmentation

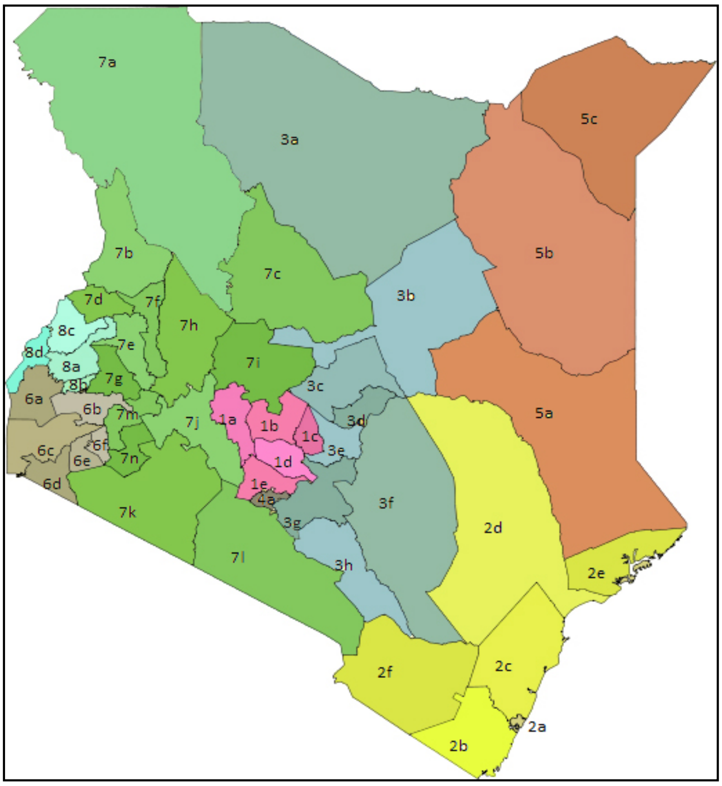
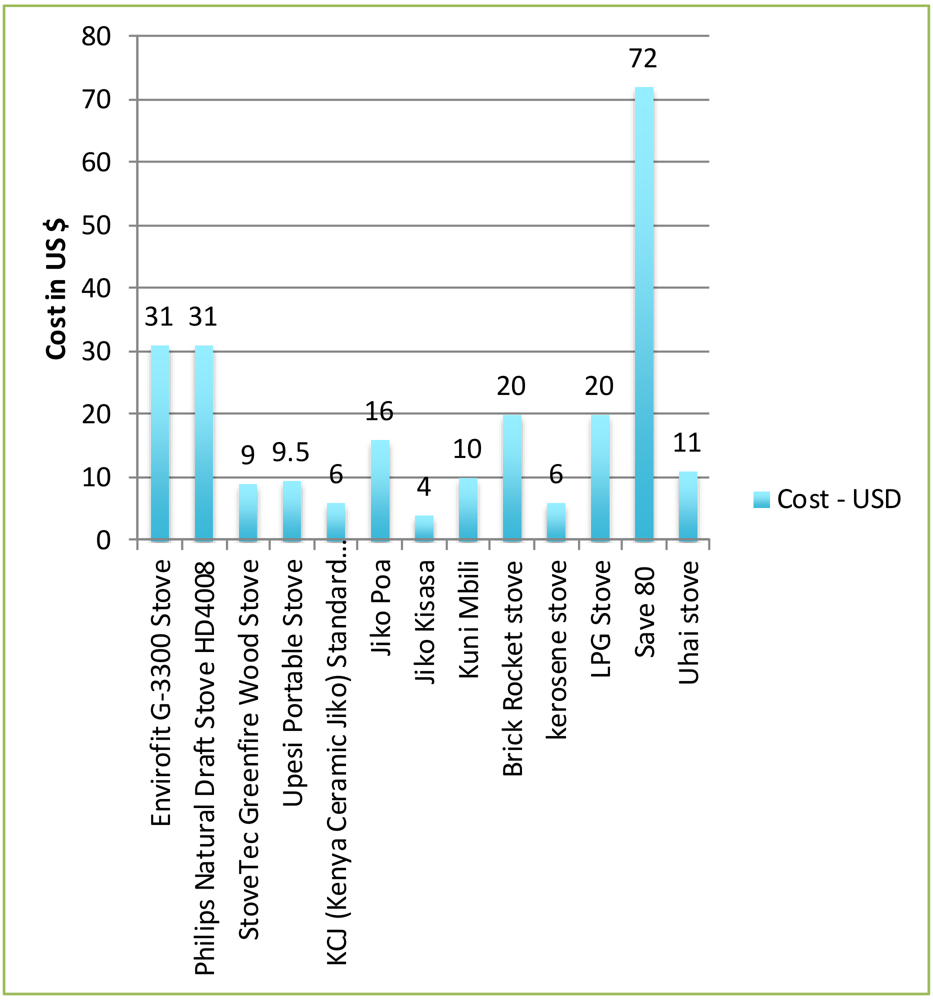


Table 10. Kenya Market Segmentation Study

Location	Willingness to pay
Segment 1a - Central region- rural fuelwood cook stove users (Murang'a)– Low income	98%
Segment 1b – Central region- Urban charcoal cook stove users (Nyeri)– High income	93%
Segment 2 –Western Region – Rural fuelwood cook stove users (Kakamega) – Middle income	94%
Segment 3a Coastal– Rural fuelwood cook stove users(Kilifi)– High income	96%
Segment 3b Coastal – Urban charcoal cook stove users(Kilifi)– Middle income	99%

Source: Global Village Energy Partnership International, Kenya Market Segmentation Study.

Graph 1. Improved Cook Stoves Current Market– Upfront Costs



Source: Global Village Energy Partnership International, Kenya Market Segmentation Study.

Average cook stove prices range from US $3.50 for a moderately improved charcoal cook stove to US $100 for a top of the line imported improved forced-draft Philips fan stove. LPG and electric cookers range from US $50 for single burner counter top units up to US $120 for deluxe models. Portable firewood stoves cost as low as US $9 for the locally produced Upesi woodstove and US $50 for the Envirofit single burner with pot skirt models. Charcoal prices per day per family cost US $5 for single tin purchase of about 2 kg.

Modern ethanol gel fuel stoves cost US $30 in supermarkets for a single burner stove and about US $0.90 for a litre of the gel fuel for a day's cooking.

Biomass energy, kerosene, LPG, and electricity stand as the four most important fuel energy carriers under consideration for the Kenyan fuel user (Global Network on Energy for Sustainable Development, 2008). The requisite infrastructure for the promotion and use of these energy options is already in place and can be piggy-backed on by new initiatives that seek to introduce new fuels and stoves into the sector.

The Global LPG Partnership (GLPGP) complements the work that is being done by GACC. With its initial focus on five countries[4] in Sub-Saharan Africa, GLPGP aims to transition 50 million to 70 million people to LPG for cooking, create over 150,000 new jobs, and offset more than 18 million metric tons of wood used for cooking per year.

Lack of large storage facilities in the country means only small consignments of LPG could be brought in at any given time and these could still be subject to unforeseen hitches. A public-private partnership will see the construction of a 7,000 metric ton storage facility that is being built by Africa Gas and Oil Company. Initially, it will be for 7,000 tons and thereafter, it will increase to 14,000 tons and then up to 25,000 tons. In order to reach its objectives, GLPGP seeks to mobilize financial investments and policy reforms to support (i) consumer finance and education, (ii) a supportive policy, regulatory, and safety environment, and (iii) LPG infrastructure and distribution development to meet consumer demand. The GACC identified Kenya as one of its focus countries in its goal to provide clean energy access to 100 million households by the year 2020.

Overview of Current and Projected Ethanol Production

Production of ethanol in Kenya is closely tied to sugar production because of the raw materials used in ethanol distillation.

Several key institutions also play a role in Kenya's sugar value chain. These include:

(1) The Government of Kenya (GOK), which is responsible for the sector's overall development, and is a significant sugar industry shareholder
(2) The Kenya Sugar Board (KSB), which is a public body responsible for industry regulation, promotion, coordination and equity insurance; and

[4] Countries that GLPGP will focus on in SSA are Cameroon, Ghana, Kenya, Tanzania, and Uganda

(3) The Kenya Sugar Research Foundation (KESREF), which is responsible for the development and transfer of appropriate technology in the sugar sector.

The Kenya Sugar Board is the regulatory body of the sugar industry, established April 2002, under the Sugar Act of 2001, succeeding the defunct Kenya Sugar Authority. The mandate of the Kenya Sugar Board as stipulated in Section 4(1) and 4(2) of the Sugar Act pf 2001 is as follows:

(1) Regulate, develop and promote the sugar industry.
(2) Coordinate the activities of individuals and organizations within the industry.
(3) Facilitate equitable access to the benefits and resources of the industry by all interested parties.

In 2013, the Board required firms to start ethanol and electricity production in the next two years as a precondition for operational licensing.

Bioethanol in Kenya is produced through the distillation of molasses, which is a waste product from the sugar production process. The largest producers in Kenya are Mumias Sugar Company, Spectre International Limited, and Agro-Food and Chemical Company. A significant product from molasses distillation is Extra Neutral Spirit, a pure potable alcohol used in the manufacture or blending of alcoholic beverages conventionally prepared as gins, vodkas, whiskies, brandies, and rums, and in fortification of wines and cream liqueurs. It is also used for a wide range of other industrial manufacturing applications where it is usually referred to as 'highly quality industrial alcohol.'

Molasses enjoys a lucrative underground market especially since sugar factories are not obligated to dispose of their supplies in a formal manner. There exists an elaborate market chain that disposes quite lucratively of the existing supplies, primarily to micro-distillers and other producers of illicit alcoholic drinks. There is no excess molasses in Kenya.

Recently the Kenya Bureau of Standards withdrew the licenses of 300 second generation liquor brands after the government ordered a crackdown on the production, distribution and consumption of the alcohol (Mukami, 2015). Media reports estimated that producers and other supply chain players lost about US $50,000,000 during the crackdown (Gitonga, 2015). The crackdown indirectly highlighted the widespread nature of the micro-distilleries in the country, both in terms of numbers and spread of technologies. It shows that the production of the alcoholic beverages enjoys communal level knowledge and depth of supply chain realities, and implies that with the support of formal systems and government structures, production would shoot very quickly in a short period.

Regionally, Kenya is a member of the Common Market of Eastern and Southern Africa (COMESA). It is a regional economic cooperation organization, working to reduce trade barriers applied to goods produced within and traded among its 19 member countries. Under COMESA, a Free Trade Area has been in effect since 2000. For successive years, Kenya has been obtaining deferment of COMESA rules application to safeguard its inefficient sugar industry from competition from the other COMESA states that run better sugar industries.

Ethanol Production Capacity

There are currently 11 operating sugar factories in Kenya. One more (Kwale International Sugar Company Limited, or KISCOL) is the most recently commissioned. KISCOL intends to install a state-of-the-art distillery for production of 30,000 litres/day of ethanol from molasses as a byproduct of sugar production. All factories generate the steam and power required for their own operations from sugar cane waste, known as bagasse. Only one factory (Mummies) is currently producing surplus power for export. Despite this, there is little evidence of unused molasses in the sector, and this study hypotheses a shortage of the material, in light of the various molasses value chain uses in the illicit production of alcohol which makes it commercially valuable.

Table 11. Ethanol production capacity from sugar companies-Kenya

Sugar Company	Tons Crushed per Day (TCD)
Mumias Sugar Company	8,600
Sony (South Nyanza) Sugar Company	3,000
Chemelil Sugar Company	3,000
Nzoia Sugar Company	3,000
Muhoroni Sugar Company	2,000
West Kenya Sugar Company	2,500
Kibos and Allied Industries	800
Butali Sugar Mills	2,500
Sukari Industries	1,500
Transmara Sugar Company	1,250
Soin Sugar Company	100

Projections in 2009 indicated that Kenya would require 1.7 million litres and 4.1 million litres of petrol and automotive diesel respectively per day by 2014. By 2030, fuel consumption will be 2.7 million litres and 6.5 million litres of petrol and automotive diesel respectively per day. Currently, Kenya requires 85 million litres of ethanol per year for a national 10 per cent (E10) blend. At current consumption levels, this would need to grow to 93 million litres and 148 million litres by 2014 and 2030 respectively. It is estimated that a ton of molasses can be converted into 220 litres of ethanol.

Sony Sugar Company completed a feasibility study for 35-kiloliters per day (KLPD) ethanol distillery utilizing molasses from the sugar plant that has been completed. An Environmental Impact Assessment (EIA) study was completed, and the firm is currently sourcing funding for the planned plants. The company is therefore venturing into co-generation, ethanol production, water bottling, and briquettes production.

Spectre International distils approximately 60,000 litres of ethanol daily, which is less than half its capacity of 175,000 litres per day. Low supplies of molasses and other raw materials has limited Spectre's production to below its capacity. Spectre exports its ethanol but some of it is used locally. It is the lucrative local market that has led to the development of a booming diversion trade. Local ethanol is subject to 100 per cent excise duty and 16 per cent VAT, but export ethanol is not taxed, hence the tendency to divert export product into the local market. Mumias Sugar Company is responsible for between 60 per cent and 65 per cent of the total amount of sugar produced annually in Kenya. This also makes it the largest sugar manufacturing operation in all of East Africa. It is implementing an ethanol project with production capacity for technical alcohol (96.5 per cent alcohol concentration) of 4,000 litres for every eight-hour shift, expected to rise to 22 million litres annual production at full operational capacity. It sells technical alcohol and has so far been selling to firms that secured tax exemption and purchase it at KES 20.00 per litre. The Mumias ethanol project produces extra neutral spirit, which is used for alcohol production, besides the technical alcohol (TA) that is generated for industrial use. However, Mumias is currently not producing in light of the plant maintenance and general factory management wrangles and economic downturn.

Agro Chemical and Food Company: The installed capacity of the alcohol plant is 18 million litres of alcohol per year. Its major products are alcohol, active dry yeast (ADY), and wet yeast (WY). The ADY plant has achieved its installed capacity of 1,200 tons and requires immediate expansion due to rising demand. Wet yeast has not, but it has a good potential for acceptance in the bakery segment market. Despite its government ownership ACFC has to compete for supplies of molasses like the other distillers. It is not clear at the time of this survey how much ethanol ACFC was producing due to uncertainties arising from the alcohol crackdown. The beverage alcohol production market is significant and is supplied by all three of these major producers.

The Major Actors in Clean Cook Stoves

In the clean cooking sector, there are many actors in Kenya. For example, EcoZoom is a social enterprise working to make improved cook stoves accessible and affordable in developing countries. EcoZoom has the exclusive rights to internationally distribute cook stoves engineered by the Aprovecho Research Centre, a leader in the design, engineering and testing of improved cook stoves (ICS). EcoZoom has made Kenya the lead market for its stove product, the Zoom-Jet firewood stove.

In 2008, GVEP began the 'Developing Energy Enterprises Project (DEEP)' in East Africa in order to create a sustainable and widespread network of energy entrepreneurs involved in the manufacture and/or supply of clean cook stoves, solar PV products and services, clean fuel briquettes, and biogas systems. This program was set to deliver energy access to 1.8 million people in Kenya, Tanzania, and Uganda. Working with women and men in over 900 energy-related micro, small and medium enterprises (MSMEs), the program has far exceeded its goals with over 4 million beneficiaries as of February 2013.

Practical Action (EA) has been a key factor in the ICS sector in Kenya from the early 1980s when it was known as Intermediate Technology Development Group (ITDG). Through its Rural Stoves West Kenya Project, it developed key technologies and initiatives that resulted in women stove producer groups that work 2 to 3 days per week on average, selling 510 stove liners/year (per person working); receive incomes of US $175 annually per woman in each producer group with stove promoters earning an average of US $200 USD annually; and saving cook stove users up to US $82 annually with fuelwood savings of up to 43 per cent. Additionally, time savings of about 10 hours/month were reported along with smoke reduction of 60 per cent. Additional reported achievement was the reduction of acute respiratory infections in children by 60 per cent, and in mothers by 65 per cent (Njenga, UNDP, 2001).

CARE's wPOWER program works through CARE's 10,000 existing Village Savings and Loans Associations (VLSA) which have over one million members, as well as their Village Agent (VA) trainers across Kenya, Rwanda, and Tanzania. The program uses training, access to quality products, and microfinance to empower female VAs to work in the clean energy sector and establish micro-enterprises. They work with private sector partners who use the VSLAs as a network to access both urban and rural markets. The goal of the program is to train over 3,000 VAs to become clean energy-entrepreneurs, selling a bundle of clean energy products to VSLA members and beyond. Ex-Spring Valley Kayole (ESVAK) is a Kenyan Community-Based Organization (CBO) working to create sustainable initiatives that empower community members. ESVAK is currently working with the US-based Johns Hopkins University to implement a capacity-building program focused on empowerment training to help marginalized Kenyan women to become cook stove entrepreneurs. ESVAK, Johns Hopkins University, and Envirofit are conducting systematic research examining the role of this empowerment workshop in improving the selling, distribution, and adoption of improved cook stoves in Kenya.

EnDev Kenya facilitates promotion of ICS in the Transmara, Western, Lower Eastern, and Central districts. ICSs are much more efficient and resource-friendly than traditional stoves or three-stone fires. EnDev Kenya supports individuals, institutions, or groups involved in the market of energy saving technology by providing training in technical and business skills.

EnDev established financing mechanisms to provide loans that link financial institutions, small and medium enterprises, and customers.

Other Stakeholders in the Improved Cook Stove Sector

- Government initiatives and departments: Ministry of Energy, Ministry of Agriculture, Ministry of Health, Ministry of Environment and Natural Resources, National Environment Management Authority (NEMA), National Economic and Social Council (NESC), Kenya Bureau of Standards (KEBS), Kenya Industrial Research Development Institute (KIRDI), Energy Regulatory Commission (ERC), and the Community Development Trust Fund (CDTF).
- Donors: European Union (EU), the Dutch Directorate-General for International Cooperation (DGIS), World Bank, the UK Department for International Development (DFID), the US Agency for International Development (USAID), Shell Foundation, the Dutch Humanist Institute for Cooperation (HIVOS), the German government, and the Global Environment Facility (GEF).
- International NGOs: Practical Action, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), CARE International, GVEP International, SNV Netherlands Development Organization, East Africa Energy, UN High Commission for Refugees (UNHCR), Millennium Village Projects, International Lifeline Fund, World Vision, Food for the Hungry, Energy Sector Management Assistance Program (ESMAP), UN Development Program (UNDP), Rural Energy Technology Assistance Programme (RETAP), Energy, Environment and Development Network for Africa (AFREPREN/FWD), and Winrock International.
- Private Sector: Paradigm Project, Musaki Enterprises, Improved Stoves Association of Kenya (ISAK), Premier Gas Company Limited, Keyo Pottery Enterprise, Kartech, Envirofit, Unilever, Ekero, Riumbaini Energy Saving Stoves, Lakenet Energy Solutions, Chujio Ceramics, Rural Technology Enterprise, and Fine Engineering.
- Carbon projects/developers: CO2Balance, Carbon Manna, Eco2librium[5], Impact Carbon, My Climate, and Climate Pal limited.
- Research organizations: University of Nairobi, African Centre for Technology Studies (ACTS), and Berkeley Air Monitoring Group.

Relevant Government Energy Policies

(1) Kenya Vision 2030 recognizes energy as central to the economic, social, and political development of the country. It is an energy policy providing a framework for "cost-effective, affordable, and adequate quality energy services" on a sustainable basis over the period 2004-2023, developed by the Kenyan

[5] A certified B Corporation, uses business solutions to affect social and environmental change

government. Vision 2030 as a key government policy framework positions the agricultural sector as a key driver for delivering the 10 per cent annual economic growth rate envisaged under the economic pillar of Vision 2030. The sector has set itself a goal of achieving an average growth rate of 7 per cent by 2015. A key thrust of the current agricultural development strategy is to increase productivity, commercialization, and competitiveness of agricultural commodities and enterprises.

(2) Kenya's power industry generation and transmission system planning is undertaken on the basis of a 20-year rolling Least Cost Power Development Plan (LCPDP). According to this plan, the forecast demand and energy is 1,205 MW and 7,391 GWh in 2009 rising to 15,065 MW and 92,380 GWh by 2030. The optimal development plan includes geothermal, hydro, wind, imports, thermal, coal, and nuclear energy sources.

(3) Rural Electrification Authority (REA) was formed under the Energy Act 2006, to develop and update the Rural Electrification Master plan (REM) and promote the use of renewable energy sources. The REM recognizes that Kenya has considerable potential for renewable energy, mainly through solar photovoltaic cells, for less developed, sparsely populated areas. It recommends exploiting wind energy as a substitute for fossil fuels, conducting detailed feasibility studies for small hydro projects for rural electrification and exploiting the potential for energy generation from biomass.

(4) The Energy Sector Plan 2008-2012 identifies various flagship projects for implementation in the medium term linked to the objectives of Vision 2030. The strategic objectives over the five-year period are to increase power generation capacity, increase electricity access, develop new and renewable energy technologies, and improve security of the supply of petroleum fuels.

(5) The government has developed the Solar Water Heating Regulations to make it mandatory for all premises within the jurisdiction of a local authority with hot water requirements exceeding 100 litres per day to install and use Solar Water Heaters. Plans on charcoal, firewood, biogas, LPG and kerosene strategies are also to be developed.

(6) A National Climate Change Response Strategy of 2010 has been established as one measure of mitigation and adaptation to climate change. Apart from the focus on pursuing an energy mix that emphasizes carbon–neutral energy sources it also reviews the country's building codes to incorporate measures that will encourage climate–proofing and the construction of energy–efficient buildings.

(7) Under the Feed-in Tariff policy (2008, revised 2010), a total of 2,050 MW of capacity from 47 separate projects (13 small hydro, 16 wind, six biomass, and one solar projects) have been approved for development. The tariff ranges from US $0.06/kWh to US $0.12/kWh, with a special rate of US $0.85/kWh applied for geothermal power. These tariffs are secured for 20 years.

Other Relevant Government Policies

The policy climate still remains an unclear area that requires careful navigation. The list below is a summary of pertinent policy documents that must be considered in the development of fuels.

Table 12. Government policies pertaining to Ethanol production

Environmental policy documents such as Environmental Management and Coordination Act, (EMCA)	1999	The Environmental Impact Assessment (EIA) regulations state that "no licensing authority under any law in force in Kenya shall issue a trading, commercial or development permit or license for any micro project activity likely to have cumulative significant negative environmental impact before it ensures that a strategic environmental plan encompassing mitigation measures and approved by the Authority is in place".
Environmental Management and Coordination (Water Quality) Regulations	2006	Water Quality Regulations outline Standards for effluent discharge into the environment; and a monitoring guide for discharge into the environment, key considerations in sugar industry operations.
Environmental Management and Coordination (Waste Management) Regulations	2006	Outlines requirements for handling, storing, transporting, and treatment/ disposal of various categories of waste and its disposal by NEMA licensed company.
The Sugar Act	2001	Governs the operations of the Kenya Sugar Board.
The Agriculture Act (Cap 318)	2012	An Act of Parliament to promote and maintain a stable agriculture, to provide for the conservation of the soil and its fertility and to stimulate the development of agricultural land in accordance with the accepted practices of good land management and animal husbandry. It permits "Fixing of prices for scheduled crops" and formation of agricultural committees and boards.
The Water Act	2002	Establishes the Water Resources Management Authority and defines its duties, regulates the ownership and control of water. Makes provision for the conservation of surface and groundwater and the supply of services in relation with water and sewerage.
The Public Health Act (Cap 242)	2012	Makes it an offence if the landowner or occupier allows nuisance or any other condition injurious to health in his premise, such as obstruction, smell, accumulation of waste or refuse, smoky chimneys, dirty dwellings, premises used without sanitation, and factories emitting smoke or smell.
The Forest Act	2005	provision for the conservation and management of public and private forests and areas of forest land that require

		special protection, defines the rights in forests and prescribes rules for the use of forest land.
Alcoholic Drinks Control Act	2010	Imposes stiff penalties on illicit production and distribution of alcohol (beverage).
The Alcoholic Drinks Control (Amendment) Bill	2013	As above
Laws of Kenya National Authority for the Campaign Against Alcohol and Drug Abuse Act	2012	Supplements law enforcement on illicit alcohol use and drug abuse
The Value Added Tax Act	2013	Determines the 16% value added tax rate.

Exemptions: These are currently granted on a case-by-case basis and can be a protracted process with long waiting periods. The process involves getting a project approval from the Ministry of Energy and Petroleum, after which the application is then submitted to the National Treasury and the Kenya Revenue Authority. The exemption is only allowed for limited and controlled quantities of ethanol for a specific period of time, making it hard for business forecasting (UNDP, 2014).

Table .13. Kenya-Excise duty rates

Goods	Description or Usage	Rate of Duty € (EUR)
Electricity	Business use	0.50 per megawatt hour
	Non-Business Use	1.00 per megawatt hour
Spirits		42.57 per litre of alcohol in the spirits
Beer	Exceeding 0.5% volume but not exceeding 1.2% volume	0.00
	Exceeding 1.2% volume but not exceeding 2.8% volume	11.27 per hectolitre% of alcohol in the beer
	Exceeding 2.8% volume	22.55 per hectolitre percent of alcohol in the beer
Wine	Still and sparkling, not exceeding 5.5% volume	141.57 per hectolitre
	Still, exceeding 5.5% volume but not exceeding 15% volume	424.84 per hectolitre
	Still, exceeding 15% volume	616.45 per hectolitre
	Sparkling, exceeding 5.5% volume	849.68 per hectolitre

Source: Revenue: Irish Tax and Customs, 'Excise Duty Rates', last modified 2015, accessed September 22, 2015, http://www.revenue.ie/en/tax/excise/duties/excise-duty-rates.html.

The categorization of ethanol as a spirit within the Kenyan tax regime puts it under the excise duty brackets, as follows;

- It is a duty imposed on goods and services manufactured in Kenya or imported into Kenya as specified in the 5th Schedule of the Customs and Excise Act Cap 472 of the Laws of Kenya. The Excise duty on locally manufactured excisable goods and services is payable to the Commissioner of Domestic Taxes at the rates specified in the 5th Schedule
- It is a specific duty rate, which refers to where a specified amount of tax is charged per unit of measure of an excisable product e.g. KES 120 per litre of spirit
- Ethanol is classified as a spirit. Spirits attract KES 120 per litre or 65 per cent of the excisable value
- All manufacturers, providers, and importers of excisable goods and services should pay excise duty
- Excise duty on spirit shall be charged and collected upon delivery of the spirit from the compounders (bottlers)
- Duty paid on neutral spirit upon delivery from the distillery or importation shall be deducted in accordance with Section 149A. Where a compounder is also a distiller, duty shall be charged only once at the point of delivery of the finished spirit product.[6]

Conclusions and Recommendations

(1) The multi-billion new corridor, the Lamu Port-South Sudan-Ethiopia, or LAPSSET, linking the Lamu Port with South Sudan and Ethiopia, stands out as a significant investment in energy infrastructure in the region. However, local impacts are unlikely to be felt in the short and medium terms. The discovery of oil, methane and natural gas in the region has been significant. Local utilization of oil products still falls short of the levels required to sustain commercial extraction of the deposits.

(2) This means that external investments will be needed to finance the extraction of the new fossil fuel discoveries. The returns from these investments, also expected to be in the hundreds of millions of dollars, are unlikely to benefit the household and small-scale energy service consumers in the short and medium terms. This implies the need for investments in the immediate term to cater to the clean energy needs of small-scale disaggregated users. Their needs involve for their cooking, lighting, and commercial use purposes, and the need to address the related supply chain and distribution systems as with the proposed micro-distilleries.

(3) Kerosene is the most important modern energy option for the poor for both lighting and cooking. Electricity also appears to be a relatively important energy option.

[6] Kenya Revenue Authority, *The Customs and Excise Act (Chap 472)* (Government of Kenya, n.d.).

Biomass in the form of charcoal and LPG appear to be consumed by a relatively small segment of the urban poor.

(4) The poor tend to pay more per unit of energy than other socio-economic groups due to the lack of economies of scale in the retail trade, especially for kerosene and charcoal, sometimes as much as double the general retail price.

Local Considerations

In 2014, agriculture, forestry, and fishing contributed KES 1,464,310,000 to the national GDP and of this, growing crops contributed KES 1,057,882,000, or 72 per cent of the total. In 2010, this was 67.4 per cent; in 2011, it rose to 70 per cent, dropped marginally to 68.9 per cent in 2012, and rose again to 69.9 per cent in 2013. It has been rising in terms of proportion of contribution to the GDP, and this is expected to be sustained. Between 2010 and 2012 the value of growing crops (as a percentage of the value of agriculture to the GDP) rose 29 per cent, then another 12 per cent in 2012 and another 21 per cent in 2013, for a sustained growth trend.

The introduction of cash crop feedstock production in the main producer regions of Kenya, from the trend shown above, is quite likely to sustain growth contributions and profitability, and so this survey recommends the introduction of selected cash crops as feedstock material for micro-distilleries.

Gender Perspective for Implementing Ethanol Production and the Adoption of Clean Fuels

Several reports exist, that analyze and investigate the importance of effectively integrating women into energy initiatives through gender mainstreaming practices. But there has not yet been a practical guide on how to specifically integrate women throughout the clean cooking sector, until the Global Alliance for Clean Cookstoves (GACC) developed its resource, Scaling Adoption of Clean Cooking Solutions through Women's Empowerment (GACC, 2015).

The GACC recognizes that women have critical roles to play across the entire clean cooking value chain, and has explicitly prioritized women in their mission to save lives, improve livelihoods, empower women, and protect the environment by creating a thriving global market for clean cook stoves and fuels. With a global target of reaching 100 million households with clean stoves and fuels, the GACC's effort remains the single most significant effort to promote gender issues in the adoption of cooking fuels.

Potential for Ethanol to displace other fuels

Petroleum products are an important source of government revenue because they attract excise duty, petroleum development duty, and road maintenance levy which are vital to funding government activities. Therefore, there is little enthusiasm to regulate its cost downwards, further implying that consumers are not always able to enjoy international oil price reductions in the country.

This thirst for tax revenues makes it therefore unlikely, in the view of this survey, for electricity to become a key source of cooking energy in the short to medium term, given the significant portion of its cost that is made up of taxes that feed a government hungry for revenues to finance a new constitutional dispensation. Options such as ethanol stand higher chances to displace polluting fuels from households, due to factors of production, local availability of the bulk of the raw materials. However, ethanol faces a hostile policy climate. It is important to note here that there is a distinction in government between the revenue managers and the energy access managers. What is needed is a clear demonstration of the win-win situation that is expected when VAT is extracted from sales of the fuel to large numbers of Kenyan users, which is currently not happening.

The latter are fully convinced of the viability of clean fuels such as ethanol, but the revenue managers are placed at critical policy seats that hinder any proposals that would dilute government revenue streams[7]. Studies such as the ethanol pilot in Kisumu demonstrated that ethanol use is extremely cost effective in relation to both charcoal and kerosene, over the long-term period, but only with the removal of the excise taxes applicable and arising from wrongful product classification in the revenue collection troughs.

Government likelihood on policy change and how to affect change

The Ministry of Energy is the lead institution entrusted with the mandate and responsibility of facilitating the provision of secure and sustainable supplies of energy for socio-economic development.

The New Energy Bill 2015 is a good attempt to recognize the changing environment of energy regulation in Kenya. For instance, there is recognition of different sources of renewable energy and the creation of the corresponding licensing and regulatory agencies.

It provides for the establishment of the National Electrification and Renewable Energy Authority, mandated among others,

[7] UNDP in Kenya, 'Piloting Bioethanol as an Alternative Cooking Fuel in Western Kenya'.

"(l) to undertake feasibility studies and maintain data with a view to availing the same to developers of renewable energy resources;
(m) develop and promote, in collaboration with other agencies, the use of renewable energy and technologies, including but not limited to biomass, biodiesel, bio-ethanol, charcoal, fuel-wood, solar, wind, tidal waves, mini-hydropower, biogas, co-generation and municipal waste…" [8]

It also creates a plethora of regulatory bodies all of which have different incorporation identities such as an "Agency" (the Centre for Energy Efficiency and Conservation), an "Authority" (the Energy Regulatory Authority, or ERA), a "corporation" (the Rural Electrification and Renewal Energy Corporation), an "institute" (the Nuclear Electricity Tribunal), and a number of advisory committees. However, while each of these entities has its own legal personality and is capable of suing and being sued, it would have been more user-friendly to have a homogenous set of regulatory bodies with similar corporate structures with different functions. With the addition of so many regulatory bodies, the 2015 Bill fails to streamline energy regulation and to ensure that red-tape is eliminated. In addition to the above bodies, any potential energy sponsor is also meant to deal with county governments and local communities. Far from reducing the enormous lag time between project conception and an operations start date, this set up will only add to delays in project implementation.

The 2015 Bill provides that any person carrying out any undertaking or works under it shall comply with the local content provisions. The release of the 2015 Bill was coupled with the release of the draft "Energy (Local Content) Regulations, 2014" (the "Regulations"). In summary, "local content" refers to the preference given to suitably skilled and trained Kenyan citizens in matters of employment for operations governed by the 2015 Bill and secondly, it refers to the use of certain goods which should be produced in Kenya and in the specific county where an energy project is being implemented. The ERA requires that any foreign project sponsor shall have a local office where procurement, project management and implementation decision making are to take place to the satisfaction of the ERA. Due to the poor drafting of the Regulations, it does not mention by whom such decisions are to be made and therefore defeats its own purpose. In addition to the local office, any potential license applicant must also file a "Local Content Plan" which should generally contain plans for the following: employment, training and succession, research and development, technology transfer, legal services, and financial and insurance services.

[8] Rainbow Field, 'New Energy Bill in Kenya Tabled – The Good and The Bad', *Polity*, last modified 2015, accessed August 22, 2015, http://www.polity.org.za/article/new-energy-bill-in-kenya-tabled-the-good-and-the-bad-2015-05-20.

Competitiveness of Ethanol in the Local Market

At the moment, ethanol cannot be considered as competitive in the local market solely due to its pricing regime, as dictated by government policy.

Besides being relatively highly priced at KES 88.00 a litre, it also attracts VAT at 16 per cent and excise duty at KES 120.00, raising the total cost per litre to KES 220.00. A pilot study conducted in Kisumu, Kenya by UNDP reported a 98 per cent usage preference among the test group. During the test period, the CLEANCOOK ethanol stove was greatly accepted, preferred and found to have health as well as time saving advantages for women. During the indoor air quality monitoring, all households reported 'much less smoke', and the project was able to establish that the community was willing to pay between KES 2,000 to 4,000 (between US $20 and US $40) for the CLEANCOOK stove piloted. They were willing to pay between KES 50 -100 per litre for the fuel. By the end of the pilot a local manufacturer had produced a prototype copy of the stove using a variant of the technology and released some units into the local market, with favourable reviews and test results.

The nearest competitors for the use of ethanol, i.e., charcoal, LPG and kerosene, were considered desirable by the consumers surveyed due to an interesting mix of factors. These included quickness and efficiency, ease of use, cleanliness, less smoke, reduced cost, availability, and the ability to use for both lighting and cooking. Convenience and reduced need for electricity were also the factors (Global Network on Energy for Sustainable Development, 2008). It is the view of this study that it is possible to develop the ethanol supply chain to a point where these factors are applicable in describing ethanol's features and desirable aspects. The fact that Mumias Sugar Company supplies and sells Technical Alcohol to firms that secured tax exemption at KES 20 per litre indicates that the production costs for ethanol do not form a core part of the total retail price for ethanol when it reaches regular consumers. It also highlights the importance of securing tax exemptions for ethanol, but by means of a reclassification of the product from beverage to household fuel within the government revenue frameworks.

3.3. Rwanda

Country and Demographic Information

Rwanda is a landlocked East African country referred to as the "land of a thousand hills". It covers an area of 26,340 square kilometers. It is densely populated (483 persons per Sq. km), with a population of 11.9 million people. About 80.26 per cent live in the rural areas, and 19.74 per cent are in urban areas. The country borders Burundi, Democratic Republic of Congo, Tanzania and Uganda. The largest ethnic groups are the Hutus (85 per cent), the Tutsis (14 per cent), and the TWAs (1 per cent). All the groups speak one language, Kinyarwanda, a Bantoid language that belongs to the branch of the Niger-Congo language family. Kinyarwanda is spoken by more than 90 per cent of the people living in Rwanda. The national languages of Rwanda are Kinyarwanda, English and French, while Kiswahili is spoken by some of the population. The population growth rate trend in the last 25 years has been inconsistent. In 1980, the growth rate was on the increase at 3.3 per cent. By 1987, the growth rate was at 5.5 per cent. Following the genocide, the growth rate declined to the negative. After 1994, the growth rate grew up rapidly to 10 per cent in 1998, started stabilizing in 2003, and by 2015 was estimated to be 2.5 per cent.

Ninety percent of Rwanda's population depends on subsistence agriculture. Despite the decline in the economy during the genocide, the country has made significant progress, and the GDP is currently growing 7 per cent to 8 per cent annually with reduced inflation. About 45 per cent of the population lives below the poverty line, compared to 57 per cent in 2006. Rwanda joined the EAC and is aligning its budget, trade, and immigration policies with its regional partners. The government has embraced an expansionary fiscal policy to reduce poverty by improving education, infrastructure, and foreign and domestic investment. Lack of proper transportation linkages with other countries continues to handicap private sector growth. The Rwandan government is seeking to become a regional leader in information and communication technologies.

Although still poor and mostly agricultural, the nation has made significant progress in recent years. The growth rate of Rwanda's economy is 8.9 per cent, and the government is targeting to achieve an annual growth rate of 11.5 per cent over the period of 2017/2018 (SE4ALL, 2014). New industries such as tourism, cut flowers and fish farming have been gaining importance. The major source of foreign trade is coffee, tea, tin cassiterite, wolframite and pyrethrum. The infant mortality rate is 59.59 deaths per 1,000 live births whereas the maternal mortality rate is 340 deaths per 100,000 births and the Low birth weight rate is 11.7 per cent. According to the Global Disease Burden (2010), the profile of Rwanda indicates that HAP is a leading risk factor through disability adjusted life years (DALYs), resulting in annual deaths of 5,680 people due to HAP, more than the deaths attributed to malaria.

Baseline Energy Information

Only 19.8 per cent of the population has access to electricity, comprising of 71.8 per cent living in urban areas and only 9.1 per cent in the rural areas. Only 2 per cent of the population has access to clean energy sources for cooking (World bank, 2014). More than 90 per cent of Rwanda's primary energy needs are met by biomass in the form of wood, charcoal, and agricultural wastes (European Union Energy Initiative, 2015).

The total demand for woody biomass in 2009 was 4.8 million tons. Urban areas continue to demand biomass for energy. Kigali city has 80 per cent of Rwanda's population. As of 2009, it consumed 20.7 per cent of the entire woody biomass consumption and 60 per cent of the national charcoal consumption (Drigo, et.al., 2014). The actual consumption of this supply varies by sector. In the industrial sector, tea factories and brick making factories use about 26,000 tons and 125,000 tons respectively. The commercial sector consumption is estimated at 48,000 tons. The public sector consumes 47,000 mainly for secondary schools and prisons (Drigo and Nzabanita, FAO, 2011).

Households are the dominant consumers of energy (91 per cent), followed by the transport sector (4 per cent), industry (3 per cent), and public services (2 per cent). Households are also the dominant consumers of electricity (51 per cent), which is primarily used for lighting. The second largest consumer is the industrial sector (42 per cent), which mainly comes from motor-drivers and lighting. Public sector consumption (6 per cent) is largely due to public buildings, street lighting and water pumping.

Fuelwood

There are various types of woodstoves. In the rural areas, about 48 per cent to 49 per cent of the households use the traditional stoves, mainly three-stone fires. About 52 per cent use mud stoves, which are considered improved stoves following the government initiative after the genocide as well as recent initiatives. About 4 per cent use other woodstoves, such as non-improved traditional clay stoves and improved clay stoves, including the Canarumwe. The cost of the mud stoves is RWF 4000-6000 ($5.44 to $8.16) depending on who the installer is. The Canarumwe stoves cost the end-user RWF 2500. Other traditional improved stoves cost about RWF 1000.

The woodfuel is still largely burnt on traditional three stone fires. Fifty one per cent of households in the rural areas live in poorly ventilated houses leading to high risks of exposure to smoke, resulting in negative health impacts due to Household Air Pollution (HAP). The soot from the wood smoke also tends to make the kitchens dirty.

The primary uses of improved stoves are for making family food or foods to sell by the food kiosks or food vendors. The staple food is beans, which are cooked in almost all regions of Rwanda at least once a week by each family. This is normally accompanied with bananas, potatoes, or cassava. Households also cook Ugali (Ubugari) made from either maize meal or cassava flour. In the rural areas brewing of banana or sorghum beer is common and this is done using domestic stoves.

Charcoal

More than 90 per cent of the households living in major urban areas like Kigali, Butare, and Rwamagana, use charcoal to meet most of their cooking needs. The value of the charcoal market of Rwanda in 2009 was estimated at 37.9 billion RWF, [[in $?]] with 22.3 billion RWF in the urban area of Kigali. Most of the charcoal is produced locally. The national government, in response to the need for better energy efficiency, has been promoting improved carbonization technologies. There are about 8,000 producers of charcoal. The government regulates the charcoal production through the implementation of the forest management policy (N 01/2003) prohibiting the cutting of immature trees. The implementation of this policy was decentralized to District Local Authorities in 2006, and the districts give permits for woodcutting for a fee. In some districts, the permits include carbonization. The districts often ban permits in dry periods or do not allow permits for a certain area. Some districts charge a tax per bag of charcoal and it varies by district (Blodgett, 2011).

Both traditional and improved cook stoves are used to burn charcoal. A bag of charcoal costs RWF 7000 to RWF 10000 ($9.52 to $13.60) depending on the quality of the charcoal and its origin. The stoves used to burn charcoal are the traditional stoves and improved Canamake stoves, which are produced by the local artisans. There are also a number of traditional clay stoves made by potters all over the country. The improved Canamake stoves cost RWF 2500 to RWF 5000 ($3.40 to $6.80), and the traditional charcoal stoves cost about RWF 500 to RWF 1000 ($0.68 to $1.36). More than 90 per cent of the urban households use charcoal stoves as their primary means for cooking all their meals. At the same time, more than 90 per cent of the rural households rely on biomass for meeting their cooking needs.

Crop Residue/Animal Dung

Crop residues are widely used in rural areas with little woody biomass. These residues include maize cobs, groundnut shells, maize and sorghum stalks. These constitute only a small percentage of fuels used by the households. Rice husk is used as a fuel, but mainly for brick firing in the major rice growing areas: Cyangugu, Butare and Rwamagana where there are three major rice factories.

Electricity as Fuel

Electricity provides a small portion of the national energy demand. Only 20 per cent of households in Rwanda are connected to the grid. Rwanda uses diesel engines for generation of electricity. Rwanda also generates electricity from hydropower. Currently, 55MW is generated and is expected to grow to over 120MW by 2018. Electricity is typically used for lighting, industrial processing, and other commercial activities. About 5 per cent of the households in Kigali use electricity for cooking. This represents about 25MW as of 2009.

Kerosene Fuel

Kerosene is imported into Rwanda. The cost is quite high, and very few families can afford it. The kerosene is not subsidized and has a 5 per cent tax. According to RURA, Rwanda imports all its oil products either through the central or north (via Kenya) corridors. Kerosene costs RWF 674 ($0.91) per liter.

LPG

Penetration of LPG in Rwanda is still relatively limited, but the situation is evolving rapidly, demonstrated by the sharp increase of imports in the last few years (Drigo, 2014). The monthly sale of LPG by Society Petroliere (SP) increased from 25 tons in 2010 to 45-48 tons in only 18 months, due to an intense promotional campaign. SP predicts a steady annual increase of 10 per cent to 15 per cent per year under current conditions, but this rate could be much higher if some form of subsidy is put in place. The monthly sale by Kobil increased from 10 tons in 2007 to the current 50 tons. Consumption surveys of urban households do not adequately reflect the increasing penetration of LPG in the energy mix of Kigali households, because this evolution is very recent, and LPG is often used in combination with charcoal, the principal cooking fuel. The penetration of LPG in the urban energy mix will significantly influence the role of charcoal in urban households. In the rural areas, LPG use is estimated at 3.4 per cent. The LPG bottles come in various sizes and refill prices vary with size of the bottle. The 20kg bottle costs RWF 32,000 ($43.53), 13kg costs RWF 20,000 ($27.21) and 6kg bottle costs RWF 10,000 ($13.60).

Biofuels

Key policy documents are silent on biofuels, including the recent gap analysis for Rwanda by Sustainable Energy for All (SE4ALL). This document discusses the country’s challenges with energy access, energy efficiency, and developing renewable energy resources. It also covers opportunities for achieving SE4ALL goals, mainly at institutional and policy levels. Little is mentioned regarding biofuels. Currently, pharmaceutical companies and beverage alcohol companies are the only market for ethanol. The ethanol for their use is mostly imported.

Biofuels are not currently used for energy at a household level. However, the exploration of the potential production and use of ethanol for family use would be a large innovation for the energy section in Rwanda.

There have been efforts to produce biodiesel in the past without much progress. GIZ points to the scarcity of land for crops and competition for food sources as issues hindering biodiesel production. However, various biodiesel crops can grow in Rwanda, including jatropha, moringa, and soya. In a report on sustainable liquid biofuel production in Rwanda, GIZ concludes that cassava and sugarcane would be the only feedstocks suitable for profitable biofuel production (GIZ, 2011).

Biogas

Biogas is promoted in Rwanda by the government and other stakeholders and companies. To date, more than 3,000 biogas digesters have been disseminated to households and more than 13 institutions, particularly prisons. A review by the Netherlands Development Organization (SNV) Board showed that there were fewer uptakes than expected of biogas, and 10 per cent of the digesters did not produce gas.

Many of the digesters that produced gas, produced less than expected by farmers. One reason for slow uptake is the cost, and underperformance of the digesters was mainly due to incomplete construction and poor maintenance. About 25 per cent of biogas digester owners were dissatisfied. Despite these professed downsides, 80 per cent of users still reported benefits from using biogas (SNV, 2013).

The cost of a digester for a household is RWF 300,000 ($408) and is subsidized by the government. The biogas digesters are constructed by companies, which are commissioned either by the government or organizations such as SNV. The SNV review indicates presence of 42 active biogas construction companies.

Biogas stoves are manufactured locally with a cost of RWF2000 to RWF4000 ($2.72 to $5.44). Most biogas users are well-off families in the rural areas and base of the pyramid consumers. Biogas is rarely used as a primary fuel or stove. Most biogas users often have a second stove, which is either a traditional stove or an improved biomass stove. Most families tend to use biogas for cooking lighter meals, such as tea and potatoes.

Current Initiatives for Clean Cooking and Energy

Electricity Generation

Energy efficiency has been positioned as the fifth pillar in the Ministry of Infrastructure's Energy Policy. There is opportunity to meet the needs of those who want to use electricity for cooking following the current initiatives in power generation. One key initiative is the recent completed Nyabarongo river hydroelectric power plant, which contributes 23MW to the grid electricity. The Lake Kivu thermal power plant will be completed in 2015 and is expected to add 25MW to the grid. There are also several other electricity generation programs coming online using peat and solar.

Improved Cookstove Initiatives

The Rwandan government initiated an Improved Cook Stove (ICS) program in the late 1980s and early 1990s to combat deforestation. Various ICS programs have been implemented since then, which have led to a stove penetration rate of over 40 per cent to 50 per cent nationwide by 2012. The largest initiative after the genocide was of Darfur stoves, a mud stove with pieces of bricks forming the firebox. The Rwanda Defense Forces led the initiative. The Ministry of Infrastructure (MININFRA) also initiated an ICS dissemination program in the rural regions of Rwanda from 2011 to 2012. The latest intervention is led by the National Improved Cookstove Program for Rural and Urban Rwanda. This intervention has distributed Canarumwe stoves in the rural areas and Canamake stoves in the urban areas. These are much more efficient that traditional cookstoves, and their production process allows for standards to be implemented. These stoves have been lab and field tested by the government as well as by the third parties.

Delagua Health Organization (a private carbon company) leads another key initiative with the Ministry of Health. They intended to distribute 600,000 Ecozoom stoves and 600,000 water filters to 30 per cent of the people at the base of the pyramid in the rural areas of Rwanda. If achieved, this intervention will reach about 3,000,000 people with Ecozoom stoves. They have so far distributed 100,000 stoves in the Western province. These stoves are given for free along with the water filters. This free distribution has presented a challenge for the improved stoves market in Rwanda.

Biogas Initiatives

Another potential contributor to sustainable heat supply is biogas. This is a government initiative implemented through a number of companies and NGOs, such as SNV Rwanda. The government is targeting the instillation 100,000 home biogas digesters and the incorporation of digesters at relevant institutions by 2018 through two programs:

(1) The National Biogas Program (NDBP): Started in 2007 and follows the principle of supporting the poorest while leveraging private sector involvement and developing a commercial and sustainable domestic biogas sector. It does so by ensuring that the companies know how to maintain and install digesters. Since initiation, roughly 3,700 digesters have been disseminated with the support of a 50 per cent government subsidy through local credit giving institutions. If the program is to reach 100,000 biogas digesters by 2018, the total cost of the program, which includes the training of masons, subsidies, etc., is estimated at $37.3 million.
(2) The Institutional Biogas Program has resulted in 14 installations.

There are a variety of constraints to the provision of biogas digesters. Market absorption capacity is constrained by low purchasing power of households, and financing options need to be developed.

Stakeholders

Government initiatives involve a vast number of stakeholders, including: international governments and donors, government agencies, international non-profit organizations, national non-profit organizations, academic institutions, research institutions, and the private sector companies. The key government agencies are the Rwanda Energy Group (REG), and Rwanda Utilities Regulation Agency (RURA).

Key international governments and international Agencies include: The World Bank, African Development Bank, European Union, Belgium, France, Germany, Japan, The Netherlands, South Korea, The United Kingdom, and The United States of America governments. The key International organizations are SNV, Care International Rwanda, and VI Life Agroforestry, Practical Action Eastern Africa, and GIZ.

There are various private sector companies dealing with various stoves and fuels. Stoves range from household to institutional stoves. Inyenyeri is leasing the Phillips Gasifier Stove to urban users in Gisenyi (Rubavu town). They also manufacture wood pellets from biomass that is collected from the community. There are a number of carbon companies with initiatives in Rwanda such are Delhagua, Hestian Innovations, and Atmosfair.

Key Local Funding Institutions

Rwanda has a National Climate Change and Environment Fund (FONERWA). FONERWA's purpose is to spur the next 50 years of green growth in Rwanda. Its strategy is to provide unheralded technical and financial support to the best public and private projects that align with Rwanda's commitment to a green economy.

Platform for Improved Cookstoves Stakeholders

Recently, Rwanda Energy Group and Care International initiated a discussion leading to formation of the Improved Cookstove Platform in Rwanda with the objective of creating space for sharing and supporting each other as well as strengthening linkages with the policy and regulatory institutions.

Government Regulations for Ethanol

Rwanda has a National Energy Policy and energy efficiency is one of its key pillars. The Electricity Policy was enacted in July 2011 and the key principles of the law are:

- Liberation and regulation of electricity sector
- Development of power supply for Rwanda's economic and social development
- Creation of an environment that attracts private sector investments
- Development of a competitive electricity sector

Key principles likely in linkage to biofuel programs are:

- Maximize the use of indigenous energy resources
- Improve energy access
- Promote efficient utilization of energy resources
- Promote new and renewable energy technologies through enabling frameworks including feed-in tariffs

Specific objectives include developing alternative energy systems including solar energy and biomass energy systems.

There are many regulatory bodies in the Rwandan energy and environmental sectors. MININFRA is generally responsible for overall regulations and policies in the energy sector. The power utility is regulated by Electrogaz. The energy regulating body in Rwanda is RURA, which was formed in 2001 and is defined by law as an autonomous entity. Its mandate is to regulate an efficient, sustainable, and reliable energy sector.

The Rwanda Energy Group (REG) has the legal mandate to translate energy sector policy and programs into tangible projects to achieve the government's vision for the sector and to efficiently operate and maintain the power system in the country.

Rwanda Development Board (RDB) plays a lead role in investment, mobilization, and promotion of the energy sector. It promotes private sector participation. The RDB also issues environmental impact assessments or exemptions for energy projects.

The National Forest Authority (NAFA) regulates the Forest Management Act, which is implemented by various district authorities.

Rwanda Environment Management Authority (REMA) regulates climate change activities for environmental sustainability. They are the designated national authority for carbon projects in Rwanda and issue all project developers with Letters of Approval.

There are regulations on the quality of beverage alcohol that is sold in the country. Ethanol is imported at 80 percent to 90 per cent alcohol from other countries, and the Rwanda Bureau of Standards allows the wine and spirit companies to dilute the imported alcohol to 45 per cent. This is the maximum acceptable level by law. This means that if ethanol was to be used for cooking, then there would be regulatory issues regarding the quality of fuel which needs to be addressed. Rwanda has been keen exploring on fuel blending for transportation. However, this is currently not happening and the country still relies on use of petroleum fuels.

Overview of Current Ethanol Production in Country

All the ethanol production for Rwanda is still in planning stage. The only existing sugar company, Kabuye Sugar Works, has promised future expansion but declines to say when. The Kabuye Sugar Works is located outside Kigali and has a capacity to process 60,000 tons of sugar per year but is only producing 10,000 tons currently. The factory produces much less than its capacity because of floods that affect sugarcane production adversely. Rwanda imports a large portion of its sugar to meet its annual demand. Currently the company sells all of its molasses to dairy farmers. Molasses is sold at RWF 190,000 ($259) per ton (Ansoms, 2009). As of 2013, the Ministry of Agriculture and Kabuye Sugar Works are working together with support from the Netherland's government to reclaim land in the Nyabarongo swamp and carry out water management to prevent future floods and damages. They are also working to introduce high yielding sugar cane varieties.

Rwanda imports some 160 million liters of fuel annually in the form of diesel, petrol, and kerosene. The Rwanda Biodiesel and Bioethanol Project was intended to produce about 13 per cent of total fuel consumed through transportation fuel blending. The project has stalled for the last seven years for unclear reasons. Rumors for the delays indicate the lack of a biofuel policy and a deficit of feedstocks.

A Mauritius-based Sugar Company, Omnicane, has an investment plan to produce much larger amounts of ethanol, 24 million liters annually, along with sugar. There are no clear time lines for this plan. Otherwise, Rwanda currently imports all its ethanol for pharmaceutical needs and beverage alcohol. According to the Rwanda Revenue Authority, in 2014, Rwanda imported 793,793 liters of indentured ethanol and 3,833,935 liters of denatured alcohol.[9]

[9] Personal conversation between Rwanda Revenue Authority official and Hellen Owala, July 2015.

Conclusions and Recommendations

To date, the potential for the production of bioethanol has been considered low due to lack of land and doubts regarding economic viability. However, with integrated food and energy systems and by utilizing the waste biomass, there may be better potential for ethanol than commonly believed. The GIZ study of the biofuels' industry demonstrates that cassava, sugarcane, molasses, and other organic wastes may be ideal feedstocks for sustainable bioethanol distilleries. Although much of Rwanda's arable land is under crop cultivation currently, there are opportunities for energy crop integration and some of the land does lie fallow over time (GIZ, 2011). Agricultural production is largely subsistence, and both men and women are involved in agriculture. Production of energy feedstocks and utilization of current wastes would provide families with more income and security.

Although molasses provides a good feedstock for ethanol production, it is not readily available in Rwanda currently. However, there is growing potential for sugarcane in Rwanda and the expansion plans by the Kabuye Sugar Works and the promised Omnicane Sugar Company demonstrate that molasses may be available in the future. A small distillery could be tried alongside Kabuye Sugar Works since it is located in a peri-urban area outside of Kigali. This would minimize transportation costs and target a market that is already purchasing cooking fuels.

Adoption of new cooking fuels and stoves has been slow in Rwanda. The key barriers to adoption include low awareness among the potential users, affordability, and lack of enough stakeholder linkages to support the stoves distribution chain, such as appropriate financial services for the stove actors. Practical Action and the Global Alliance for Clean Cookstoves conducted a National Stakeholders Meeting to identify barriers to dissemination of ICS in Rwanda (EU, 2014) A three-pronged strategy was developed: enhancing demand, strengthening supply, and fostering an enabling environment (Global Alliance for Clean Cookstoves, 2012). With more education and awareness on the negative health impacts of using wood and charcoal for cooking, there are high chances of Rwanda embracing clean cooking. Key issues will remain affordability for certain market segments, such as those in the rural areas. The working people in urban households should be able to make payments towards stoves and fuel as long as the price is affordable for them. Embracing carbon financing systems could help enable affordability. For ethanol, the fuel distribution system would also determine whether households could easily access it or not. The potential for ethanol displacing other fuels is still uncertain, but is likely to be a good fuel substitute for purchased charcoal, paraffin, electricity, and LPG.

In the discussions with MININFRA, [this consultant questioned] why biofuels were not featured in recent documents, particularly the Gap Analysis for the SE4ALL Country Plan. The response was that there were no strategic decisions to exclude it, and in future, the government will embrace biofuels. So far, there has been no biofuels policy, making this a highly innovative area. The government may need support to develop ideal policies and regulations in this area.

Any initiatives in bioethanol production would need a detailed feasibility study. There is a vast potential for ethanol stove use in the urban areas, due to the small percentage of kerosene use and the continued demand for charcoal. The presence of the main sugar factory in Kigali is an advantage as well.

Rwanda has other key urban centres, and the centralized marketing system has potential for the collection of organic wastes from markets to be used for bioethanol generation. However, the current waste collection system has little separation methods, and these would have to be developed to ensure separation of what is needed for ethanol production from what goes to landfills. This initiative would complement the waste collection structures, as currently there is very little waste recycling.

3.4. Tanzania

Country and Demographic Information

The total land area of mainland Tanzania is 883,343 sq. km[10] with a population of 55.6 million (2016). About 70.9 per cent live in rural areas and the rest in urban areas. The proportion of the country's urban population is growing at a rate of approximately 5 per cent per year. As with population growth, urbanization can have both positive and negative implications for human development. The average annual population growth rate has been 3.1 per cent. Life expectancy has been increasing over time. According to the 2012 census, life expectancy increased from 42 years in 1967 to 51 years in 2002, and to 61 years in 2012.

Culturally, Tanzania is one of the most diverse countries in Africa with more than 120 local tribes and languages spoken in the country. English is the language for official communications, instruction at academic institutions, administration, and business. Swahili is a national language and mostly widely used language in daily life. Tanzania is free of ideological confrontations and ethnic problems. A multiparty democracy adopted in 1992 has not disturbed the peaceful political climate of the country. The political scene is characterized by parliamentary democracy and public consensus on key social and economic priorities.

Tanzania's economy is predominantly rural-based, with relatively low levels of manufacturing and value addition to the commodities produced. According to the Bank of Tanzania (BoT), the Gross Domestic Product (GDP) grew by 7.0 per cent in real terms compared with 6.9 per cent in 2012. Constant GDP growth rate was witnessed in 2014, 2015 and 2016 (World Bank, 2016). GDP at constant prices amounted to TZS 20.5 trillion (US$13.04 billion) compared with TZS 19.2 trillion (US$12.2 billion) in 2012. The strong economic performance was underpinned by communication, financial intermediation, construction, and trade and repairs activities. In terms of contribution to the GDP growth, imports and exports trade and repairs accounted for the largest share (17.7 per cent), followed by agriculture (13.7 per cent), communication (12.7 per cent) and manufacturing (10.9 per cent). In terms of share to GDP in 2013, agriculture, hunting, forestry, and fishing activities had the largest share of 22.2 per cent, followed by trade and repairs 15.0 per cent, and real estates and business services 10.2 per cent. Annual headline inflation remained at single digit over the course of 2013/14, averaging at 6.3 per cent.

According to the UNDP's Human Development Report for 2014, Tanzania's GDP per capita income (constant 2011 PPP$) in 2012 was US$1,654 compared to the global average of US$

[10] The study primarily focused on mainland Tanzania; Zanzibar has separate energy systems and its own development policies and plans.

13,599. In the Tanzanian economy, GDP per capita at current market prices shows an increasing trend in the last decade, ranging from TZS. 276,741 in 2001 to TZS. 1,025,038 (US$651.9) in 2012 (UNDP, 2014). Additionally, Tanzania is characterized by low levels of both HDI and national income. Tanzania's GNI per capita in 2013 was US$1,702 (constant 2011 PPP$), compared to US$2,126 which is the average for the least developed countries and US$13,723 which is the average for the world.

According to BoT, in 2013/14, the value of imported goods increased by 8.3 per cent to US$ 11,347.1 million from the amount recorded in 2012/13. Import categories were capital, intermediate, and consumer goods. The value of goods exported was US$5,619.1 million, being 4.1 per cent higher than 2012/2013. Composition of exported commodities was coffee (2.6 per cent), Cotton (1.9 per cent), Sisal (0.4 per cent), tea (1.0 per cent), tobacco (7.3 per cent), cashew nuts (2.7 per cent), cloves (1.2 per cent), gold (33.9 per cent), other minerals (2.7 per cent), manufactured goods (26.5 per cent) fish and fish products (3.4 per cent), horticultural products (0.6 per cent), and other export products (12.2 per cent).

About 28.2 per cent of Tanzanians are poor, and 9.7 per cent are extremely poor. However, it has been noted that there is progress in poverty reduction since the beginning of the last decade. For example, the poverty rate marginally declined from 33.3 per cent to 28.2 per cent over a period of five years from 2007 to 2012.

Energy Situation

Tanzania is well-endowed with enormous and diversified energy resources for immediate, medium, and long-term needs of the country that are largely untapped. These sources include hydropower (large and small hydro), natural gas, solar, wind, biomass, coal reserves, and geothermal. However, Tanzania's energy situation is characterized by a low per capita consumption of commercial energy (petroleum, coal, and electricity) and a relatively large dependence on biomass energy in the form of firewood, charcoal, and bio-waste. According to the BoT, biomass accounts for 90 per cent of the total energy demand while petroleum and gas accounts for 8 per cent and electricity is only 2 per cent. Only 15.5 per cent of the population has access to electricity sources while only 2 per cent of the population has access to clean energy sources for cooking (World Bank, 2014).

According to the International Energy Agency (IEA), the domestic residential sector consumes about 73 per cent of the total energy in all productive sectors of the economy (industry – 14.4 per cent, agriculture – 4.2 per cent, transport – 5.8 per cent, other sectors- 3.1 per cent). This high residential proportion of the total energy depends on mainly the use of firewood and charcoal for cooking using rather inefficient stoves (IEA, 2013).

Consumption of commercial energy is very low. Tanzania is one of the countries in sub-Saharan Africa that depend entirely on imported fossils fuels for local consumption. The country's demand for petroleum products is estimated to be over 1.8 million metric tons per year. According to BoT, the country spends significant amount of foreign currency on oil imports. For example, between March 2014 and March 2015, fuel imports nationwide were US$1,886.10 million.

The access to electricity in Tanzania is still very low. As of May 2014, about 24 per cent of the mainland Tanzanian population was connected with electricity services, of which 7 per cent is in rural areas. This means the vast majority of rural population are left in the dark. According to MEM, annual per capita consumption of electricity is 97kWh and the annual demand growth for electricity is 10-15 per cent. The government plans to increase the connectivity level to 50 per cent by 2025 and at least 75 per cent by 2033. This growth is mainly due to accelerated productive investments, increasing population, and increasing access. The installed capacity stands at 1,277.22MW with an average available generation of 950MW, with maximum demand of 950MW.

Nearly 95 per cent of the population uses biomass in the form of firewood and charcoal as their primary fuel for cooking. It is estimated that only 1.2 million households out of 9.359 million households are using improved cookstoves in Tanzania. Poor households spend a considerable share of household resources (up to 35 per cent) to meet their domestic energy needs through the use of biomass fuels (SNV Tanzania, 2012). Most households rely on inefficient stoves like the traditional three-stone method for cooking. These technologies have poor energy conversion rates, which lead to:

- High HAP rates: The World Health Organization (WHO) estimates that about 18,900 deaths are attributable to HAP annually in Tanzania (Legros, et.al.,2009).
- More time/money investment to collect/purchase firewood and/or charcoal, effecting mainly women and children who traditionally have the responsibility for collecting firewood.
- High pressure on the exisitng natural biomass resources, leading to higher deforestation and forest degradation levels. A World Bank report on the charcoal situation in Tanzania informs that around 100,000-125,000 hectares of annual forest loss is attributed to unsustainable charcoal production (World Bank, 2010).

Even if efforts to increase production of electricity and modern fuels succeed, it is not likely that access to the electrical grid and other sources of modern energy in Tanzania will be greatly improved in the short-to-medium term. Renewable energy technologies such as biogas, solar, wind, improved stoves, etc. provide an alternative to mitigate this situation and enable improved access to energy without the need to invest in large-scale infrastructure for distribution. To date, there is no official Renewable Energy policy in place and as a consequence, there are no supportive institutional arrangements at the level of local government authorities (district level), and no clear subsidy and incentive schemes. Rural electrification projects provide connection subsidies to rural customers. Also, Liquefied Petroleum Gas (LPG), solar, and wind technologies are exempted from all forms of taxation. But the same subsidy and exemption policies need to be extended to other forms of clean technologies and fuels.

Baseline Energy Information

According to the National Agriculture Survey (2012), the most prevalent source of energy for cooking is firewood, which was estimated at 94.5 per cent of all rural agricultural households, followed by charcoal (3.9 per cent), and crop residues (0.7 per cent), electricity (0.3 per cent), LPG (0.2 per cent), kerosene (0.1 per cent), solar (0.1 per cent), biogas (0.1 per cent) and dung (0.1 per cent).

It is estimated that about eight million households in Tanzania cook with firewood and/or charcoal on traditional cookstoves. In the Tanzanian context, traditional cookstoves are three-stone firewood and single-walled metal charcoal stove designs. Use of traditional cookstoves presents a health risk to users, mainly women and children who normally spend much of their time in the kitchen. However, there is less awareness on the health risks of HAP among the general population.

Improved cookstoves are a relative concept, which depends on the desired improvement from the traditional stove designs. The improvement can be on fuelwood saving, reduction in emissions, safety, portability, affordability, convenience and usability, quick cooking, etc. The term "improved cookstove" is mainly associated with fuel saving because when cookstove programs started in Tanzania in 1980s, the drive was on forests conservation and energy saving in general. Depending on the region or district, improved cookstoves are also different. It is estimated that the adoption of improved cookstoves in Dar es Salaam city with about 800,000 households is about 40 per cent; whereas in other urban centres adoption is about 20 per cent; and less than 3 per cent of households at national level are using improved cookstoves.

In addition to the health problems associated with current cooking practices in Tanzania, rising fuel prices and increasing pressure on natural resources have increased the price of fuels and decreased the accessibility of wood and charcoal fuels. This means that the market for more improved cookstoves, which use less fuel, is becoming more and more appealing to consumers, particularly poor families who have to walk long distances to fetch firewood.

Currently, the manufacturing of cookstoves in Tanzania takes place primarily in the informal sector with localized sales, substandard quality, and little consistency in stove quality.

However, imported improved cookstoves and alternative fuels have started to emerge in Tanzania, but sales are limited by low demand and higher prices due to low scales of production and supply.

Firewood

Firewood is the energy source of choice for rural households, public institutions and some agro-processing industries, notably tea drying and tobacco curing. While household consumption of firewood by the dispersedly settled rural population is not believed to endanger national biomass resources to any significant degree, public sector consumption of firewood in schools, health centers and prisons is important. Firewood use is also widespread for the making of bricks as well as fish smoking, local brewing and pottery making.

Over 90 per cent of rural households depend on firewood for cooking. In urban areas, less than 19 per cent of households cook with firewood. In places with abundant firewood supply, firewood is collected free of charge. Time spent in collecting firewood ranges between one to eight hours. In areas with a scarcity of firewood, rural people buy firewood. Three-stone stoves dominate in the rural areas – made at no cost. The three-stone firewood stove is very inefficient (less than 10 per cent efficiency) and wastes a lot of wood (Songela, 2001). For general domestic use, per capita firewood consumption ranges between 1 and 1.5 m^3 per year. Therefore, for a household with five members, consumption is between 5 and 7.5 m^3 per year. Assuming a price of wood at TZS 5,000 per m^3 (average price normally charged by District Forest Offices), average household monthly expenditure on firewood is roughly TZS 3,000.

Improved firewood stoves in rural areas have a significant role to play in terms of reducing HAP (approximately 40 per cent), saving time, and reducing wood wastage (about 70 per cent) (Songela, 2006). Field observations show that a typical locally manufactured household stove costs between TZS 1,000 (US$0.5) to TZS 10,000 (US$5). Imported improved firewood stoves costs around TZS 60,000 (US$30). ARTI Energy Ltd and L's Solution Ltd are companies distributing a range of stoves manufactured by Envirofit Ltd, a US-based company. These stoves are regarded to be expensive by majority of rural households. However, a distribution model established by CARE International and ARTI Energy, which targets rural village savings groups, has demonstrated that savings groups are a potential market and can address the end-consumer financing challenge. Through this approach, CARE and ARTI have distributed more than 800 firewood stoves (M500 model) in rural and peri-urban areas.

Charcoal

Approximately 71 per cent of urban Tanzanian households use charcoal as their primary source of energy for cooking meals. Charcoal is one of the largest sources of cash income in rural Tanzania. Hundreds of thousands of rural and urban people are engaged in the production and supply of charcoal. Charcoal and commercial fuel wood generated approximately TZS 1.6 trillion (approximately US$1 billion) in revenues for actors along the chain. Charcoal demand has nearly doubled over the past ten years. The Ministry of Energy and Minerals projects that demand for charcoal, without supply- and demand-side interventions, will double by 2030, from approximately 2.3 million tonnes of charcoal in 2012; this will significantly contribute to the loss of forests. A World Bank report on the charcoal situation in Tanzania informs that around 100,000hectares to 125,000 hectares of annual forest loss is attributed to the unsustainable charcoal production – roughly about 0.3 per cent to 0.4 per cent of the total forest cover. Areas where forestry supply for charcoal is greatest include around Dar es Salaam, Arusha, Mwanza, Njombe, Tanga, Coast, Lindi, Mtwara and Morogoro.

Increased demand for charcoal is driven by rapid urbanization and high relative prices, scarcity, or unavailability of alternative fuels such as electricity, biogas, biomass briquettes, and LPG. Inefficient charcoal kilns are widely used in Tanzania. The most common type of kiln used in charcoal production is the traditional earth-mound kiln with varying degrees of efficiency. The efficiency of a kiln depends on its construction, including the arrangement of the logs or billets, moisture contents of wood and the monitoring of the carbonization process. One study showed that the traditional earth-mound kilns in Tanzania had efficiencies ranging between 11 per cent and 30 percent (European Union, 2002); however, in other studies the efficiency of traditional kilns was reported to range between 10 per cent and 20 per cent. Field tests by TaTEDO in the Coast region showed that traditional kilns produce between 1 bag and 1.5 bags[11] of charcoal for each cubic metre of wood. The carbonization process for the traditional kiln takes between seven and fourteen days. In addition, the charcoal-harvesting guide issued by the Forestry and Beekeeping Division in 2007 directs all charcoal users to use earth pit kilns for charcoal production. According to charcoal producers, the kiln remains untried due to difficulties in digging pits, arranging logs, offloading charcoal, and other issues.

The charcoal stoves that urban households use are frequently all metal designs (traditional stoves) with a low efficiency of approximately 15 per cent. The stove emits heat at a rapid rate and costs only TZS 5,500. Efficient charcoal stoves that include ceramic liners for retaining heat have efficiencies of between 30 per cent and 40 per cent (Songela, 2009). These stoves are up to 35 per cent more expensive than traditional stoves. According to

[11] Weight of a bag of charcoal was 28kg

MNRT, a typical household consumes approximately one ton of charcoal per year when using a traditional stove, equivalent to TZS 125,000[12] (US$62.5) per month. This falls to 0.4 tonne when using an efficient charcoal stove, TZS 50,000 (US$25) per month. An Enviroft charcoal stove (CH5200 model) costs more than other improved charcoal cookstoves, TZS 75,000 (US$35), but saves more. CARE and ARTI have distributed more than 800 firewood stoves (M500 model) in rural and peri-urban areas.

Forest Wastes

The major source of forest residues comes from the wood harvesting and processing industries. It includes forest harvest wastes (e.g. stumps, roots, trunks, leaves/branches, etc.) and process mill wastes (e.g. sawdust, off-cuts, etc.).

Big-particle wastes, either from forest harvesting or sawmills are collected by firewood scavengers and used for fuel. However, sawdust, which is produced in large quantities in areas with many sawmills such as Iringa, Tanga and Kilimanjaro, is normally not utilized with the exception of a small percentage that is used to make biomass briquettes and burning bricks. To a large extent, the disposal of sawdust is a problem faced by sawmill owners. According to MEM, there are two companies, MENA Briquetting Company (Iringa) and Kilimanjaro Industrial Development Trust (Kilimanjaro), using sawdust as feedstock to produce biomass briquettes mainly used by institutions such as schools and hospitals.[13]

In addition, forest biomass is also used for co-generation of electricity and heat. According to EWURA, one power plant owned by Tanganyika Wattle Company uses wood waste to generate 2.5MW of electricity of which 1.5MW is supplied to TANESCO’s national grid under Standardized Power Purchase Agreement (SPPA).[14]

Agricultural Residues

Agricultural residues can be categorized as agro-processing (or crop-processing) residues and field residues. Field residues are crop remainders that are left in the field after harvesting. They are mainly straw-type materials. Depending on their heat value, bulk density, and distance from the village to the farms, they are not very attractive for fuel application due to economic (handling and transportation costs) and technical reasons (efficiency and emissions). Furthermore, they are thinly scattered and spread over a large area, which makes their collection laborious.

[12] Current price of a kilo of charcoal in Dar es Salaam is TZS. 1500.

[13] Personal communication between Biomass Unit Lead person and Francis Songela, August 2015.

[14] Personal communication between Senior Electrical Engineer and Francis Songela, August 2015.

These types of residues are normally left in the field, used as animal fodder, or collected and burned at the fields to control pests and diseases. Agro-processing residues are crop wastes from crop processing industries and mills (wastes include rice husk, coffee husks, bagasse, coconut husks, coconut shells, groundnuts and cashew nut shells, and corn cobs). The main advantage of agro-processing residues is their uniform physical-chemical properties (partide size, calorific value, moisture, and ash contents), and they are found in huge piles around the processing facilities within villages, small towns and cities. In most cases, the owners of the mills have to incur extra cost to dispose them according to the village or city council disposal regulations. These residues have better prospects as an important source of feedstock for biomass fuels both for domestic as well as industrial purposes.

In 1990 and 2002, the Ministry of Agriculture and Livestock estimated the amount of residues generated from major crops in Tanzania to be about 15 million tons per year. Since then, no other estimates have been published. However, crop-residue ratios can be used to estimate current amounts of residues generated.

There are a number of initiatives by private companies to convert some of the agricultural residues such as coffee husks, coconut shells, rice husks and rice straw into briquettes and pellets to substitute firewood and charcoal in households and institutions. There are about nine small and medium scale factories situated in the following regions: Dar es Salaam (2), Coast (1) Tanga (2), Arusha (3) and Shinyanga (1). Most of these factories operate below their full capacity due to a low demand caused by poor awareness on this energy type of energy by most of the Tanzanians. Field observations revealed that a factory owned by ARTI Energy in the Coastal region produces up to 5 tons/day while its capacity is about 15 tons/day. According to ARTI Energy, briquettes are currently less than half the price per kilo than charcoal – retail price is approximately TZS 600 per kilo as opposed to over TZS 1500 per kilo for charcoal. A typical household use one kilo of briquettes each day, equal to TZS 18,000 (US$ 9) per month.

Bagasse

Sugar factories use bagasse in their boilers for steam generation and electricity generation. According to EWURA, four sugar factories use bagasse to generate 12.5MW of electricity for their own use and supply the surplus to the national grid. Excess bagasse from the four sugar factories had the estimated energy generation potential of about 99.42 GWh per year, equivalent to 3.5 per cent of the national electricity generation (Gwang'ombe, 2004).

Sisal Wastes

On average about 625,000 tons of sisal waste in generated annually from the 46 decorticators. It is estimated that 15,000 tonnes of waste can generate 1 MW of electricity.

Therefore, technical potential to generate electricity using sisal waste is about 46 MW. Mkonge Energy System, a subsidiary company of Katani Limited in the Tanga Region, has installed a biogas plant in one of its estates, which produces 150kW of electricity, enough for use in sisal decorticating machines.

According to Katani Ltd, the future of sisal lies in industrialization and its transformation from being just a fibre producer to being an energy producer and utilizing of the total plant instead of the current 2 per cent. The 98 per cent biomass – the so-called "waste" hitherto thrown away is now known to be more valuable than the 2 per cent when fully exploited. Products like biogas, electricity, short fibres, organic fertilizers, industrial alcohol and other chemicals/pharmaceuticals can easily be commercially produced profitably in very large quantities resulting in the fibre being the by-product.

Animal Dung

Tanzania has potential of generating a total of 25 million tonnes of animal waste per year mainly from cattle, goats and sheep. Animal waste can be fed in digesters for biogas production. CAMARTEC, a public institution with support from GTZ (now GIZ), started promoting biogas technology in 1980s. However, there has been little success and adoption. The failure to disseminate biogas technology has been attributed to the exclusively technical approach without sufficient attention to institutional and financial sustainability and the inclusion of actors from private sector and financial institutions (SNV Tanzania, 2009).

Two independent feasibility studies were carried out in 2007 and both indicated that there was a potential market for around 165,000 bio-digesters in Tanzania (Marree and Nijboer, 2007). To tap into this market potential, SNV and CAMARTEC, through the Tanzania Domestic Biogas Program (TDBP), adopted a market-led and multi-actor focused sector approach in hopes that it could lead to a sustainable, large and viable domestic biogas market in Tanzania. Between 2008 and 2013, a total of 8,796 biogas plants have been installed countrywide for domestic use.

Electricity

Electricity is a source of power for lighting in urban areas and is also used as energy for cooking by upper class households. According to NBS, by 2012 only 0.4 per cent of households in Tanzania were using electricity for cooking (0.2 per cent in rural and 1 per cent in urban). The cost of electricity for this customer category is TZS 306 (US$0.153) per kWh. If a household uses two units/kWh of electricity per meal cooked, or six units per day at TZS 1,836 (US$0.92), monthly consumption of electricity for cooking would approximate TZS 55,080 (US$27.54), currently more expensive than charcoal.

Frequent power cuts also frustrate households that cook with electricity, often requiring a back-up supply of household fuel – often charcoal and LPG. Very few Tanzanians think that they will ever have the opportunity to cook using electricity. Access, reliability, and cost seem to be steep obstacles to the promotion of electricity as an alternative to biomass (firewood and charcoal); therefore, it is difficult to imagine electricity as a realistic alternative energy in the foreseeable future.

Kerosene

Kerosene is used for both lighting and cooking. Kerosene is popular among medium and low-income households, because it is generally available in both urban and rural areas of Tanzania. Households use kerosene for domestic energy but not necessarily as their primary energy source. It is more frequently used to complement charcoal (or firewood) for boiling water or heating up meals left over from the previous day. In 2004, about 25 per cent of households were using kerosene as domestic energy for cooking. By 2012, about 2.1 per cent of households (7 per cent of urban and 0.4 per cent of rural) were cooking using kerosene.

Decreased use of kerosene for cooking has been influenced primarily by price increases. Increased excise duty has also contributed to the rise of the price. Excise duty on kerosene was low, unscrupulous traders purchased it in bulk and mixed it with diesel. In order to curb fuel adulterations, which were rampant in the country, in 2011 the government of Tanzania signed a Finance Bill to hike the excise duty on the fuel from TZS 52 to 400.30 per litre.

Smaller families prefer kerosene because Chinese kerosene stoves are generally smaller than other stoves. Kerosene is therefore not perceived as entirely practical for larger families. It is easy to use, fast, and widely available in any Tanzanian city. The main disadvantages of kerosene stoves lie in their relatively short lifespan and the potential risks associated with their use (fire hazards, burn injuries, etc.). There is no recent data on energy cost for cooking, but in 2012, the MNRT estimated that household expenditure on kerosene for cooking is about TZS 20,000 per month.

Liquefied Petroleum Gas (LPG)

LPG is used as fuel in industry, trucks, and especially in homes as a cooking fuel. In 2006, the Tanzanian government recognized the importance of promoting fuel switching from charcoal to LPG by exempting LPG cylinders and gas from all forms of taxation.[15] However,

[15] The Tanzania Association of Oil Marketing Companies – including British Petroleum, Total, NatOil and Oryx – commissioned in 2002 a study entitled "The True Cost of Charcoal: A rapid appraisal of the potential economic and environmental benefits of substituting LPG for charcoal as an urban fuel in Tanzania". After describing the negative impacts of the growing supply and demand of charcoal, the study argues that charcoal is effectively

all taxes remain on LPG cookers and other accessories. Tax exemption decision has accelerated the penetration of LPG market.

LPG is sold retail in 6kg, 15kg and 38 kg containers, the 15kg container being the most commonly used by an average family. In 2006, LPG market was estimated to be 6,000 metric tons per annum. By 2012, only 10,000 households were cooking with LPG. However, according to Alternative Energy, a LPG retailing company, the market grew by 30 per cent to 40 per cent for the last three years.[16] The LPG market nationally has been constrained by the high cost of constructing refilling stations and a lack of distribution networks in urban and peri-urban areas.

LPG is considered to cook quickly compared to charcoal and firewood. A full six kg cylinder plus stove and other necessary accessories suited for an average household costs approximately TZS 150,000 (US$75), making the start-up costs for LPG substantially higher than those for charcoal. However, monthly refills of the cylinder cost TZS 28,000 (US$ 14), making LPG monthly fuel costs less than the average amount spent on charcoal by a typical family.

Biofuels

In February 2015, Safi International, a Norwegian bio-ethanol stove and fuel company, launched its operations in Tanzania with affor Safi International sells and distributes ethanol stoves (e-cookers) and ethanol fuel through a franchising model. As of August 2015, the company has sold more than 1,680 ethanol stoves and established more than 35 sales outlets in Dar es Salaam. The company wants to establish 10 sales points in Arusha, Morogoro, Dodoma, and Mbeya.

SAFI ethanol stoves (two-burner stoves) are manufactured and shipped from China. Actual price of the stove is TZS 100,000 (US$50), which is regarded to be expensive; however, the Norwegian Agency for Development Cooperation has subsidized the first 15,000 stoves bringing the retail price to TZS 54,000 (US$27) per stove. SAFI is currently getting ethanol from Kilombero Sugar and stores it in two tanks (10,000 litres each). The company does the packaging and denaturing of the ethanol before it is retailed. Ethanol is retailed in one litre bottles, which cost about TZS 2,350 (US$1.1). According to SAFI, one litre can last for 1.5 days, making the monthly fuel costs less than the average amount spent on charcoal by a typical family.

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subsidized due to ineffective tax collection, while LPG is penalized by high import duties. The study, admittedly from a lobby group, makes the case for exempting LPG, LPG cylinders and accessories (gas cookers, hoses, etc.) from import, excise and value-added taxes.

[16] Personal communication between Managing Director of Alternative Energy Company Limited and Francis Songela, 2015

Between 2014 and 2015, UNIDO commissioned Project Gaia to implement an ethanol cooking fuel pilot project in Zanzibar.[17] The objective was to test the adoption and potential benefits of ethanol fuel and stoves for household energy. A total of 122 ethanol stoves were distributed to the households for market and technology testing. The pilot demonstrated that ethanol is an ideal and clean fuel for rural and urban people in Zanzibar. Findings show that households purchased two to three litres of ethanol fuel each week at TZS 1,600 per litre. Ethanol fuel was sourced from Zanzibar Sugar Factory. Based on the positive results from the pilot project, it was recommended to scale-up the pilot and include health, environment, and time awareness as part of the marketing strategy for the stove and fuel.

In addition, ethanol gel has been promoted in Tanzania for the past five years. Ethanol gel is a renewable form of energy made by mixing bio-ethanol with a thickening agent and water. Though the product is relatively new, its introduction on the Dar es Salaam market and marketing have been rapid and successful. Moto Poa sales points are numerous around Dar es Salaam, Tanga, Morogoro, Dodoma, Arusha, Kilimanjaro and Mbeya. It is easy to use. However, some users complain that Moto Poa cooks slowly and discharges an unpleasant smell. Manufacture of the stoves and ethanol gel takes place in Durban, South Africa, and then they are imported to Tanzania. A two-plate stove sells for TZS 35,000 (US$17.5) and a typical household spends TZS 45,000 (US$22.5) on ethanol gel per month.

Local NGOs such as TaTEDO, Jatropha Tanzania, and KAKUTE have been the first to promote biodiesel vegetable oil for local consumption such as cooking, power generation, and local soap making. Developing cooking appliances that use Jatropha oil was piloted in Arusha between 2006 and 2010 by KAKUTE. Unfortunately, the stove model proved unsatisfactory, resulting in designs that failed to meet the consumers' expectations.

Liquefied Natural Gas (LNG)

Liquefied Natural Gas (LNG) was first discovered in Tanzania in the 1970's and can be used as a fuel in homes for cooking and heating. Currently, two areas in the southern part of the country (Mnazi Bay and Songo Songo) have the capacity of two million standard cubic feet per day and 100 million standard cubic feet per day respectively. Current main off-takers are Songas power plant, TANESCO, Twiga Cement Company and other small customers. As a strategy to encourage domestic utilization, the Tanzania Petroleum Development Corporation (TPDC) is implementing a pilot project on utilization of natural gas for cooking. So far 57 houses have been connected to domestic piped gas supply in Dar es Salaam. The results so far, are impressive and this will result in significant savings on utilization of forest resources for cooking energy.

[17] Project Gaia, *Zanzibar Pilot Study Final Report* (United Nations Industrial Development Organization, 2015).

Coal

Tanzania has significant quantities of coal. The MEM revised its estimates of coal reserves from 1.5 billion tons to 5 billion tons in July 2013. Most of this is currently being utilized for electricity generation. Increasing quantities are being sold commercially to institutions and industry. Coal is not common as a source of household energy, due to uncertainties and lack of infrastructure for the promotion and marketing of coal.

Wide usage of coal briquettes in households and institutions is hindered by a lack of analysis related to health and cooking habits. The Ministry of Energy and Minerals and The Tanzania Commission for Science and Technology are exploring coal as a household charcoal substitute and investigating health impacts related to the usage of coal.

Solar Energy

Solar cookers are extremely limited in use and are virtually unknown to the public. Food preparation in Tanzania cannot be realistically limited to those hours and days when the sun shines. They could be used as an occasional alternative under perfect circumstances. A company called Sunshine Solar in Dar es Salaam, sells imported parabolic solar cookers for TZS 250,000. These cookers reflect sunlight and heat towards a cooking pot situated in the centre of the cooker. They are effective for boiling water and heating liquids during peak daylight hours. On the other hand, they cannot be used during early morning or late afternoon hours, or at night, when most households usually prepare meals. A church organization in Bunda, *Maisha na Maji* is promoting low cost solar cookers; one costs TZS 3,500. Solar cookers also have limitations. They cannot be used for grilling meat, the meal of choice for many Tanzanians.

Current Initiatives for Clean Cooking

ARTI's Initiatives

- *ARTI Energy Limited:* ARTI Energy Limited *(*www.arti-africa.org*)* is a commercial enterprise established in 2011 with a mission to identify quality clean energy products and market them to the end-consumers with the support of quality sales and service.
- *Clean Cookstoves:* Since 2013, ARTI has been promoting Envirofit and Burns stoves. So far, more than 45,000 units have been sold across Tanzania. The retail cost of the stoves is between TZS 65,000 and TZS 85,000 while the energy efficiency level is 60 per cent, saving energy up to three times less when compared to the traditional stoves. (example a bag of charcoal which is used for three weeks on a traditional stove can be used for three months on the improved stove).

- *Biomass Briquettes:* ARTI has established a biomass briquettes small-scale factory in the Coastal region, about 65km from Dar es Salaam. The factory produces up to five tonnes a day. Main customers are both domestic institutions/industries[18].

CARE's Clean Energy Programme

Since September 2012, CARE has been implementing a three-year program "Partnership on Women's Entrepreneurship in Renewables (Wpower)" funded by the US Department of State. The project's intention is to integrate women from Village Savings and Loans Groups into small-scale clean energy value chains across Kenya, Tanzania, and Rwanda. The project is designed as a supply enhancement model. In this, the women at the bottom of the pyramid become entrepreneurs for solar lanterns and clean cookstoves by participating in a market driven process. This is achieved through linkages with respected global/local manufacturers or suppliers of clean energy products[19].

In Tanzania, CARE implements [[Wpower or wPOWER]] project in 19 districts of the following regions: Dar es Salaam, Tanga, Arusha, Manyara, Morogoro, Mwanza, Shinyanga. The wPOWER trained more than 200 entrepreneurs, who sold over 7,500 clean cookstoves and 11,662 solar lamps, positively impacting more than 96,000 people in these regions.

SNV's Tanzania Improved Cookstoves (TICS) Programme

The overall objective of the Tanzania Improved Cookstoves Programme (TICS) is to improve access and sustained use of appropriate cooking technologies for poor rural households and urban commercial biomass users in the Lake Zone of Tanzania. This is accomplished through market linkages with quality private sector ICS product and service providers. SNV has been actively implementing the TICS program in the following areas: Misungwi, Magu, Sengerema, Kahama, Geita, Bukoba, Morogoro, Singida and Dodoma. To date, more than 20 micro/small enterprises have been established and about 6,500 stoves have been produced and sold[20].

Tanzania Domestic Biogas Programme (TDBP)

The Centre for Agricultural Mechanization and Rural Technology (CAMARTEC) in Arusha is a parastatal organization founded in 1972, working on a number of biomass technologies to reduce charcoal and wood consumption. Since 2008, CAMARTEC has been collaborating with Netherlands Development Organization (SNV) and MEM in implementing the Tanzania

[18] Personal communication between Sales Manager, ARTI Energy and Francis Songela, July, 2015.
[19] Personal communications between Programme Manager, CARE, and Francis Songela, July, 2015.
[20] Personal communication between Renewable Energy Advisor, SNV, and Francis Songela, July 2015.

Domestic Biogas Programme (TDBP) under the African Biogas Partnership Programme. The first phase was from 2009 to 2013 and second phase commenced in 2014 and will end in 2017. The TDBP aims to support the construction of domestic biogas installations through a market-oriented approach. Between 2008 and 2013, a total of 8,796 biogas plants have been installed countrywide for domestic consumers. The second phase is targeting 20,700 plants.

Country Action Plan for Clean Cookstoves and Fuels

In 2014, SNV, TAREA, and the Clean Cookstoves and Fuels Alliance of Tanzania (CCFAT) in consultation with a wide range of clean energy stakeholders developed a Country Action Plan for Clean Cookstoves and Fuels. The Country Action Plan aims to support and accelerate the change needed to achieve sustainable, commercial ICS production and distribution, which would reduce charcoal consumption by 50 per cent in half of the fuelwood consuming households and all the institutions by 2020.

Key interventions in the Country Action Plan include:

- Supporting and lobbying with the government through the Ministry of Energy and Minerals (MEM) for the development and implementation of the biomass energy policy & strategy through stakeholder involvement.
- Strengthening an agreed coordinating entity/ platform (chapter or working group) to enhance collaborative efforts among stakeholders thereby creating an enabling environment for market growth, and securing funding for its operations.
- Establishing Standards Working Group with the Tanzania Bureau of Standards (TBS) through the above-mentioned acceptable platform, chapter, or working group, and supporting TBS to develop clean cook stoves and fuels standards based on the ISO standards
- Advocating for policy frameworks that support tax relief and incentives for clean cookstoves and fuels producers in Tanzania
- Carrying out action research (value chain analysis) to identify existing stove producers, their products and their clientele. The focus will be on identifying enterprises and gaps in the market and building linkages for the expansion of the clean cookstoves market
- Commissioning a study into the challenges and opportunities for women in the sector
- Undertake a baseline market demand assessment study at district and regional levels Special focus on usage and preference of women
- Developing appropriate strategies, mediums, tools and messages for raising awareness
- Establishing M&E data collection systems

- Supporting the expansion of the charcoal briquette and biomass briquettes and pellet industries
- Supporting the development of clean cookstoves and fuels market networks

This country action plan requires financial support to truly put it into action. CCFAT calls for the financial support from the Government of Tanzania and other development partners.

Tanzania Traditional Energy Development Organization (TaTEDO)

TaTEDO is a sustainable energy development organization established in 1990 committed to enabling the rural majority in Tanzania to access modern energy services. By 2011, TaTEDO was active in 10 regions and more than 100 villages in Tanzania. The organization is actively involved in promoting clean cookstoves, sustainable charcoal, biomass briquettes, biogas, and biofuels (biodiesel/jatropha'sVSO). Between 2000 and 2011, TaTEDO facilitated distribution of more than 2,100,000 charcoal stoves, 136,000 firewood stoves and 70 biogas digesters. It has also trained more than 740 stoves artisans and 950 charcoal producers.

Promotion of Gasification Stoves

In 2010, Partners for Development (PfD) a USA-based NGO in Tanzania with funding from the United States Department of Agriculture (USDA), supported and promoted two gasifier cookstove models, which were under development in Arusha by Kiwia and Laustsen Ltd, and Jetcity Stoveworks of USA. The two gasifier stove models namely, *Jiko Mbono (*now *Jiko Bomba)* developed by Kiwia and Laustsen Ltd, and *Jiko Safi* of Jetcity Stoveworks are both natural draft top-lit updraft gasifier stoves, both stoves are fabricated locally using mild steel sheets and channels. Jiko Mbono uses pellets as fuel, which are made from grounded agricultural waste with jatropha cake binder, whereas Jiko Safi uses jatropha whole seeds as fuel. (Johnson, et.al., 2015)

Government and Public Institutions Initiatives

Rural Energy Agency (REA)

The Rural Energy Agency (REA) was established in 2005 as an autonomous agency subordinated to the MEM. REA funds a range of rural energy activities. It obtains its finances from small levies on electricity (per kilowatt hour) and on petroleum products, as well as from support by development partners and development banks. REA is active in a number of areas, particularly rural electrification. On clean cooking stoves and fuels, REA has undertaken several energy-gender and biomass energy studies. REA has also piloted several small biomass energy projects (e.g. small-scale gasification of crop residues in Manyata Village).

Tanzania Petroleum Development Cooperation (TPDC)

The Tanzania Petroleum Development Cooperation (TPDC) is a public company formed in 1969, mandated to spearhead, facilitate, and undertake oil exploration and development in Tanzania. In 2014, TPDC in collaboration with BQ Constructors Limited launched a pilot project of gas distribution services for domestic and industrial use in Dar es Salaam (Mwalimu, 2015). So far, the distribution pipelines have been connected to 57 homes in Mikocheni area initially. The aim according to TPDC is to see most homes in Dar es Salaam connected to the natural gas supply system, raising new hopes of accessing the crucial energy, at a cheaper rate. TPDC has engaged Exim Bank of India to fund completion of the project that will enable the city residents to enjoy cheap natural gas. About US$8 million (over Sh12.8 billion) was needed to finance the project to supply gas to the residents of Sinza, Mikocheni, University of Dar es Salaam, Ardhi University, Mbezi Beach, and Mikocheni Coca-Cola.

Tanzania Commission for Science and Technology (COSTECH)

The Tanzania Commission for Science and Technology (COSTECH) is a public institution established in 1988 with the task of advising the government. It deals with the matters pertaining to scientific research and innovations, formulation of policy briefs on research and development, coordination of research, and dissemination of scientific information (TAREA, 2015).

In 2013, COSETCH and Tanzania Renewable Energy Association (TAREA) signed a three-year Memorandum of Understanding for the purpose of promoting sustainable development of renewable energy technologies in Tanzania. Through this partnership, a number of training and marketing activities on clean cookstoves and biomass briquettes have been conducted in Linid, Mtwara, Geita, Kagera, Tabora, Shinyanga, Kigoma, Rukwa and Katavi regions.

The Ministry of Energy and Minerals (MEM)

Recently, the Government of Tanzania through the Ministry of Energy and Minerals (MEM) in collaboration with UNDP launched a programme called Capacity Development in the Energy Sector and Extractive Industries (CADESE). One of the key objectives of the project is to accelerate achievement of the Sustainable Energy for All (SE4ALL) initiative through a wider adoption of Renewable Energy Technologies (RETs). Clean cookstoves and fuels is one of the key interventions of the programme.[21]

Government Regulations for Biofuels

[21] Personal communication between Assistant Commissioner for Renewable Energy, MEM, and Francis Songela, July 2015.

Petroleum Act of 2008

The Petroleum Act recognizes biofuels as potential fuels for blending with petroleum products. The Act gives mandate to the Minister for Energy to make regulations on blending of biofuels with petroleum products. However, there are no regulations on ethanol or biofuels blending. The Ministry of Energy and Minerals (MEM) wants to develop Bioenergy Act which, among other aspects will include regulations on the use of biofuels for transport and cooking.

Guideline for Sustainable Liquid Biofuels Development.

In 2010, the government developed a Guideline for Sustainable Liquid Biofuels Development. The guideline has been prepared in order to create an avenue for biofuels development. It provides minimum requirements to ensure that biofuels development does not compromise sustainability criteria. These criteria include biodiversity, conservation, Greenhouse Gases (GHG) reduction, food security, land use rights, and social wellbeing. Key aspects in the guideline that are pertinent to this assignment include:

- The maximum land size per biofuels developer(s)/investor(s) is 20,000 ha.
- The government encourages out-growers to form associations/cooperatives that may enter into contractual agreements and encourage them to be more involved in value adding activities.
- To ensure that biofuels production has a positive impact on food production, all investors/developers shall set up to five per cent (exact figure to be issued by the One Stop Centre) of land acquired for biofuels production to grow relevant food crops by applying the state of the art agricultural techniques.
- Biofuel seeds production shall be certified according to the regulations governing seed production in Tanzania; and biofuel seeds shall not be imported or exported without permit from the Ministry responsible for agriculture or/and forestry whichever is appropriate.
- To ensure efficient utilization of biofuels crops, by-products from farms, plantations and processing plants should be channeled to where they can be used for electricity generation, production of organic fertilizer, animal feeds, biogas production or other useful products.
- Processing of biofuels feedstock up to a final biofuel product shall be done within Tanzania.
- Liquid biofuels, which include biodiesel and bioethanol can be blended with petroleum products at various ratios. Blending ratios will be issued by the Energy Regulator from time to time.
- Vegetable oil can be used locally for various applications such as cooking fuel, soap making, running stationary machines, automobiles and the excess can be exported.

Other Relevant Policies

Energy Policy

The new Energy Policy was drafted in 2014. The policy promotes fuel switching from wood to other sources for cooking. It also encourages small-scale initiatives on the production and use of bio-fuels.

Energy Water and Utilities Regulatory Authority Act (2012)

This Act gives mandate to The Energy and Water Utilities Regulatory Authority (EWURA) to regulate the electricity, petroleum, natural gas, and water sectors. Oil Marketing Companies (OMCs) are local and international companies licensed to import petroleum products for local consumptions as well as transit business through bulk procurement arrangement coordinated by Petroleum Importation Coordinator (PIC). EWURA is responsible to regulate and publish, cap, petroleum products prices applicable in Tanzania mainland in every month. For example, in August 2015, EWURA published retail prices for diesel, kerosene and petrol. It indicates that retail prices for diesel and kerosene have decreased by TZS 18/litre or 0.86 per cent and TZS 29/Litre or 1.47 per cent respectively, while petrol price has increased by TZS 92/litre or 4.19 per cent. Similarly, compared to the last month's publications, wholesale prices for diesel and kerosene have decreased by TZS 17.50 /litre or 0.90 per cent, and TZS 29.27/litre or 1.55 per cent respectively, while petrol price has increased by TZS 92.07/litre or 4.40 per cent. These changes have been caused by changes in prices of petroleum products in the world market.

Tanzania Biomass Energy Strategy (BEST, 2014)

In 2014, MEM with support from the European Union Energy Initiative Partnership Dialogue Facility (EUEI –PDF) under Africa-EU Renewable Energy Cooperation Programme (RECP) developed a national Biomass Energy Strategy and Action Plan that identifies means of ensuring a more sustainable supply of biomass energy to raise the efficiency, with which biomass energy is used to promote access to alternative energy sources where appropriate and affordable, and, to ensure an enabling institutional environment for implementing the BEST Tanzania Strategy and Action Plan.

The Food Security Act (1991) and amending Cereals and other Products Act (2009)

This Act includes a mechanism for coordinating the production, provision of information regarding food security and specific procedures to deal with food shortages. The Act also foresees the establishment of a Cereals and Other Products Regulatory Authority, which should be in charge of the regulation of international trade in food products. With the modifications included in the Cereals and Other Produce Act (2009), a new board was created and vested with significant powers to intervene in rice and maize markets. Eight commodities have laws establishing and regulating the commodity specific board. These include cashew nuts, coffee, cotton, pytherym, sugar, tobacco, tea, and sisal. The original laws were amended by the overall Cereals and Other Products Act (2009) mentioned above. Each board is established for the purpose of managing the specific industry, including production and marketing of the respective crops.

The Seeds Act (2003)

This Act regulates the production and trade of all varieties of agricultural seeds, including the necessary provisions for quality assurance. The law is implemented by the Crop Development Department at Ministry of Agriculture and the Tanzania Official Seed Certification Institute (TOSCI). It lays down the procedures for dealing with seeds and includes a register of authorized producers and dealers.

The Fertilizer Act (2009)

This Act provides for the regulation and control of the quality of fertilizer, either domestically produced or imported. It establishes the Tanzania Fertilizer Regulatory Authority (TFRA), which is responsible for the coordination of manufacture, trade, distribution, sale and use of fertilizers. Any agent involved in the fertilizer business must be registered with the TFRA and dealers must obtain a license from TFRA. Additional supportive legislation was developed as the Public–Private Partnership Act of 2010, with further implementing regulations developed in June 2011. Also, related to fertilizer the Agricultural Input Trust Fund Act (1994) regulates the provision of inputs to farmers by the government.

The Land Act

The Land Act came into force in 2001, and it consists of The Land Act No. 4 of 1999, and The Village Land Act No. 5 of 1992. These acts specify three categories of land in Tanzania:

- Reserved Land: These are conservation areas, for example game and forest reserves, and national parks. This category occupies about 40 per cent of the total land area.
- Village Land: The Village Land Act recognizes the rights of villages to land held collectively by village residents under customary law. Village land can include communal land and land that has been individualized. Villages have rights to the land that their residents have traditionally used and that are considered within the ambit of village land under customary principles, including grazing land,

fallow land, and unoccupied land. Villages can demarcate their land, register their rights and obtain certificates evidencing their rights.

- General Land: It consists of all land, which is not village or reserved land. It is important to note that the 1999 Land Act places overall ownership of all land with the President of the United Republic of Tanzania – as Trustee of the People. Another new development states that, "customary land rights of occupancy are legally equivalent to any deemed or granted right of occupancy." Additionally, the government also put in place the Property and Business Formalization Programme (MKURABITA) with the purpose of improving access to credit by the formalization of property rights.

Existing Tax Exemptions and Subsidies

Energy

In 2006, the Tanzanian government waived LPG cylinders and gas from all forms of taxation. In the six months following that tax exemption decision, industry stakeholders confirm that the market grew by 50 per cent, and since then, the market has subsequently stabilized. Additionally, in 2014, the government decided to subsidize electricity connection charges to TANESCO's customers. For example, connection charges for a customer who is 30m away from an electric pole dropped from TZS 512,000 to TZS 240,000. In the rural areas, where REA implements rural electrification projects, supported by the World Bank, the Norwegian Government, the Swedish Government, and others, connection charges have been reduced further to TZS 43,000 per customer. The subsidy has accelerated the rate of rural electrification.[22]

Agriculture

In 2010, registered farmers and cooperatives were exempted from VAT on goods and services needed for developing infrastructure such as irrigation canals, feeder roads and storage facilities (Mkulo, 2011). Tanzania is a member of the EAC and applies the Common External Tariff (CET) on imports from outside the EAC, and reduced or zero tariffs on imports from the other four member countries (Kenya, Uganda, Rwanda and Burundi). It also applies reduced tariffs on some commodities from members of SADC and/or the Common Market for Eastern and Southern Africa (COMESA). In the face of food shortages and deficits, the government has temporarily waived import duties on sugar, maize, and other cereals in accordance with the provisions of the EAC Customs Union Protocol. Tanzania is the only government in East Africa that still bans exports, albeit temporarily. High export taxes have been imposed and designed to encourage local processing and value-added exports.

[22] *Personal communications between Director of Technical Services, REA, and Francis Songela, August 2015.*

In 2009, the government launched the National Agricultural Input Voucher Scheme (NAIVS). This input voucher scheme focused on six crops: maize, paddy, tea, coffee, cotton, and cashew nut. This initial targeting has since been expanded to cover sorghum and sunflower. There are seven eligibility criteria for NAIVS: i) being a full-time farmer residing in the village; ii) cultivating less than 1 ha of maize or rice; iii) using the subsidized inputs for maize or rice; iv) agreeing to serve as an example of the use of good agricultural practices; v) being willing and able to take part in co-financing; vi) being a female-headed household (priority); and vii) not having used inputs for the past five years (priority).

Overview of Current and Projected Ethanol Production

Potential Feedstock

Generally, ethanol can be produced from crops that contain starch. In Tanzania, sweet sorghum, cassava and sugarcane have the greatest potential for ethanol production (German Technical Cooperation, 2005). According to GTZ, potential ethanol production from these crops is 4000-8000s/Ha (sugarcane), 3000-6000 litres/Ha (sweet sorghum) and 1750-5400 litres/Ha (cassava).

(1) Sugarcane is an important commercial crop in Tanzania. It is a monocrop currently grown in four estates, Kilombero Sugar Company, Mtibwa Sugar Estate (MSE), Tanganyika Planting Company (TPC) and Kagera Sugar Limited. Estimated annual demand for sugar is around 300,000 tonnes. Tanzania imports sugar to offset the shortfall. However, there are few new investments in the sugar sub-sector that are meant to increase sugar production in Tanzania. For example, EcoEnergy Africa AB, a Swedish company, is investing over US$ 500 million (TZS 800 billion) into a sugarcane plantation and a factory producing sugar in Bagamoyo, approximately 60 km from Dar es Salaam. The project is expected to generate 130,000 tons of sugar annually for the domestic Tanzanian market. Construction works have started in March 2014 and production is expected to start in 2016. Apart from sugar cane grown by the estates, sugar cane is also grown by outgrowers who are found at Kilombero, Kagera and Mtibwa estates. For example, Kilombero Sugar is collaborating with nine sugarcane growers' associations with more than 10,000 members. In 2013/2014, out growers supplied a total of 562,000 tons of cane, which is about 41 per cent of the cane supplied to the factory. Low capacity of existing sugar mills leads to under harvesting and after/post-harvest losses is one of the main challenges facing sugar sector in Tanzania. This affects many of the outgrowers. In 2011/2012, sugar production was 294,419 tons and area under cane was 62,569Ha but harvested area was 44,194 Ha of which 35 per cent of the area was under outgower's scheme. In

Kilombero, about 300,000 tons were left un-harvested and about 5,900 tons of canes were rejected in 2013/2014.

(2) Cassava is a staple food and grown in most parts of Tanzania including Mtwara, Tanga, Linid, Coast/Pwani, Dar es Salaam, Shinyanga, Tabora, Mwanza, Rukwa, Kagera and Mara. Tanzania has 4,547,940 tons annual production of cassava from 873,000 Ha of land. Yields of cassava are around 5.21tons/ha. There is reported case on the use of cassava for ethanol production. However, FJS African Starch Development Co Ltd (www.starchtanzania.com), a local company based in Dar es Salaam is constructing a starch-processing factory in Rufiji, Coast/Pwani region, about 110km from Dar es Salaam. The factory will have capacity to process 260 tons of cassava per day, equivalent to 60 tons of starch per day. The company intends to engage a total of 150 small holder farmers and 10 commercial farmers, and offer farming contracts to produce and sell their cassava to the factory.

(3) Sweet Sorghum is grown almost entirely by small-scale farmers on small plots of land between 1.5Ha and 3Ha and in the Lake Zone. Most of these farmers do mixed crop farming system. Individual farmers grow both brown- and white- grained varieties. These types of sorghum are used for grain for food/feed and local beer, stripped leaves, and bagasse/ stillage for animal feed. In a few cases, fresh stalks are chewed similarly to cane. In 2008, a British energy firm, CAMS Group, had plans to produce 240 million litres of ethanol a year from sweet sorghum in Tanzania. Also, Abengoa Bio-energy, a Spanish Company aimed to use sweet sorghum to produce ethanol in the Coast region. Unfortunately, these investments never happened.

Existing Ethanol Distilleries

Sugarcane is the main feedstock for ethanol production at the moment. The potential for ethanol production from the four sugar industries in 2004/2005 was estimated to be 20 million litres per year. These industries have shown growing interest in the production of ethanol in order to diversify their income opportunities. However, only two distilleries are currently producing ethanol from molasses.

Kilombero Sugar Company located about 250km from Dar es Salaam produces about 750,000 litres of ethanol per year. Most of this ethanol is used for beverage processing by Tanzania Breweries Limited. Recently, a small quantity is supplied to SAFI Tanzania for cooking. In March 2015, SAFI bought 20,000 litres of ethanol from Kilombero Sugar.[23] Ethanol is taxed like any other alcoholic beverages. The Tanzania Revenue Authority has imposed the following taxes on alcoholic beverages – VAT (18 per cent), import, excise, and import duties. For example, excise duties for wine is TZS 820/litre and spirit is TZS 1,216 per litre.

[23] Wholesale price at Kilombero Sugar is TZS 1970/litre (USD 0.99/litre). SAFI is retailing in 1 litre bottle at TZS 2350 (USD 1.1)

Kilimanjaro Biochem Ltd has set-up a bioethanol plant with a capacity of 22,000 litres per day located at Mwanga in Kilimanjaro Region. The company's distillery converts molasses, a waste product from Tanzanian Sugar plants (mainly from TPC) into Extra Neutral Alcohol (96.4 per cent) and technical grade alcohol (94 per cent) for medicinal use and fuel. Also, EcoEnergy Africa AB's investment into sugar factory intends to produce 10 million litres of ethanol per year. This is projected to come online in 2017.

Conclusions and Recommendations

Fuel Switching

Switching from biomass-based fuels to cleaner, safer, and more efficient fuels for cooking can improve living standards and reduce the negative health and environmental impacts associated with traditional biomass use. However, the following barriers to adoption must be understood and addressed:

(1) Inadequate awareness: There is still inadequate awareness among consumers on the costs and benefits of clean cooking. Key messages have not been communicated clearly to the end consumers. These include socio-economic, health, and safety benefits.

(2) Lack of good quality products and services: Limited supply and poor durability of improved stoves have undermined the trust of consumers. Therefore, there is a need to regain consumers' trust with quality products, reliable supplies, warranties, after-sales services, and reliable distributors.

(3) Insufficient access to finance and end-consumer financing: While there is potential for the production and use of clean cookstoves and fuels to contribute to economic development, a good number of end-consumers have low purchasing power, and most of them have limited access to credit facilities.

(4) Inefficient distribution channels: Clean energy suppliers, including some of the largest and most reliable dealers in the nation, are based in urban areas. Despite strong potential for expansion of clean energy products to under-served rural and peri-urban areas, the lack of viable distribution channels effectively limits the distribution of quality products from the cities.

Competition and Potential for Ethanol to Displace Other Cooking Fuels

Ethanol is among the cleanest of household fuels when burned in proper appliances, and it is widely cost-competitive compared with electricity, LPG, and kerosene. It can be distributed through existing infrastructure and markets. Impressive results and growing demand for ethanol fuels, such as the on-going initiative by SAFI Tanzania, indicate potential for scaling up. However, the main challenge remains a reliable supply of ethanol fuel. SAFI is currently procuring ethanol from Kilombero Sugar, competing with brewing industries, who can pay a higher price for ethanol (CARE, 2014). Ethanol fuel needs to be retailed to the end-consumer at a competitive price a monthly fuel costs need to be less than the average amount spent on charcoal by a typical family.

Gender Aspects

Women have more tasks to perform at home, compared to men. As a result, they have less time to rest and do not have free time that can be used for additional income generating activities. Women spend as much as 50 per cent of their income on food, then on fuel, followed by clothing and health care. Men's expenditure is concentrated on food for the household, school fees, clothes, mobile phones, airtime, and other technologies such as radios. Husbands supplement their wives' income to enable them to purchase basic items required in the household. In most cases, the women have control of the budgets for different items required in the household even though it is the husband who pays for some of the items. In general, women appear to have complete control over the income they generate in their small businesses.

Women are aware that they are spending a lot of money and time on kerosene, charcoal, and wood and do not need convincing that clean cookstoves and solar lanterns are a better replacement. Women's control of their own income and some of that of their husbands' places them in a strong position to acquire clean energy technologies and fuels.

In addition, both women and men can become manufacturers and distributors of small-scale clean technologies and fuels. CARE's experience in their clean energy rural sale programme indicates that involving women in scaling-up affordable and reliable energy services can lead to the creation of additional entrepreneurial activities for women and provide a dynamic engine for economic development and poverty elimination in local communities.

Taxation

Currently, ethanol is taxed like any other alcoholic beverages. Tax exemption on alternative cooking energy and technologies is one of the strong incentives to stimulate demand and markets. As a step towards promoting alternative fuels, the government of Tanzania exempted LPG from all from of taxes. One of the impacts of this exemption was the market growth for LPG. In addition, solar energy products receive exemption from all taxes. Simultaneously, ethanol fuel users pay VAT. Companies who will produce ethanol for cooking will favour the removal of VAT on their product in order to decrease prices and stimulate demand. It is expected that the Bioenergy Act, apart from addressing blending issues, will also provide incentive framework for ethanol fuels for cooking

3.5. Uganda

Country and Demographic information

Uganda is a landlocked country in East Africa and is divided into 112 districts across its four regions: Northern, Eastern, Western and Central regions. Each district is further divided into counties, sub-counties, parishes and villages. Uganda has a population of 41.5 million people as at 2016 with 81 per cent of them living in rural areas. Uganda has the second highest birth rate in the world with an annual Population Growth Rate of 3 per cent, increasing the demand on the available energy resources. The majority of the population (96 per cent) relies almost exclusively on biomass for cooking.

Uganda has many tribes speaking different languages. Fifty six tribes and nine indigenous communities are recognized in the 1995 constitutional amendment of 2005. The Baganda tribe of the Bantu ethnic group is the largest comprising of 16.2 per cent of the population. Other tribes indude Basoga, Bagisu, Banyoro, Banyarwanda, the Banyankore, Karimojong, Langi, Iteso, Acholi, Lugbara and others (Kurian, 1987). English is the official language with Luganda widely spoken in most parts of the country. Swahili is mainly spoken by the business (trading) community.

Uganda has substantial natural resources. Agriculture is the mainstay of the economy, employing over 71.9 per cent of the working population. GDP stands at $20 billion, growing at 5.2 per cent per annum. The GDP per capita is $509, which is among the lowest in Sub-Saharan Africa. The contribution of agriculture to total GDP has been declining over the years, from 31.1 per cent in 2007 to 20.9 per cent in 2013 (Statistical Abstract-Government of Uganda, 2014). The major food crops include bananas, cassava, maize and sweet potatoes. Although the country witnesses substantial yields of these products, some areas experience food shortages and insecurity. The yield (MT/Ha) of these crops is substantially lower than the average yield of other nations. In Nigeria, for example, farmers working in conjunction with the USAID-funded Cassava Enterprise Development Project (CEDP) achieved an average yield of cassava of about 25 MT per hectare in one year. This is almost ten times the output for Mukono district in Uganda (Cleary, Jung and Noyes, 2015).

The biomass industry is an important sector to the economy contributing $74.8 million to GDP, with firewood contributing $48 million and charcoal $26.8 million per annum.The county's major exports are coffee, fish and fish products, tea, cotton, flowers, horticultural products the major markets being Sudan, Kenya and Rwanda, with palm oil, wheat, sugar, beer, and cigarettes the major imports in 2011 (FAO, 2015).

Although Uganda is blessed with plenty of rainfall, good weather and fertile soils, it imports some agricultural commodities which is an indicator that the country is not self-sufficient in food supplies, with maize ranked as the 13th import for 2011 even though it is the third most-produced crop in the country. Uganda is a relatively easy place to do business by sub-Saharan Africa standards although it is quite challenging by international norms.

About 86 per cent of the population relies on agriculture to earn a living (Agriculture Census, 2015). The vast majority are involved in agricultural production and trade of the agricultural products. The majority of the workers in the value chain (planting, harvesting, processing and retailing) are women who do not necessarily have any modernized agricultural equipment to ease their work and maximize productivity, often working in unfavorable environments.

The traditional cash crops of Uganda over the years have been coffee, tea, cotton, and tobacco. Robusta and Arabica are the two types of coffee grown here. The Robusta type is produced in much higher quantity compared to Arabica type. In 2013, Uganda produced a total of 232,561 tons of coffee of which 75 percent was Robusta. Sixteen major crops are grown in the country, including cereals; which include maize, millet, sorghum and rice; root crops namely; cassava, sweet potatoes, Irish potatoes; pulses including beans, cow peas, field peas, pigeon peas; oil crops namely groundnuts, soya beans, sim-sim; plantains (bananas) and coffee. Wheat, which has been grown in the rest of East Africa over the years is becoming a major crop in Uganda as well. The harvested cereal crops are consumed, sold, or stored. Total production of sugar was 438,400 MT in 2014, an increase of 27 per cent from that of 2013. This figure is expected to increase in the coming years to meet expected increase in consumption due to the rising population.

Current Energy Situation

Uganda is endowed with abundant hydropower, biomass, solar, geothermal, peat and fossil energy resources fairly distributed throughout the country. The energy resource of the country is estimated at 2,000 MW of hydropower, 450 MW of geothermal, and 1,650 MW of biomass, an average of 5.1 kWh/m^2 of solar energy radiation and 800 MW of peat. In addition, petroleum reserves estimated to the tune of 6.5 billion barrels have been discovered in the western part of the country (Biryabarema, 2014). The national total primary energy consumption is 1,125,528 ktoe. Biomass is the most important source of energy contributing about 90 per cent of the total primary energy consumption with firewood contributing 78.6 per cent, charcoal 5.6 per cent and crop residues 4.7 per cent. Electricity contributes only 1.4 per cent to the total energy balance while hydrocarbon-based fuels contribute 9.7 per cent. Forest wood biomass demand is estimated

Box 5. Uganda energy potential

Uganda Energy potential (MW)	
Hydropower	*2,0000*
Geothermal	*450*
Biomass	*1650*
Solar	*5.1kWh/m2*
Peat	*800*

at 44 million tonnes per annum (12 tonnes of oil equivalent). However, the tree resource can sustainably supply only 26 million tonnes per annum, well below the demand.

The total installed power generation capacity is 822 MW with the overall national access to electricity at 20.4 per cent while less than 10.3 per cent (2014 figures) of households in the rural areas are connected to the grid. As a result, the country has one of the lowest per capita electricity consumption in the world at 215 kWh per capita per year compared to the Sub-Saharan Africa's average of 552 kWh per capita and world average of 2,975 kWh per capita per year. The energy sector is the key to Ugandan economy providing revenue to the government in the form of taxes from import duties, VAT, levies on transmission bulk purchases of electricity, license fees, royalties and foreign exchange earnings from power exports.

Wood fuels are predominantly used for cooking in rural areas, while charcoal is mostly used to fulfil the cooking energy needs of the urban population. Between 2005 and 2008 the charcoal prices rose at an enormous (nominal) rate of 14 per cent per year owing to the decline in supply of biomass resource. The high demand of wood fuels has led to depletion of the available forest cover. It is estimated that the country loses about 92,000 hectares of forest cover every year and actually lost 25 per cent of its forest cover between 1990 and 2005 mainly to meet fuel wood demand for household cooking and industrial use. Cooking is still done using traditional methods, which are very inefficient with the production of charcoal done using inefficient methods and kilns, which have efficiencies of only 10 per cent to 12 per cent. Coupled with inefficient cooking methods, less than 40 per cent irreversible environmental degradation is projected due to the massive destruction of the existing forests which will impact the overall national and regional climatic weather patterns. Households in rural areas mainly use traditional lighting technologies such as candles or kerosene lamps that give poor quality lighting, emit noxious fumes and are unsafe especially for children.

Health, HAP and the Environment

About 3.8 million Ugandan households cook on open fires in enclosed spaces and nearly 1 million additional households use traditional charcoal stoves which is about 70 per cent of the total number of households (total number of households is 7 million). As a result, Household Air Pollution (HAP) is a big concern in these households affecting mainly women and children leading to 19,700 deaths each year, the majority of whom (17,800) are children dying from pneumonia, mental impairment and cardiovascular diseases caused by the noxious gases such as Sulphur dioxide and carbon monoxide. Improved Cookstoves (ICS) are mostly found among charcoal users who are mainly located in the urban areas although their penetration is less than one third of the households. Women and children spend long hours looking for firewood, and huge household expenditures (about 15 per cent of poor households' expenditure is spent on cooking and lighting fuels while the rich households' expenditure is about 9 per cent on the same) are incurred in fuel costs for those that purchase the fuels (World Bank, 2015). Women are therefore deprived of valuable time to engage in income generating activities and children are denied opportunity to go to school and study.

The rising population has put enormous pressure on natural resources, especially on forests. Biomass fuels are becoming increasingly more expensive due to the continuing pressure on the remaining biomass resources, which are becoming scarce. Due to the high electricity tariffs, the majority of electrified households continue to use wood and charcoal for cooking purposes. The penetration of other fuels such as Liquefied Petroleum Gas (LPG) is very low at 1 per cent because of the initial investment that is needed to acquire an LPG canister and the relatively high costs of the fuel. Briquettes which have been introduced to the market still have to be accepted by the population. They only contribute a minor fraction to cooking energy, as they still have to overcome a number of technological issues including quality and energy density as well as marketing and distribution challenges.

Baseline Energy Information

Cooking using traditional methods such as the three-stone fire and the traditional charcoal stoves (metal sigiri) is still common though cleaner and efficient cookstoves have been promoted for many years. The availability and uptake of improved cookstoves is still low as one moves away from Kampala and the neighbouring urban and peri-urban areas. A variety of firewood and charcoal cookstoves exist on the market to serve both urban and rural consumer segments; however, there is still a long way to go regarding the quality of the cookstoves. The majority have efficiencies that fall in into either ISO Tier 1 with small functional improvements over baseline technologies and are typically made from local materials by local artisans or self-built or ISO Tier 2 with improved efficiency of combustion of fuel and less emissions using typically rocket principles and higher end materials. LPG usage is low and restricted mainly to urban, higher income families. It is often perceived as a dangerous fuel and availability outside urban centres is low. LPG receives no government subsidy. Kerosene is used by a small percent of the population mainly smaller families in urban areas. The government recently removed subsidies on electricity and very few households can afford to cook with this fuel.

Past donor programs have targeted selected regions for promotion of improved cookstoves which has contributed to localized uptake. Imported cookstoves such as Envirofit and Jiko Poa stoves have been introduced on the market but sales and adoption has been concentrated in urban and peri-urban areas. Low income households prefer basic, cheap cookstoves which they perceive as affordable, even when they are aware that the durability of these cookstoves is very low.

Image 1. Types of charcoal and briquettes cookstoves in the market

Traditional **Tier 0**	**Basic improved** **Tier 1**	**Intermediate** **Tier 2**	**Advanced** **Tier 3**	**Modern** **Tier 4**
 Metal sigiri made using scrap metal and very inefficient.	 Have small functional improvements over traditional technologies typically made from local materials by local artisans or self-built	 Have improved efficiency of combustion of fuel and emission gases typically with rocket principles and higher end materials	 Improved thermal aesthetics efficiency, emissions performance.	 Non-biomass stoves relying on LPG, kerosene, biogas or electricity.

Image 2. Types of firewood cookstoves in the market

Traditional **Tier 0**	**Basic improved** **Tier 1**	**Intermediate** **Tier 2**	**Advanced** **Tier 3**	**Modern** **Tier 4**
 Three stone fire made using bricks, stones with or without a surrounding wind shield	 Small functional improvements over baseline technologies; typically made from local materials by local artisans or self-built	 Improved efficiency of combustion of fuel and emission gases, typically with rocket principles and (often) higher end materials	 TLUD Gasifier firewood/biomass stoves using natural draft principles or with fans, producing some biochar.	 Non-biomass stoves relying on liquid / gas fossil fuels or electricity.

Source: State of the Clean Cooking Energy Sector in Sub-Saharan Africa; Uganda Country Action Plan.

Table 14. Approximate upfront cost of cookstove, efficiency and distribution channel used

Cookstove	Cost ($)	Efficiency	Distribution channels
Three stone fire	0	Unknown	Home
Traditional metal charcoal stove	2 to 4	Unknown	Direct sales and retailers
Improved charcoal stove with ceramic liner	7 to 15	30-40%	Direct sales, network of stove vendors, retailers
Improved wood stove	Various	Various	Direct sales, retailers and middlemen
Imported wood stove	15 to 20	33%	Direct sales and network of salesmen
Gasifier stove	18 to 20	30-40%	Direct sales and network of salesmen
LPG Stove	$28	Unknown	Direct sales and network of vendors

Source: *Uganda Country Action Plan, Uganda Market Assessment: Sector Mapping.*

Carbon finance programs have increased the uptake by supporting distribution of the cookstoves and offering subsidized prices to the end users but this has greatly been affected by the slump in the carbon market. The uptake of LPG cooking appliances has been low due to the high upfront costs of the stove and gas cylinder and its low availability outside urban areas. The adoption of biogas as a cooking fuel has been quite slow given the initial upfront investment required for setting up a biogas plant. The Renewable Energy Policy of Uganda has a target of 100,000 biogas units installed by 2017.

Consumer Behaviour

Households often own several cookstoves, which they use for cooking different meals at the same time. They will also use traditional methods for certain cooking tasks which are perceived to require particular cooking methods. As much as the cost is a significant factor influencing the purchasing pattern of the customer with regard to fuels and cookstoves, their availability and minimum quantity(s) sold are also important along with affordability. Convenience of cooking is another factor that users value as very important.

The majority of rural households use firewood and agricultural wastes for cooking, while in urban areas, households use both firewood, charcoal and a few households use LPG and briquettes. Many households in rural areas collect firewood for free although it is increasingly becoming scarce. Deforestation at the macro-level is a major concern and a hot political issue for the population, as witnessed by the public demonstrations of 2007 against the President's proposal to give away 7,000 hectares of the 30,000 hectares of Mabira forest to SCOUL, one of the major sugar producers in the country to double their sugar production to 100,000 tonnes per annum. However, the fundamental micro energy needs, especially for cooking using mainly biomass based fuels supersedes any conservation aspirations. In addition, awareness on the dangers imposed by the Household Air Pollution is very low and it is not regarded as critical to the biomass users.

Cooking Costs Using Traditional Cooking Methods

(Prices will vary depending on family size, location and cookstove) Costs will reduce by about 30 per cent for firewood, charcoal and briquettes if improved cookstoves are used.

Table 15. Cooking costs using traditional cooking methods

Fuel	Purchase Unit	Usage	Cost
Firewood	1 bundle	3 days	$2.1
Charcoal (urban)	40kg sack	2 weeks	$30
LPG	13kg cylinder	3 weeks	$38.5[24]

Cooking Costs Per Week Using Traditional Cooking Methods

(Costs will reduce by about 20 percent to 30 per cent for firewood, charcoal and briquettes if improved cookstoves are used).

Table 16. Cooking costs per week using traditional cooking methods

Fuel	Purchase Unit	Usage	Cost
Firewood	2.5 bundle	1 week	$5
Charcoal (urban)	20kg sack	1 week	$15
LPG	7.5 kg cylinder	1 week	$12.8
Briquettes	20kg sack	1 week	$8.6

Consumer Segmentation

In this consumer segmentation, the northern region is not included because it was difficult to reach at the time. In addition, households with income levels less than $1/day are excluded because they have a low purchasing power. From the analysis, the market for improved cookstoves and fuels excluding the above is therefore 2.1 million households in rural areas using firewood as their major fuel and 0.55 million potential households in urban areas predominantly using charcoal.

Table 17. Consumer Segmentation-1

	Segment 1: Rural firewood	Segment 2: Peri-Urban firewood
No. of households	Not available from source data	Not available from source data
Income	$1-$3day	$1-$3day

[24] This does not include the cost of the cylinder for LPG. One cylinder will cost between $30 and $50.

Rural / Urban	Rural	Peri-urban
Willingness to pay	Minimal (mostly collects)	Minimal (half collect)
Stove ownership	6% improved firewood stove	14% improved firewood stove, Minimal (half collect), (majority installed free)
HAP awareness	Low	Low
HAP exposure	High	High
Fuel choice	Firewood, wish for dryer firewood, possibly chimneys	Firewood, wish for dryer firewood, possibly chimneys

Table 18. Consumer segmentation-2

	Segment3: Peri-urban Charcoal	**Segment 4: Urban Charcoal**	**Segment 5: Urban Charcoal**
No. of households	Not available from source data	Not available from source data	Not available from source data
Income	\$1-\$3day	\$1-\$3day	>3\$day (avg. \$5.4/day)
Rural / Urban	Peri-urban	Urban	Urban
Willingness to pay	Moderate to high (already pays for charcoal)	Moderate to high (already pays for charcoal)	Moderate to high (already pays for charcoal)
Stove ownership	Improved Jiko approx. 30% efficient, clay lined	Improved Jiko approx. 30% efficient, clay lined	Jiko, approx. 30% clay lined
HAP awareness	Low	Low to moderate	Low to moderate
HAP exposure	High	High	High
Fuel choice	Charcoal	Charcoal, some consider to switch to kerosene or electricity/LPG	Charcoal, many consider to switch to kerosene, or electricity/LPG

From the table (customer segments 3, 4 and 5), the market for improved cookstoves using charcoal, LPG, kerosene and other clean fuels in the urban and peri-urban areas is enormous. Bioethanol which can substitute charcoal presents an enormous opportunity for households as it offers better efficiency leading to reduce fuel costs. In addition, other benefits accruing include improved cleanness, faster cooking time and convenience. Households are unlikely to switch to electricity because of the associated high tariffs of energy use from this source.

Potential Market:

Given that clay cookstoves have a lifetime of six months to two years, the potential market for clean cookstoves includes households that currently have clean cookstoves and those without. The potential market for improved cookstoves is estimated at more than 4.5 million households in rural areas and another 1.5 million in the urban areas. Increasing urbanization and the rising charcoal prices are likely to increase the demand for efficient cookstoves and alternative/new biomass fuels. The cookstoves on the market that do not meet the ISO Tier 2 requirements present a potential market for alternative cooking solutions. In rural areas, the commercialization and adoption of cookstoves will become imperative as firewood becomes increasingly scarce.

Interventions by Government and Donors:

The penetration of improved cookstoves in the country has remained disappointingly low at 10 per cent despite various government and donor interventions. The majority of rural Ugandan households live on less than $3 per day and spend more than $8 per month on biomass fuels to use on traditional cookstoves. Thirty-six per cent of rural households spend a significant amount of their monthly income on firewood. About 15 per cent of poor households' expenditure is spent on cooking and lighting fuels while the rich households' expenditure is about nine per cent on the same. A large number of these consumers would have the ability to pay for improved cookstoves and fuels only if they are available in their local areas. Interventions in the sector in the past were focused on the supply side to increase production volumes. However, the distribution landscape still has a lot of challenges as very few producers have integrated distribution into their operations relying more on direct sales/promotions due to the high capital costs required for inventory financing and working capital.

Table 19. Major Actors

Organization Name	Area of operation	Areas of intervention	Clean cooking interventions being implemented
Ministry of Energy and Mineral Development	Countrywide	Supporting the development of all renewable energy including biomass; charcoal, briquettes, firewood, clean cookstoves, biogas technologies	• Overall sector regulation, guidance and policy development. Policies relevant to the biomass energy sector include the BEST, Biomass Energy Strategy finalised in 2014, the biofuels bill that will be debated in parliament • Provide policy and strategic guidance and support, coordinate specially public sector partners, support and facilitates awareness activities and facilitates market development events • Works with other government agencies, development partners to develop standards for clean cooking. • Implementing sustainable charcoal production project with the Ministry of Water and Environment and NFA • Facilitates demonstrations, exhibitions and awareness campaigns • Promotion of improved cooking technologies and fuels.
GIZ BMZ – Promotion of Renewable Energy and Energy Efficiency Program (PREEEP)	Countrywide	All renewable energy technologies	• Supporting energy sector policy development • Awareness raising around carbon finance • Supporting the ICS for East Africa PoA being implemented by Uganda Carbon Bureau • Development of a standardised baseline for institutional cookstoves • To hold the first carbon fair to match project developers and buyers of carbon credits • Supporting cookstove testing and certification standardisation of cookstoves
GIZ Energising Development (EnDev)	Countrywide	All renewable energy technologies including; clean cooking technologies including biogas	• Supports Ministry of Energy to promote and develop policy for renewable energy development • Training and capacity building of rural stove artisans to build

Organization Name	Area of operation	Areas of intervention	Clean cooking interventions being implemented
		technologies	using locally available materials and to market standardized high quality stoves • GIZ EnDev with MEMD developed a national quality brand "Good Stove – Better Cooking". The brand serves to promote partner companies and quality standards for end users • Works with private improved cookstove businesses/SMEs to improve product quality business, marketing and distribution networks. • Capacity building of SMEs
GVEP International	Countrywide (Operating in the EAC region)	All technologies, specifically institutional cookstoves in Uganda	• Accelerating access to clean cooking technologies through promoting, financing and distribution. • Capacity building of SMEs business advisory services, linkages of businesses and end users to financial institutions/investors.
Joint Energy & Environment Projects, (JEEP)	27 districts, Countrywide	Firewood and charcoal Institutional and households cookstoves	• Institutional and households cookstoves trainings • Training in briquette making • Promotion of energy-saving charcoal stoves
Mercy Corps	Northern region	Firewood and charcoal households cookstoves	• Training and capacity building of rural stove artisans and SMEs to build using locally available materials and to sell standardized high quality stoves. • Works with private improved cookstove businesses to improve quality, market and distribute. • Capacity building of local artisans and businesses
Renewable Energy Business Incubator		Clean cooking fuels, biogas, briquettes.	• Overall business support to renewable energy entrepreneurs • Capacity building for technical skills • linkages to financial institutions • Business registration, market research, feasibility studies to test viability. • Commercialization and marketing of clean cooking fuels

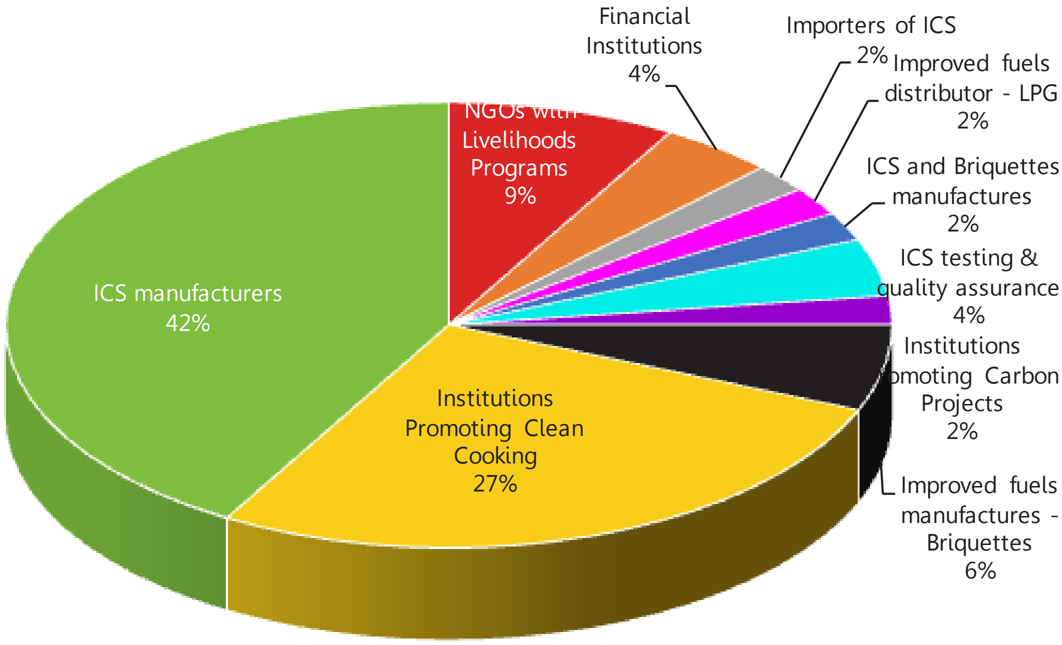
Organization Name	Area of operation	Areas of intervention	Clean cooking interventions being implemented
Living Earth Uganda	Countrywide	Briquettes, energy saving cookstoves.	• Promoting energy saving cookstoves and fuels as a way of alleviating climate change.
SNV	Countrywide	Clean cookstoves, biogas, briquettes	• Capacity building of SMEs • Innovative financing and linking SMEs to financial institutions • Awareness and promotional campaigns to stimulate demand
Inter Church Organisation for Development Cooperation (ICCO)	Lango, Acholi, Teso, and Karamoja Sub region	Improved stoves and biogas technologies	• Promotion campaigns for afforestation (wood lots) to mitigate firewood shortages and time spent on firewood collection • Awareness campaigns to reduce Household Air Pollution • Promotional activities to generate carbon credits from household clean cooking
Biomass Energy Efficient Technologies Association (BEETA)	All regions except Karamoja region	charcoal, firewood clean cookstoves	• Capacity building of members • Awareness raising and market promotions for households and institutional cookstoves
Worldwide Fund for Nature (WWF) Uganda Country Office	Albertine Region; Eastern Region; Mbale, Kapchorwa, Karamoja	charcoal, firewood clean cookstoves, biogas technologies	• Awareness raising to promote clean cooking solutions • Capacity building of local governments • Leveraging private sector engagement by supporting business and market development for SMEs. • Policy and advocacy for development of quality standards for efficient use of biomass • Environment (forests) conservation and policy development for forests protection. • Increase the access to clean and affordable cooking fuels and technologies for communities in Uganda
Centre for Integrated Research and Community Development Uganda (CIRCODU)		charcoal, firewood clean cookstoves, biogas technologies	• Coordination of testing and development of clean cooking standards • Conduct field tests for cooking technologies • Conduct cooking sector market and baseline studies

Organization Name	Area of operation	Areas of intervention	Clean cooking interventions being implemented
Centre for Research in Energy and Energy Conservation (CREEC)		All renewable energy technologies	• Conduct laboratory tests for cooking technologies • Coordinates testing and standards development processes • Works with other agencies for promotion of quality of cookstoves
UNACC			• Overall coordination of the clean cooking sector by developing and implementing capacity building and awareness programs, supporting market development as well as testing and quality assurance of clean cooking technologies

A number of institutions promoting biomass sector are active in the various regions of the country. The major players are mentioned below:

Uganda has more than 50 cookstove producers the majority of whom are located in the central region districts of Kampala and Wakiso. The majority of the businesses produce no more than 1,000 units per month. Alternative solid fuels (briquettes) manufacturers (about 100) classified into micro, small, and large producers are also mainly operating in the central region with a few livelihood NGO programs operating in the northern and eastern regions. The major distributing centres for improved cookstoves, briquettes and LPG are super and local markets and retailing kiosks attached to large producers

Graph 2. The distribution of actors in the clean cooking sector



Source: Needs Assessment and Sector Mapping of UNACC Members (Kampala: Uganda National Alliance on Clean Cooking)

The financing landscape is characterized by the limited number of financing options available to cookstove and fuel producers and the lack of information/willingness of the financial institutions to avail financial products to the sector which is perceived to be very risky. Traditional sources of capital from large domestic and international banks are out of reach for small entrepreneurs who lack sufficient collateral to be able to access debt financing. Carbon finance which provides an alternative is only sufficient to top up on the investment capital undertaken by the entrepreneurs. In addition, the current market trends do not favour investment into projects that generate carbon revenues as the price of carbon has continued to fall freely. Another barrier that needs to be addressed by the institutions promoting clean cooking is the insufficient knowledge about the dynamics of the sub-sector by the local financial institutions. The financial institutions currently active in financing the clean cooking sector include Post Bank, Equity Bank, Opportunity Bank and FINCA. Centenary Bank is currently finalizing an MOU with GVEP International to finance the adoption of institutional cookstoves by schools.

Policy and Regulatory Framework

Several government policies that are relevant to the biofuels industry are discussed briefly:

The Renewable Energy Policy

The Renewable Energy Policy has an overall goal of increasing the use of modern renewable energy from the 4 per cent in 2007 to 61 per cent of the total energy consumption by the year 2017. Specifically, it has a target of scaling-up the adoption of efficient charcoal fuel stoves from 30,000 stoves to 2,500,000 stoves and increase the adoption of efficient fuelwood stoves from 170,000 stoves to 4,000,000 stoves by 2017. The cumulative number of all types of cookstoves disseminated/installed till 2013 was 223,977. However, there is need to establish a monitoring and evaluation tool to enable the capturing and recording of concrete results on adoption of improved cookstoves and other technologies. The policy also advocates for a blend of biofuels with conventional fossil fuels up to 20 per cent and recommends the development of a biofuels policy to promote the industry.

Biofuels Bill

The Biofuels bill provides for the provision of regulations for the production of biofuels feedstock, development of biofuels storage facilities, and blending in petroleum products for transportation fuels. The bill has been gazetted after approval by the Cabinet and is currently before parliament for debate and subsequent passing. The bill stipulates that all petroleum products that will be supplied in Uganda shall be blended with biofuels.

The objectives of the bill include;

- Creation of a conducive environment for the production, management of biofuels and promotion of the sub-sector for power production and transport.

The obligations of the Minister include, among others;

- Promotion of the sustainable production and utilization of biofuels for social and economic benefit so as to increase incomes of the rural population
- Determination of the appropriate number of biofuels to be blended in petroleum products
- Issue and revoke licenses for biofuel production, storage, blending and transportation.
- In consultations with the Ministry of Finance, Planning and Economic Development institute incentives e.g. tax rebates and tax holidays for machinery and equipment imported for the production of biofuels.

The leaders of the sugar industry are the major advocates and lobbyists for this bill to be passed. The bill gives powers to the Energy Minister by a statutory order to pass regulations that will govern the sub-sector. It provides for the consultations between the energy ministry and the ministry of agriculture and NEMA to ensure that food security and environmental sustainability are not compromised by the production of biofuels.

It will specifically incentivize the sugar industry in addition to other feedstock crops to invest in the ethanol industry so as to the convert the available wastes (molasses) into bio-ethanol to be blended with petrol resulting in foreign exchange savings that would be spent on imported petrol. The country consumes about 2.24 million litres of hydrocarbon-based fuels per day, 70 million litres every month (Da Silva, 2009). If all fuel vending companies are obliged to blend fossil fuels with bio fuels with an 80:20 mixing ratio as proposed by the bill, the required production of biofuels would be 176 million litres per year. However, this would be a rather ambitious target with a lower less strenuous blend of 2 per cent is preferred during the early phases. The Minister will issue regulations that will determine appropriate blending ratios. The current consumption of fossil fuels is 100 million to 110 million litres of petrol, diesel, kerosene, and aviation fuel every month (Sanya, 2015).

Additional benefits that will result from the bioethanol industry include the creation of more local employment opportunities, a reduction in the production of informal crude waragi and a reduction in the emission of greenhouse gases from road transport.

Biomass Energy Strategy (BEST)

The Government of Uganda has developed a national Biomass Energy Strategy (BEST) which functions through a joint coordination framework. The inter-ministerial dialogue, composed of representatives from the Ministries of Health, Housing, Environment and Energy has been instituted to promote the development and implementation of national policies and regulations for the clean cooking sector and the efficient use of biomass in technologies for the industrial sector. Of relevance to the biofuels industry, the strategy advocates the promotion and use of biofuels in a sustainable and well-harmonized manner in view of other competing interests like agriculture and agroforestry.

National Sugar Policy

The National Sugar Policy passed in 2010 is a framework for enhancement of competitiveness, public-private partnership, expansion of sugar production that will result in national social transformation. It aims to bring harmony among all the key players in the sugar industry to promote and sustain steady industrial growth of the sector. It is intended to guide the development of sugar industry including location of new industries to prevent hostility over feedstock and outgrowers. (A nucleus estate for sugar factories of 25 km radius is proposed to provide sufficient land resources for the factories to break even). This expected expansion in sugarcane production which will take into account self-sufficiency in food crop production as well as environment sustainability will provide more feedstock resources for bioethanol production.

The Enguli (Manufacturing and Licensing) Act

The archaic Enguli (Ethanol) Act passed in 1965 was intended to regulate the manufacture, sale, possession and consumption of enguli (ethanol) and the apparatus used in its manufacture. It decreed that distillation of ethanol would only be possible under permission from the Central Licensing Board and that distillers would only sell their products to the government owned company, Uganda Distilleries Ltd. The law was never successfully enforced, as unlicensed production of ethanol has persisted over time. Twenty two distillers are licensed with the Uganda National Bureau of Standards with the majority of small-scale unlicensed producers spread all over the country in the Eastern region (Mbale, Jinja, Mayuge, Kaliro, Iganga districts) Central region (Buikwe, Masaka Mpigi, Mukono districts), Western (Kabale, Kasese districts) and Northern (Lira and Gulu districts) just to mention a few. The locally produced gins are drunk and sold in shops and bars across the country. The enormous increase in alcohol consumption, is therefore attributed to these alcohol (ethanol) selling points that have failed to comply with the regulation of restricting the sale to the persons above the legal age limit of 18 years. The police who have the power to arrest the culprits without a warrant do not enforce the law. An alcohol policy is in the offing to correct the shortcomings of the Enguli Act and to better guide and regulate the industry.

Taxation

Taxation for Beverage Ethanol

Generally imported spirits are taxed at higher rates than locally produced ones. Currently, all ethanol is taxed as a beverage since the Biofuel Act and by laws have not been passed yet. High taxes are imposed on branded alcohol in the form of excise duty and VAT. Given the very high taxation regime for both imported spirits (70 per cent) and locally manufactured ones (60 per cent), the majority of local distillers who control about 70 per cent of the market share will try as much as possible to evade the taxes (Uganda Youth Development link, 2010). In the 2015 budget the Ministry of Finance has proposed to increase the taxes for imported spirits to 100 per cent or more for some spirits. The leading spirits distiller (East African Breweries Limited) who has an estimated 30 per cent market share contributes 70 per cent of tax revenues from spirits.

The Biofuels bill provides for the Minister of Energy working with the Ministry of Finance to determine and propose incentives for the biofuels sub sector and it is suggested that the Minister using a statutory document in the gazette will provide incentives for the purpose of taxation and investment in the sub-sector.

Taxation for Imported Improved Cookstoves

The clean cooking sector has only one company that imports and distributes improved cookstoves, Up Energy. From the information available from Up Energy, cookstoves are taxed at a nominal rate of 25 per cent Import duty, 18 per cent VAT and 6 per cent withholding tax. VAT is refundable, that leaves 31 per cent as the tax burden for Up Energy for the importation of cookstoves.

Land Use Issues

The vision of the National Land Policy is "A transformed Ugandan Society through optimal use and management of land resources for a prosperous and industrialized economy with a developed services sector." The vision attributes among others include;

Modernization of Agriculture: There is need to shift an estimated 65 per cent peasants who currently contribute 22 per cent of GDP from subsistence to commercial agriculture to move out of poverty and attain food security using land as the major resource input. The National Agricultural Policy further elaborates on the mechanisms for achieving this transformation which includes expansion in agricultural output and increased incomes for the local communities.

Protection of the Environment: It is critical to protect the environment and restore the integrity of the degraded environments through an optimal usage and management of land resources.

Table 20. National Land Cover Statistics-Uganda (sq. km)

Type of land cover	**1990**	**2000**	**2005**
Built-Up Areas	365.7	365.7	365.7
Bushlands	14,223.9	12,624.5	11,893.6
Commercial Farmlands	684.5	684.5	684.5
Cultivated lands	84,010.0	94,526.7	99,016.6
Grasslands	51,152.7	51,152.7	51,152.7
Impediments	37.1	37.1	37.2
Plantations-Hardwoods	186.8	153.3	138.6
Plantations-Softwoods	163.8	80.0	121.5
Tropical High Forest	2,740.6	2,248.2	2,036.3
Tropical High Forest Normal	6,501.5	5,333.5	4,830.6
Water bodies	36,902.8	38,902.8	36,902.9
Wetlands	4,840.4	4,840.4	4,840.6
Woodlands	39,740.9	32,601.4	29,527.8
TOTAL	**241,550.7**	**241,550.7**	**241,550.7**

Note: The figures indicated in the above table are based on projections. Actual vegetation studies were undertaken in 1994 based on the 1992 satellite imagery
Source: National Environment Management Authority, *State of the Environment Report for Uganda*

The table above shows the total cultivated land in the four regions increased from 84,000 square kilometres to 99,000 square kilometres--an increase of 18 per cent, while tropical forests and woodlands substantially decreased by 25 per cent during the years 1990 to

2005 mainly due to increased farming activities. This indicates a serious environmental issue that must be addressed in the social and environmental management safeguards of prospective agricultural partnerships with the farming households or communities.

Overview of Current Ethanol Production in Country

An estimated 100 small-scale unlicensed producers are spread all over the country in the eastern region (Mbale, Jinja, Mayuge, Kaliro districts) central region (Buikwe, Masaka Mpigi, Mukono, districts), western (Kabale, Kasese districts) and northern (Lira, Arua and Gulu districts) just to mention a few. These small-scale distilleries produce varying amounts of ethanol which they sell locally or to middle men who in turn sell it to the larger companies that refine, package and sell the ethanol liquor. These are mainly located in the central region districts of Wakiso and Kampala. Twenty-three ethanol liquor brands are licensed with the Uganda National Bureau of Standards although more have been licensed in recent years. The high number of local distillers and packaging companies and vendors is responsible for the high consumption of alcohol in Uganda. However most of the alcohol consumed is the unregulated/unlicensed type that costs even less than the regulated type. The regulated market has beer, spirits and wines. Uganda was ranked by the WHO as the highest consumer with 19.47 litres of pure alcohol per capita per annum in 2004. In addition, the WHO Global Status Report on Alcohol and Health, 2014 indicates that 23.7 litres of pure alcohol are consumed per capita every year in Uganda which is the highest for the East African region (WHO,2014). Current medium to large-scale producers of ethanol include:

Sugar Corporation of Uganda, Lugazi (SCOUL)

Sugar Corporation of Uganda Limited is the oldest sugar mill in the country having been established in 1924. It is located in Lugazi town, Buikwe district in the central region. Its alcohol production stands at 9 million litres per annum, which it makes from cane waste molasses with products such as Extra Neutral Alcohol (beverage) and Industrial Alcohol, for local consumption and export.

East African Breweries Ltd.

East African Breweries Ltd. located in Luzira, Kampala district has the largest market share for bottled alcohol (Uganda waragi). It purchases spirits from the local distillers and refines it to produce its flagship brands.

Leading Distillers (U) Ltd.

Leading distillers located in Kampala district is an example of a local ethanol vendor that imports the concentrated liquor in bulk and blends it and repackages beverage ethanol or sale locally.

Overview of Projected Ethanol Production

Bio-Green Investments E.A Ltd.

Bio-Green Investments E.A Ltd. is located in Kayunga district in the central region. It received a concessional loan from EXIM Bank of China to set up a plant that will produce 20 million litres of bio-ethanol and 10MW of electricity annually using sweet sorghum as the feedstock. The plant was initially expected to be operational in 2015, however completion of financing closure has delayed the project and pushed the expected commissioning date to 2018. The plant will also produce briquettes and animal feeds from the sorghum stem residues.

Kakira Sugar Works

Kakira Sugar Works owned by the Madhvani Group is located in Jinja district in the eastern region and is the leading producer of sugar and electricity (50 MW) from bagasse in the country. It has contracted Praj Industries of India to build 60,000 litres per day, 20 million litres per annum of fuel ethanol and beverage alcohol using cane molasses from the Kakira Sugar Mill. The plant is expected to be commissioned in the fourth quarter of 2016. The effluents generated by the plant will be converted into bio-compost.

Sugar and Allied Industries Ltd (Kaliro Sugar Mill)

The Nordic Development Fund is working with Kaliro Sugar factory and CREEC to pilot a low cost and scalable modular technology that will enable bioethanol production at competitive prices for the transport and clean cooking fuels market. The project has a target of scaling production to produce up to 14 million litres of bioethanol per annum using sugarcane molasses and other waste from the sugar making process. The objective of the project is to scale up the small-scale modular technology for bioethanol production to all relatively smaller sugar plants. The agreement between the three parties was signed on the 27th March 2015, the expected start of the project is not known.

The project's main outputs include;

(1) The construction of two low-cost, scalable and modular bioethanol production plants with an estimated capacity of 200,000 litres/year at the Kaliro Sugar Factory;
(2) Introduction of sustainable use of bioethanol as a cooking fuel in Kaliro District;
(3) An expansion plan of biofuels production and use in the country.

Other Major Projected Production of Ethanol

With the passing of the biofuels law which will require all vendors of petroleum based fuels to blend their products with biofuels up to a 20:80 ratio of biofuels to fossil fuels, other major sugar factories including Kinyara Sugar Works in Masindi district in the western region, Sango Bay in Rakai district in the central region and Mayuge Sugar Mills in Mayuge district in the eastern region are projected to start the production of bio-ethanol using molasses. The anticipated law will create a market for bioethanol projected at 176 million litres per annum, which will be a huge incentive for the sugar industry to manufacture bioethanol.

Bioethanol production is also projected to come from small-scale farmers/distillers in the areas in the districts currently producing the liquor using the feedstock sources below:

Table 21. Regions that are likely to have new investments in bioethanol production and most probable sources:

Region with production ratings of potential sources (Derived from the statistical data of the Uganda Agricultural Census 2008-2009)					
	Feedstock	**Eastern**	**Western**	**Northern**	**Central**
1	Cassava				
2	Sweet potatoes				
3	Maize				
4	Bananas (food)				
5	Bananas (beer)				
6	Bananas (sweet)				
7	Sorghum				
8	Irish potatoes				
9	Finger millet				
10	Coffee				
11	Sugar molasses				
12	Sugar bagasse				
13	Rice				

Key

- High crop production and high probability of crop waste
- Medium crop production and moderate supply of crop waste
- Low crop production and low supply of crop waste

Table 22. Stakeholders to Engage to Develop an Ethanol Cookstove Project

Government Institutions
1. Ministry of Energy and Mineral Development
2. Ministry of Agriculture Animal Industry and Fisheries
3. Ministry of Water and the Environment
4. Ministry of Trade, Tourism and Industry
5. Ministry of Lands, Housing and Urban Development
6. Uganda Bureau of Statistics
7. Uganda National Bureau of Standards
8. Uganda Revenue Authority
9. National Forestry Authority
10. National Agriculture and Research Organization
11. National Environment Management Authority
12. National Agricultural Advisory Department
Donor Agencies
13. World Bank
14. GIZ
15. Nordic Development Fund
Non-Governmental Organizations
16. Uganda National Alliance on Clean Cooking
17. Centre for Research in Energy and Energy Conservation
18. Centre for Integrated Research and Community Development
The private sector
19. Private Sector Foundation of Uganda
20. The Uganda Manufacturers Association
21. Uganda Seed Company
22. The Sugar Manufacturers Association
23. The Sugar Technologists Association
24. Local Community Based Organizations/Civil Society Organizations
Farmers' groups
20. Uganda National Association of Sugarcane out growers (UNASGO)
21. Uganda National Farmers Federation
22. National Farmers Forum
23. Uganda Co-operative Alliance
Financial Institutions
24. Centenary Bank Ltd
25. FINCA (U) ltd
26. Pride Micro Finance Ltd

27. Opportunity Bank

Conclusions and Recommendations

Social Impact and Gender Perspective

Cooking using traditional methods impacts women and their children the most. Awareness of Household Air Pollution (HAP) is low as it affects about 4.8 million households using traditional and inefficient cookstoves. Around 19,700 deaths occur each year, the majority of them children--17,800 who suffer from pneumonia, mental impairment and cardiovascular diseases caused by the noxious gases. Women and children spend long hours looking for firewood in the rural areas and yet in the peri-urban and urban areas a sizable percentage of household income is spent on purchasing the fuels. Women therefore do not engage in income generating and other social activities and children have less time to attend school and study.

The country loses about 92,000 hectares of its forest cover every year mainly to meet household fuel wood demand for cooking, industrial use and for agricultural applications. The overdependence and unsustainable use of biomass at 44 million tonnes per annum (2013 figures) could easily rise to 135 tonnes per annum without interventions to cut down on the exploitation of forest resources. The country can only sustainably supply 26 million tonnes per annum, which is well below current demand. To sustainably supply the required energy, all other available forms of biomass should be explored. Bioethanol has an enormous potential to fill this energy supply gap sustainably as well as contributing health and social benefits of reduced HAP, faster cooking times, and savings on household incomes.

Consumer Behavior

Rural households use firewood and agricultural wastes for cooking, as these are readily available although they are increasingly becoming scarce. In urban areas, households use firewood, charcoal and very few use LPG and briquettes. Households often cook different meals at the same time on several cookstoves, which might include a traditional and improved cookstove. Affordability is a significant factor influencing purchasing behaviour of fuels and cookstoves as the disposable incomes of households especially those in rural areas is quite low. Therefore, the minimum quantity of fuels sold is very critical besides the quality of the fuels. Convenience of cooking (portability of the cooking appliance and lighting up for example) is another factor that users will value as very important. This means that consumers aspire to use more modern fuels such as LPG and bioethanol but are limited by the lack of availability of the fuels and stoves and the initial cost of investment in the gas bottle and the stoves, as well as periodic purchase of the fuels. Bioethanol presents an exciting alternative to LPG and charcoal especially in the urban areas given the cost of the fuel and its portability as it can be packaged in small affordable quantities which can be easily transported and distributed.

Cookstove Industry and Potential for Ethanol to displace other fuels

Because of the fluctuations in the prices of petroleum-based fuels on the world markets, LPG and kerosene are subject to seasonal price fluctuations. LPG receives no policy support or any government subsidies. It is therefore priced relatively higher than alternative cooking fuels. LPG usage is therefore low and its availability is restricted mainly to urban, higher income families. Safety issues have also prevented its wide adoption in these areas. Kerosene, which is used by a small percentage of the population mainly smaller families in urban areas for cooking and in rural areas for lighting used to have a lower taxation regime but has been a subject of recent hikes in taxation. Because subsidies on electricity were removed, very few households can afford to cook using electricity. Although biomass briquettes have been introduced in the country a lot of awareness activities have to be implemented before households can adopt the fuel. Bioethanol with all its price advantages has a huge potential to displace the cooking fuels currently used in the country. The biofuels law if passed will provide incentives (attractive tax regimes) to manufacturers and distributors that should make it competitive and therefore affordable to households as a cooking fuel.

Policy

The regulatory environment for biofuels is quite conducive given the aspirations of the National Renewable Energy Policy which has an overall goal of increasing the use of modern renewable energy from the 4 per cent to 61 per cent by the year 2017 which will partly be achieved by blending biofuels with conventional fossil fuels up to 20 per cent.

The biofuels law, which provides regulations for the production of biofuels feedstock and the development of storage facilities and blending with petroleum products for transportation fuels will be very critical. It will support the development of the industry, especially if the 80 per cent to 20 per cent mixing ratio of petrol to ethanol is enforced.
In addition, the National Biomass Energy Strategy, the Agricultural policy, the Land policy support the exploitation of land resources for development through agricultural applications that will ensure provision of food and energy security by promotion and use of biofuels in a sustainable and well harmonized approach in lieu of the competing interests for food and fuel production.

The National Sugar Policy will further support the development of the bioethanol industry as it envisions an expansion in sugarcane production taking into account the self-sufficiency in food crop production and environment sustainability.
An alcohol policy is under development to replace the old Enguli (ethanol) Act which is intended to regulate the manufacture, sale, possession and consumption of ethanol is under review. The policy will welcome alternative uses of ethanol to deter its population from consuming very high quantities of alcoholic products.

Taxation

The Biofuels Law provides regulations for the production of biofuels feedstock and the development of associated storage and transportation facilities. For now, it is not well perceived what the taxation regime will be for ethanol for cooking and transportation purposes. From the interviews conducted with the concerned policy making institutions (Department of New and Renewable Energy) it is perceived that a favourable taxation regime for the biofuels final products will be negotiated by the Ministry of Energy and Minerals with the Ministry of Finance, Planning and Economic Development and implemented so as to catalyse investments in the biofuels sub sector.

4. Feedstock Profiles

The production of alcohol is an old and established process practiced around the world. During fermentation, microorganisms such as yeast, convert simple sugars into ethanol and carbon dioxide. The beer, the mixture of water and ethanol, must then be distilled to separate the water from the ethanol to achieve a high concentration of alcohol (Solar Energy Research Institute, 1982).

Yeasts can only ferment simple six-carbon sugar units, namely glucose. All agricultural crops and residues are made up of glucose or compounds of glucose. There are three different arrangements of these sugar units that can be used for ethanol production: sugar crops, starch crops, and cellulosic crops. Sugar crops can be fermented without the use of enzymes. Starch and cellulosic crops must have their sugar compounds broken down into simpler units by enzymes before they can be fermented.The starch conversion process is relatively simple compared to cellulosic conversion to sugar. With the use of heat and enzymes or a mild acidic solution, the starch chains can be broken down into six-carbon units or groups of two six-carbon units. Cellulose is linked together in long carbon chains by a much stronger chemical than starch. Cellulose is also surrounded by lignin, which is resistant to enzyme or acidic pretreatment.

This report does not indude cellulosic ethanol because of the high-energy inputs and advanced machinery needed for its production. Cellulosic ethanol is considered cost prohibitive for small-scale production.

There are disadvantages and advantages to sugar and starch crops. Sugar crops need little preparation; once the crop is crushed and the sugars extracted, they can be fermented. Sugar crops tend to have high yields per acre and apart from sugarcane, crop co-products have potential to be used as fuel, livestock feed, or fertilizer. However, sugar crops tend to be difficult to store as they decay quickly. Starch crops have well-developed storage techniques and cultivation practices. They also produce a high-protein co-product that can be used for livestock feed. The downsides to starch feedstocks are that their preparation involves additional equipment, labour and energy costs.

Feedstocks selected for the study

This report defines tropical second-generation bioethanol as a biofuel derived from two plant-based sources: (1) agricultural residues or waste and (2) non-food crops. Both types of feedstocks are typical easy to mill and contain sugars and/or starches able to ferment quickly with the addition of yeasts. Second generation means that production technology is characterized by its simplicity and therefore is highly appropriate for small to medium bioethanol producers in tropical regions. First-generation bioethanol is the biofuel produced from crops that may often also be used as food crops. However, these crops are generally produced in abundance, yet may not make it to market in the EAC region because of the lack of transportation or refrigeration.

(1) Second generation bioethanol feedstocks selected for study (waste and non-food crops):

- Molasses from sugarcane
- Damaged roots, tubers, and fruits from vegetable and fruit markets: unfit for human consumption, including cassava, (sweet) potato, banana, peels of pineapple, and rotten melons and papaya
- Uncollected fruit drops below mango trees (*Mangifera indica*)

(2) First generation bioethanol feedstocks selected for study:

- Sweet potato (*Ipomoea batatas*)
- Cassava (*Manihot esculenta*)
- Taro (elephant ear; *Xanthosoma*)
- Melon (*Cucumis melo*)
- Sugarcane (*Saccharum officinarum*) and sweet sorghum (*Sorghum bicolor*)

Although there are many feedstocks available in the EAC region, some are better suited for the region and present a greater opportunity for high ethanol production as they are currently produced. The above feedstocks, both first and second generation, were chosen according to the following selection criteria developed by John Loke, an International Tropical Agriculture Specialist:

(1) Waste and non-food crops were given preference to avoid concerns with food vs. fuel and to encourage the use of under-utilized wastes and resources for decentralized bioethanol production.
(2) Feedstocks with the highest possible ethanol yield per hectare per cropping cycle were selected because water, nutrients, and land are limited resources in the EAC.
(3) Local crops that farmers had experience and knowledge growing were chosen.
(4) Crops that are productive on land where it is not feasible to cultivate sugarcane, rice and other staple crops were selected.
(5) Feedstocks were given preference if there was easy access to growing materials.

Other Feedstocks not selected for the study

Ethanol can be made from almost any sugar, starch and now cellulosic feedstock. However, not every feedstock is suitable in every environment. For the purpose of the study, the feedstocks selected were those that were best suited to the EAC region.

Maize is an important crop for ethanol production in the USA and Canada, but it is not the best feedstock option for the EAC countries as its production yields are currently low. Compared to between 7.5 tons and 8.5 tons per hectare produced in the United States, production yields in the EAC are only about 1.8 tonnes per hectare (FAO, 2015). Furthermore, there exist policies in several EAC countries that would prevent the use of maize, a food crop, for use as a biofuel feedstock. If crop yields could be increased through inputs such as fertilizer and machinery for tilling hardpan, maize could be a recommended feedstock. Maize has the following benefits as a feedstock if produced at high enough yields:

- The amount of ethanol per ton of grain is approximately 400 litres, which is high compared to other raw materials.[25]
- Maize improves the growth of other crops because: (1) it incorporates residues and increases organic matter content of soils; (2) it increases water and nutrient uptake of other crops and reduces waterlogging because the roots of maize penetrate deeper in the soil than the most ethanol crops; and (3) maize reduces dissemination of pests and diseases between plots because it functions as a barrier.
- The distillation of maize produces high protein by-products that can be used for animal feed and as a second profit stream for businesses.
- Maize can increase ethanol yields of other feedstocks by approximately 500 litres per hectare (Olasantan, et.al.,1996) because it is suitable to grow between the rows of cassava and sugarcane when these crops are still small or directly after the harvest (Shamsi, et.al., 2003).

Stems of sisal and cashew nut apples were also not included in the study because they do not contain high amounts of sugar and are not considered to be productive feedstocks for bioethanol (Tissieres, 1986). In areas where five or more tons of sugar or starch wastes are produced, it would be beneficial to test the Brix, sugar content, and starch content of these wastes. There is the potential that different varieties may have higher contents leading to increased ethanol yields.

[25] Calculated by international tropical agriculture specialist, John Loke.

Sugar beet was also not included in this report. Although different varieties are available throughout the EAC and are often categorized by high yields, the costs of nutrition, disease, and pest management are high for this crop (Razo, et.al., 2007). Seeds are also not commercially produced.[26]

This study is not meant to be exhaustive on the possibilities of feedstock cultivation for bioethanol generation, but rather to provide an overview of the EAC region and some key feedstocks, which could be used for ethanol generation. This baseline study is also not meant to pass judgment on small vs. large distillation but rather to examine the differences in the two, and to provide recommendations.

4.1. Cassava

Map 3. Average annual production of fresh cassava roots in the EAC between 2010 and 2013.

Uganda: 5,048 kt
Tanzania: 4,853 kt
Rwanda: 2,655 kt
Burundi: 1,146 kt
Kenya: 752 kt

Source: FAO, 2015

Type of Feedstock: Starch feedstock. Bioethanol from cultivated cassava is a first generation (classic) biofuel. Second generation bioethanol can be produced by processing damaged roots collected during harvest at fields and at vegetable markets.

Image 3. (a) Cassava roots

Credit: International Institute of Tropical Agriculture (IITA)

(b) Peeled cassava roots

Credit: Neil Palmer, International Center for Tropical Agriculture (CIAT)

[26] Primary research by international tropical agriculture specialist, John Loke, e.g. Syngenta does not produce actually seed of sugar beet productive in the tropics.

Description: Cassava is a crop grown by millions of farmers in East Africa. Farmers have long experience in cultivating this root crop, and seeds for several varieties are commonly available. The crop cycle is long, commonly taking about a year. However, the distilleries processing cassava can produce bioethanol all year because the dry chips can be made from fresh roots by cutting roots into slices and drying them in the sun. These dried chips can be stored for six months (Abera and Rakshit, 2004).

Cassava is mildly drought-tolerant. It can survive up to four months without any significant rainfall or irrigation (Moreno and Gourdji, 2015). Sugarcane, compared to both cassava and sweet potato needs much more water during its whole production cycle. Compared to sweet potato, there are fewer costs to produce cassava since it is less labor intensive. However, when compared to sweet potato the yields are lower. The energy and capital requirements to process cassava chips at a distillery are at least 50 per cent lower than crushing stems of sugarcane and sweet sorghum. This is due to differences in milling systems and sugar/starch content. At a micro distillery, the efficiency of starch extraction by milling roots and tubers using a hammer mill (1.5 MT/hour; 15 HP) is minimum 95 per cent, extraction of juice from the stems of sugarcane is approximately 60 per cent (0.9 MT/hour; 8 HP) (Penagos, 2015).

Benefits and Challenges: The moderate high crop yields of cassava ensure that farmers will receive an income even if growing conditions are not optimal. Cassava's water and nutrient demands are less than sugarcane and other traditional ethanol crops. However, significant yields require inputs of fertilizer and irrigation water. The amount of vinasses is low but its concentration of nutrients is high. Therefore, the digestion of vinasses is characterized by relatively high yields of biogas. The dry cake obtained after distillation can be commercialized as a bio fertilizer for cash crops, and other by-products of the distillation process can be used for animal feed. Cassava also produces small amounts of woody branches after harvest, which can be used to fuel the boilers. However, additional biomass or power will be needed.

Recommendations: Damaged roots (At least three MT a day) collected at fields and vegetable markets are good raw materials for the production of bioethanol for stoves. If farmers currently obtain yields of 15 MT per Ha per harvest - or higher, it is feasible and thus recommended to integrate sweet potato and melon in the production program of raw materials of the micro distilleries.

4.2. Elephant Ear shaped-Leaf Crops

Map 4. Average production of rhizomes from taro and cocoyam in the EAC between 2010 and 2013.

Rwanda: 149 kt
Burundi: 87 kt

* Production is small or absent in Kenya, Uganda and Tanzania.

Source: FAO, 2015

Image 4. (a) (b) and (c). Cultivation of rhizomes from taro and cocoyam

Source: Amcaja via Wikimedia Commons.

Source: Child of Midnight via Wikimedia Commons

Source: Luz Adriana Mesa

Type of feedstock: Starch feedstock. Bioethanol from elephant ear shaped-leaf crops is a first generation (classic) biofuel.

Description: Yautia (or yautía, cocoyam), malanga, new cocoyam, ocumo, tannia (Xanthosoma spp.) taro (cocoyam), dasheen, eddoe (or eddo), and old cocoyam (Colocasia spp.) are plant species with similar taxonomic (aroids) and agronomic characteristics (FAO, 1994; Irwin, et.al., 1998; Mwenye, et.al., 2015; Osuji and Nwala, 2015). These crops are grown by millions of farmers in Rwanda and Burundi. In general, farmers all over the EAC are experienced in cultivating these on a small-scale and in a traditional way (Ndabikunze et.al., 2011). Because of easy multiplication, vegetative plant material of one or more species from Xanthosoma and Colocasia is commonly available (Nwoko, 2009; Chand, et.al., 1998). The crop cycles are long, in general a year, but micro distilleries processing taro can produce bioethanol throughout the year, using dry chips from fresh rhizomes, which are cut into slices and sun dried (Ezumah, 1972). These chips can be stored for up to six months. These crops are not productive in dry agro ecological zones; they require some water; however, it can be grown in water channels of rice, among oil palm and banana plantations (Sunita, et.al., 2013; Naithani and Koch, 2014).

Compared to other crops, the cost to produce elephant ear-shaped leaf crops is low because weed management is much less laborious. Yields of taro and similar species in general are 6 to 28 MT/Ha per year (FAO, 2015; Omenyo ET.AL., 2014; Noor, et. al.,2015). Energy and capital requirements to process chips (sundried fragments of rhizomes) at the distillery are at least 50 per cent lower than crushing stems of sugarcane and sweet sorghum. Leaves can be used to feed fish cultivated in ponds (Otieno, 2012; Adejumo, 2013).

Benefits and challenges: Although rhizomes of elephant ear shaped leaf crops are suitable for ethanol production, varieties must be tested concerning ethanol yield because several contain high amounts of oxalate, which may inhibit alcohol fermentation (Adelekan, 2012, Zhang, et.al., 2013). Cultivation, though existent is not as common in other EAC countries where crops are only grown in small plots. Xanthosoma and Colocasia grown for bioethanol require permanent water (swampy areas and along stream banks), but have low associated costs because little weed management is needed (Sunita, et.al., 2013). Harvesting can be difficult due to the muddy conditions these plants need to grow. Energy requirements to obtain ethanol are the same as processing cassava or sweet potato. The biggest challenge lies in the testing of different Xanthosoma varieties for their ethanol yield, which is highly dependent on oxalates in the rhizomes that affect yeast performance during fermentation.

Recommendations: The fact that elephant ear shaped leaf crops grow in wetlands is attractive (Puste, et.al., 2012). Although people consume Xanthosoma and Colocasia, it is not a common staple crop, and thus, bioethanol production will probably not threaten food availability. The amount of vinasses (spent mash) is low but the concentration of nutrients is high compared to sugarcane and other feedstocks (Alcantara, 2013; Ndabikunze et.al., 2011). The digestion of vinasses is characterized by relative high yields of biogas. The dry cake obtained after distillation can be commercialized as a bio fertilizer for cash crops. It is recommended to grow biomass like pencil plant and devil's backbone to assure sufficient fuel for the boilers of the distilleries.

4.3. Mango Fruits

Map 5. Average production of mango fruit from 2010 to 2013 in the EAC

Kenya: 528 kt
Tanzania: 398 kt
Rwanda: 18 kt
Burundi and Uganda: N/A

Source: FAO, 2015

Image 5 (a) Mango tree

Credit: John Loke

3(b) Mango fruits

Credit: John Loke

Type of feedstock: Sugar (and starch if seeds are included) feedstock. Bioethanol obtained from mangos collected from the ground below trees and fresh seeds, is a second-generation biofuel.

Description: To achieve economic feasibility in the production of bioethanol from mango fruits (pulp and seeds) roadside collection must yield at least five MT per day. Fruits that have not begun decomposition are more easily fermented and yield a higher alcohol yield. Mango fruits must be mixed with a small amount of water during fermentation to assure pumping is possible. Ethanol yield is approximately 80 Liters per MT of waste (Arumugam and Manikandan, 2011). Storage time of waste after recollection cannot be more than four days. Both biogas production using the waste of the distilleries and bio fertilizer quality are relative high compared to sugarcane, molasses, and root and tuber crops. A relatively low amount of energy is required to produce bioethanol from mango waste at distilleries because of the high starch concentration in seeds, and thus pulp and seeds should be processed as a mixture (Fuchs, et.al., 1980). Investment is inexpensive because the milling system does not require huge motors.

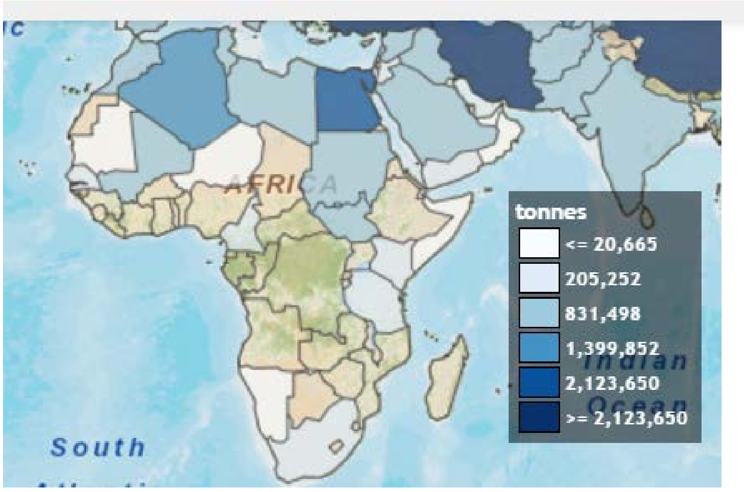
Benefits and challenges: Mango is commonly cultivated in most countries of the EAC as a means to provide shade near roads, fields, and houses (FAO, 2015). Usually, only a part of all fruit is harvested for human consumption. Compared to other raw materials, mango is a cheap feedstock to produce ethanol for stoves, mainly because the yield of ethanol from both pulp and seed is high and collection of fallen fruits below the canopy is easy and fast. All fresh (not completely rotten) fruit is suitable for fermentation.[27] Employment generation in production of bioethanol from mango will be relative low compared to the production of crops; however, mango is commonly grown in economically neglected regions of the EAC and thus the employment that is created will be in regions where innovation is needed. Waste after fermentation can then be used as a fertilizer for mango or for rice (Dhingra, et.al.,1985). To fuel the boilers, shrubs with growing conditions similar to mango trees, like pencil plant and devil's backbone, can be grown nearby and they act as natural fences (Loke, Mesa and Franken, 2011).

Recommendations: Micro distilleries using mango waste cannot operate throughout the year because raw material will not be available. To produce ethanol continuously, it is highly beneficial to combine milled mango (pulp and seeds) with other feedstocks like grinded dry chips of sweet potato and cassava (Gonzalez, 2009).

[27] Primary Research by International Tropical Agricultural Specialist, John Loke.

4.4. Melons

Map 6. Average production of watermelon in the EAC between 2010 and 2013.



Kenya: 79.9 kt.
Tanzania: 26.3 kt.

*Rwanda, Burundi and Uganda: production is small or absent.

Source: FAO, 2015

Image 6. (a) and (b) Cultivation of Watermelon

Source: JiElle via Wikipedia.

Source: Fred Hsu via Wikipedia.

Type of feedstock: Bioethanol from melon is a first generation (classic) biofuel.

Description: To produce bioethanol from melon fruits grown specifically for bioethanol, three factors are important: 1) the land must be available at a low cost, 2) melon varieties must be sweet (Brix higher than 14 per cent) and 3) biomass (wood) shrubs should be easy to cultivate (e.g. as living fences). If diesel is expensive, seeds can be used to produce pure plant oil fuel or biodiesel (Aktas, et.al., 2010). The pure plant oil can be used to fuel diesel generators for electricity generation of the micro distilleries or can be commercialized to fuel diesel engines outside the micro distilleries. Several varieties can be grown and is recommended, in order to reduce the risk of losses by diseases and pests.

Melon yields in Africa average 24 MT fruits/Ha per year (FAO, 2015). The ethanol yield is approximately 70 liters per MT of fruit (Gomez, 2008; Gomez, 2005). The fruit cannot be stored for more than a day after collection because the harvest time is not being longer than four months per year, it is worthwhile to preserve the fruit as a juice concentrate. The fruit juice and peels of melon can be converted into molasses. The molasses can be stored for a longer period of time, for example up to eight months.

Biomass of the shrub *E. tirucalli* (ET) can be used to evaporate water of the juices since this species is tolerant to semi-arid conditions, similar to prickly pear cactus. Both biogas production using the waste of the distilleries and the quality of the bio fertilizer are extremely high compared to sugarcane, molasses, and root and tuber crops. The energy requirement to produce bioethanol from melon at the distilleries is high because of the concentration of sugars in fruits (14 per cent Brix) is low compared to cactus and mango (Brown, 2014; Collin, et.al., 2015). The investment in distillery equipment to produce ethanol should be low because the milling system does not require large motors. Establishment of high yielding production fields will cost approximately US $500 to US $1,000 per Ha assuming that plant material is available.

Benefits and challenges: The integration of melon into crop rotation cycles with crops that out-yield melon is beneficial because the management of soil fertility, pests and diseases will be optimized (Olaoye, 2012; Chivenge, et.al., 2015). Due to the fact that the time between sowing and harvest is short (three to four months) melon is a very suitable crop to plant between the rows of crops like cactus and oil palm. Water and nutrient demand of non-hybrid melons is much less than hybrid seed (Bardiviesso, et.al., 2013). It is highly beneficial that the quality of the fruit does not have an effect on fermentation (e.g. sun burning of melon fruits is not an issue). The amount of vinasse is high, but the concentration of nutrients is low. Therefore, the digestion of vinasse is characterized by relatively low yields of biogas. The small amounts of dry cake obtained after distillation can be commercialized as a biofertilizer for low value crops. Melons do not produce any biomass to fuel the boilers of the micro distilleries; additional other fuels (biomass) are needed.

Recommendations: Because the production costs are low, melons can be an important crop to rotate with one or more other bioethanol crops (e.g.: two cycles of sweet potato, one cycle of melon, followed by six months of fallow land). Fences can be established using prickly pear cactus.

4.5. Molasses

Production: The average production of molasses from sugarcane from 2010 to 2013 in the EAC is as follows

Map 7. Molasses production EAC region

Kenya: 140 kt
Uganda: 71 kt
Tanzania: 62 kt
Burundi: 5 kt
Rwanda: 2 kt

Source: FAO, 2015

Type of Feedstock: Sugar feedstock. Bioethanol from molasses is the most commonly used second-generation biofuel in the EAC.

Picture 7. (a) Sugarcane plantation

Sugarcane. Photo: Mette Nielsen via Wikimedia Commons

b) Molasses

Photo: John Loke.

Description: Bulk quantities of molasses can be purchased from sugar producers. For fermentation, molasses must be mixed with water (Thorsson, 1989). Ethanol yield is approximately 200 liters per MT molasses (Mata and Fransisco, 2015). Molasses can be stored for years and is easier to store than other waste materials, such as fruits, roots, tubers, and stems of crops. The energy and capital requirements to produce bioethanol from molasses are at least 25 per cent lower than the requirements for sugarcane and sweet sorghum because no milling is required (Palacios-Bereche et al.,2014). Compared to chips of cassava and sweet potato, the ethanol yield from molasses is low (Zhen-Chong, et.al., 2008). Mixing molasses with cassava or sweet potato chips will increase distillation efficiency of both energy and purchase/maintenance of equipment by approximately 50 per cent. The higher the content of sugar of molasses and dextrose (starch) from cassava in the fermented beer (mash), the more ethanol per liter of beer will be distilled with relative less boiler fuel, using the same equipment at the micro distillery.

Benefits and Challenges: Molasses enables ethanol producers to operate independent of smallholder farmers, making their supply of feedstock more secure. Distilleries can be located close to or on the premises of the sugar factories that produce molasses. Distilleries using molasses can operate round the year, because the raw material can be stored easily for years. The cost of molasses is similar or higher compared to other raw materials in the EAC. In 2015, international prices of molasses ranged from US $120 to US $ 140 per MT (Lichts, 2015). To fuel the boilers, biomass or power is needed. If the distillery is located close to the sugar factory, bagasse can be used for power. The amount of vinasses, or spent mash, from molasses is high and has a low concentration of nutrients compared to the by-products of feedstocks such as cassava and sweet potato (Hidalgo, 2015; Menezes, et.al., 2013; Ahmed, O. et.al., 2013; Krzywonos et.al., 2009; Prado et.al.,2013). Biogas digestion of vinasses typically has low yields (Baez-Smith, 2006). No dry cakes or animal feed can be obtained from the vinasses.

Recommendations: Molasses is an ideal feedstock for large distilleries located close to the sugar factories providing molasses. Molasses is also a recommended feedstock to start production at micro-distilleries because a milling system is not required, reducing the start-up costs. It is possible to achieve an 8 per cent concentration of ethanol from molasses at micro distilleries. To ensure that the production costs of the molasses ethanol are as low as possible, it is beneficial to concentrate diluted molasses with other feedstocks like grinded dry chips of sweet potato and cassava, or waste of different fruits.[28]

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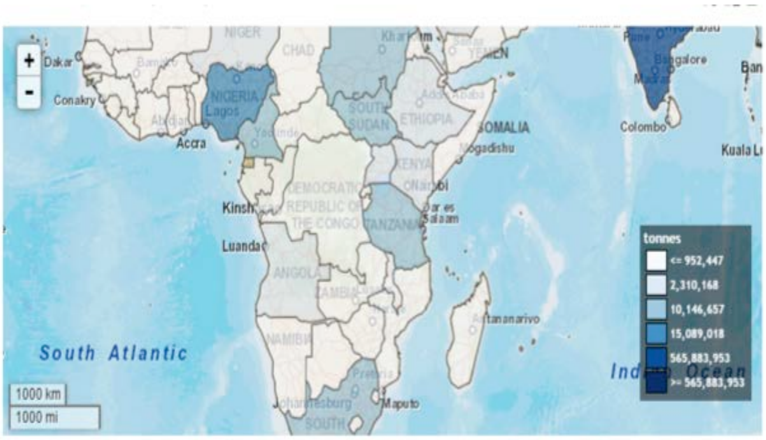
[28] Primary Research by International Tropical Agricultural Specialist, John Loke.

4.6. Roots and Fruits at Markets Unfit for Human Consumption

The average production of vegetables, melons, and pineapples from 2010 to 2013 in the EAC is as follows:

Map 9. Production of vegetables and melons in the EAC region



Tanzania: 2,385 kt
Kenya: 2,246 kt
Uganda: 1,080 kt
Rwanda: 658 kt
Burundi: 442 kt

Source: FAO, 2015

Map 10. Production of pineapples in the EAC region:

Tanzania: 338 kt
Kenya: 164 kt
Uganda: 3 kt

*Burundi and Rwanda – not commonly cultivated.

Type of feedstock: Bioethanol from damaged roots, tubers, rhizomes, fruits and grains post-harvest and from vegetable markets (food waste within food supply chains), which are unfit for human consumption is a second-generation biofuel (Gustavsson, et.al., 2015; Nahman and Lange, 2013; Kereth, et.al., 2015). Wastes from the following crops are suitable: cassava, (sweet) potato, banana, plantain, pineapple peels, rotten melons, carrot and papaya.

Description. To assure that the production of bioethanol from waste collected at vegetable markets will be economically feasible, at least five Metric Tons (MT) of waste per day should be collected. The fresher the waste, the easier it will be to have alcoholic fermentation.

To ferment waste, the feedstock must be mixed with water to assure that pumping is possible. The ethanol yield is approximately 80 liters per MT of waste. The storage time of waste feedstocks cannot be more than one night. Fresh roots and tubers can be stored for approximately four days, maximum. Biogas production using the waste of the distilleries and the quality of the biofertilizer with these feedstocks are relatively high compared to others (e.g. molasses and sugarcane). The energy requirement to produce bioethanol from wasted fruits at the distillery is relatively high because of the high water content required. Investment is low because the milling system can be low-powered. Mixing the waste of fruits with roots and tubers will increase the distillation efficiency and thus reduce the cost of the purchased technology and the maintenance of equipment (Arumugam and Manikandan, 2011; Ketzi, et.al., 2013; Choi, et.al., 2015).

Benefits and challenges: The use of waste feedstocks allows the ethanol producers to be independent from of any type of relationship with farmers. Waste fruits and vegetables cause many issues worldwide including: attracting flies, producing a bad odour, blocking drainage channels, the need for collection and transport to garbage disposals outside the cities, and the emission of methane. Compared to other raw materials, market waste will be cheap to produce ethanol for cookstove fuel in the EAC.

Not all waste is suitable for distillation: only waste containing starch and/or sugars is suitable. It should also be available in relative large volumes to produce at least 1,000 Liters bioethanol per day at each distillery and it is expected that production of ethanol will only be feasible in cities with more than 500,000 inhabitants. Cost to store separated waste for ethanol production from other waste and to transport this waste to the distilleries can be high in certain cities. Livestock keepers (of pigs and cows) are competitors to the use of the waste found at vegetable markets.

Micro distilleries using waste can operate throughout the year because raw material will be available. Employment generation during the production of bioethanol will be relatively low compared to the production of crops. A huge benefit is that if micro distilleries are located close to the consumers, the transportation of the ethanol to the consumers using ethanol cookstoves would be easy. To fuel the boilers biomass is needed. In large cities and nearby areas, waste generated from carpentry work should also be available at a low cost.

The amount of vinasse (spent mash) will be high and has a low concentration of nutrients. This requires a proper site: 100 meters away from people and at least 25 m x 50 m of terrain for the micro distillery. Digestion of vinasse is characterized by low yields of biogas compared to other raw materials and therefore the effluent of the digesters can be commercialized to growers (e.g. urban vegetable growers near to the distilleries). Small amounts of dry cake will be obtained.

Economically it will be an advantage to agree with truck companies to transport vinasses to the farms, which produce vegetable for the markets. Truckloads of dry chips of sweet potato and cassava can also be transported easily. To assure that the production cost of the ethanol to market is as low as possible, it is highly beneficial to concentrate diluted wastes with other feedstocks like grinded dry chips of sweet potato and cassava.[29]

4.7. Sugarcane and sweet sorghum

Map 11. Average production of stems from sugarcane in the EAC between 2010 and 2013.

Kenya: 5,693 kt
Uganda: 3,363 kt
Tanzania: 2,933 kt
Burundi: 192 kt
Rwanda: 115 kt

Source: FAO, 2015

Type of Feedstock: Sugar feedstocks. Bioethanol from sugarcane is the most important first generation (classic) biofuel in tropical regions. Bioethanol from sweet sorghum is also a first generation biofuel. These have been grouped together in the same feedstock profile because they are similar in their requirements.

[29] Primary Research by International Tropical Agricultural Specialist, John Loke.

Sugarcane:

Image 8. (a) Sugarcane cultivation (b) Sugarcane juice

Credit: Luz Adriana Mesa

Credit: Creative Commons Corporation

Picture 9. (a) and (b). Sweet Sorghum:

Credit: Swathi Sridharan via Creative Commons

Credit: Kansas State University

Distilleries operating in regions where sugarcane is grown during two rainy seasons or one prolonged rainy season a year can produce ethanol during the whole year. This is the case in most regions in Rwanda, Uganda, Burundi, and Tanzania. In many regions of Ethiopia and Kenya, sugarcane and sweet sorghum can be grown only during one season although irrigation may change this (Ganduglia et.al., 2015).

Sugarcane needs large amounts of water to achieve high yields, but sweet sorghum needs less (Reddy, et.al., 2007). Compared to cassava and sweet potato, the costs to produce sugarcane and sweet sorghum are higher because planting, harvesting, and milling require significant amount of labor and machinery. Sugarcane will not be highly productive if the soil has low fertility. Sweet sorghum is much less demanding (Wiedenfeld, 1984). Energy and capital requirements to process canes at a distillery are at least 50 per cent higher than milling roots or tubers.

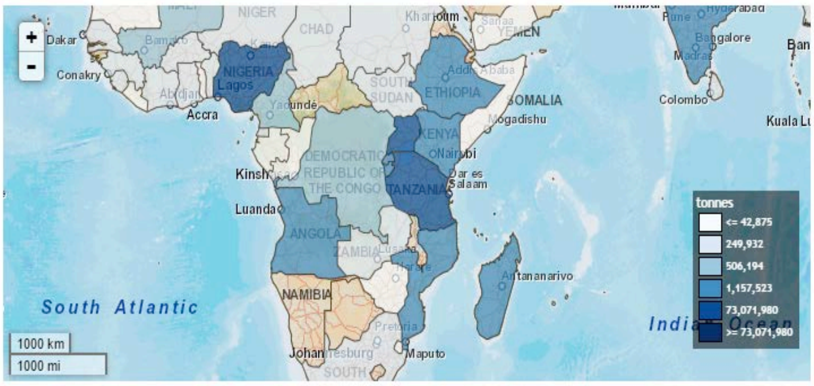
Sweet sorghum is still not commonly grown in Africa. However, it is an ideal crop because it can survive some months without significant rainfall (Mastroorilli et.al., 1999). Benefits and Challenges: Because efficient milling systems to extract juice from canes of sugarcane and sweet sorghum are large and expensive, only medium or large-scale distillation of these feedstocks will be effective in producing bioethanol for stoves.

It is more economical to extract sugar from sugarcane than to make bioethanol. It is a challenge to use smaller machinery able to extract 90 per cent of the juice out of the stems. Frequently, only 60 per cent of the juice is obtained (Adewole, et.al., 2015). Efficient machinery, a diffuser combined with a small sized mill, is available for producers of 5,000 liters of bioethanol per day.

However, at least twice as much capital is required to equip micro-distilleries to process sugarcane and sweet sorghum compared to micro-distilleries processing molasses, roots, tubers, and juice. Power consumption to crush canes is also at least two times higher than processing roots, tubers, and fruits. Production technology to grow sugarcane is developed and fine-tuned in all of the EAC countries. Soil fertility and water availability should be optimal to guarantee reasonable high crop yields. Water and nutrient demand of sugarcane is high. A huge benefit of using sugarcane as a feedstock is the availability of bagasses for the boilers at the distilleries (Pandey, 2000; Hernandez, et.al., 2011).The amount of vinasses both of processing sugarcane and sweet sorghum is large, but the concentration of nutrients is low, and therefore, the digestion of vinasses is characterized by relatively low yields of biogas (Christofoletti et.al., 2013; Espana-Gamboa et.al., 2011). No dry cake will be obtained after distillation. Vinasses can be recycled as a source of water and biofertilizer in the sugarcane and sweet sorghum fields nearby the distilleries (Ganduglia et.al., 2009).

4.8. Sweet Potato

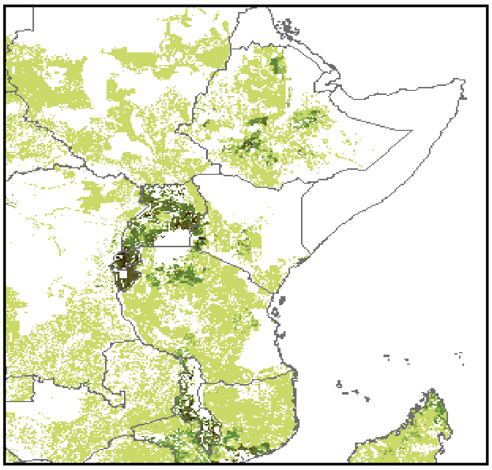
Map 12. Average production of tubers of sweet potato in the EAC (between 2010 and 2013 in kilotons) (1 kt = 1,000 MT).



Tanzania: 3,121 kt
Uganda: 2,656 kt
Rwanda: 943 kt
Kenya: 898 kt
Burundi: 855 kt

Source: FAO, 2015

Map 13. Region with high production of tubers



Type of feedstock: Starch feedstock. Bioethanol from cultivated sweet potato is a first generation (classic) biofuel; second generation bioethanol can be produced by processing damaged tubers recollected during the harvest at the fields and vegetable markets. Dark green indicates regions with high production of sweet potato

(IFPRI, 2011).

Picture 10. **Sweet potato leaves**

Source: Drew Avery via Wikimedia Commons

Image 11. (a) and (b) Sweet Potato

Source: Miya via Wikimedia Commons.

Source: Scot Nelson via Flickr.com.

Description: Sweet potato is the third most important food crop in seven eastern and central African countries (outranking cassava and maize), which is the reason that farming knowledge and plant material of many varieties is commonly available in the EAC (Gibson, 2013). Distilleries operating in regions where sweet potato is grown during two rainy seasons; either two harvests, or one prolonged rainy season (one harvest) per year can produce ethanol for the whole year. This is the case in most of the regions in Rwanda, Uganda, Burundi and Tanzania. In contrast, many regions of Ethiopia and Kenya only have one season in which sweet potato can be produced. Sweet potatoes are mildly drought-tolerant and can survive for months without significant rainfall. Sundried, fragmented tubers can be stored for a maximum of two months. Farmers in Burundi, Tanzania, and Uganda often slice and sun-dry roots and tubers for ease of storage and transport.

Compared to cassava, the cost to produce sweet potato is higher because planting and harvesting require more labor, but this is compensated by higher yields every six months instead of every 12 to 14 months. Energy and capital requirements to process chips (sundried fragments of tubers) at the distillery are at least 50 per cent lower compared to crushing stems of sugarcane and sweet sorghum. This is because of the differences in milling systems and sugar/starch content (Project Gaia, 2015).

Benefits and challenges: Less land is needed to grow sweet potatoes than other crops due to their high crop yields (Lebot, 2009). Water footprint is also much less compared to sugarcane and other traditional ethanol crops (Cusumano and Zamudio, 2013; Gerbens-Leenes and Hoekstra, 2012). Employment generation during the production and processing of sweet potato will vary because of the introduction and use of small agricultural machinery in some areas, which could result in the production of tubers at a lower cost than the tubers meant for food. The amount of vinasse (spent mash) is low but the concentration of nutrients is high compared to sugarcane.

Therefore, the digestion of vinasse is characterized by relatively high yields of biogas. The dry cake obtained after distillation can be commercialized as a biofertilizer for cash crops. Sweet potato doesn't produce any biomass (e.g. bagasse of sugarcane) to fuel the boilers of the distilleries and therefore other fuels (biomass) are needed.

Recommendations: Damaged tubers (Three MT a day at minimum) collected at farmer's fields and vegetable markets are always highly beneficial for the production of bioethanol for clean cookstoves. If farmers currently obtain yields of 15 MT per hectare per harvest, it is highly recommended to integrate sweet potato in the production program of raw materials of the micro distilleries. Average yields (MT/ha; 2013) vary between four (Tanzania), five (Uganda), nine (Burundi), 10 (Rwanda), 18 (Kenya) and 38 (Ethiopia).

5. Recommendations for Establishing a Micro distillery

There are important issues to consider when planning to setting up a micro distillery. One must decide what type of feedstocks to use and what would be the supply pattern of feedstock throughout the year. One must be able to obtain the site for building the distillery. This site must have water supply and access to roadway. Grid power supply is a plus but not an absolute requirement. One must determine the quantity and quality of the fuel to be produced and the benefits that can be obtained from the production of by-products. Finally, one must consider access to market and labor supply. Careful consideration must be given to develop a sustainable and economic business model and a thorough written business plan that will meet the requirements of lenders and investors. One must realize that there are many ways in which a micro-distillery and cookstove business could fail. These include:

- Lack of proper management to oversee day-to-day operations, marketing of fuel and by-products, and procurement of inputs
- Not working closely with farmers or famers' cooperatives to build community ownership and reliable feedstock supply
- Not enough capital for purchasing suitable equipment, management and labour, or for the marketing and sale of fuel and co-products
- The project lacks sufficient financing
- Bioethanol production occurs only during some months of the year because there is no year-round feedstock supply or proper storage available
- The cost of feedstocks suddenly increases because there is a new demand created by competing interests
- The micro distillery entrepreneur did not receive proper training or follow-up support to operate and maintain the distillery
- There are low crop yields
- Not enough water is available to ferment the raw material. Shortage of boiler fuel or is not cheap enough to fire the boiler to produce steam
- The firm lacks access to necessary enzymes, yeasts, acid, or yeast nutrients
- The distillery does not have a reliable source of electricity to support its power demands
- The local and national governments do not have policies that are supportive of ethanol production and its sale as fuel
- There are not enough stoves in the market to use the fuel
- The by-products from fermentation and distillation are not included in the business plan

By recognizing risks and pitfalls and addressing them in the planning stages, it is possible to build and run a successful and profitable micro distillery. This section of the report outlines various aspects involved in the planning and building a micro distillery. It also provides recommendations for organizations and entrepreneurs who plan to start a distillery in the East African Community region.

Scale

Quite unique for liquid fuels, fuel grade ethanol can be produced at almost any scale, from a micro plant situated on a few square meters of land to a relatively small but somewhat larger plant that fits easily on 0.5 Ha of land. Micro distilleries are general defined as those producing less than 5,000 litres of ethanol per day. For the purpose of this discussion, the distinction of microplants vs. small plants used in David Blume's book, *Alcohol Can Be a Gas!* will be adopted. This is a distinction made to distinguish fermentation process and the equipment used. Blume notes that there are two basic approaches that can be used to size very small plants. These are for a micro plant ranging up to 15,000 gallons per year (approximately 150 litres per day) and a small plant ranging up to 250,000 gallons per year (approximately 2,500 litres per day (Blume, et.al., 2007). We define all of these plants as micro distilleries, but we adopt Blume's distinction here to discuss very small micro distilleries.

In considering very small micro distilleries, Blume notes that there are two approaches that can be taken. One is a very simple micro plant. The micro plant starts with a system that uses one tank for cooking, fermentation, and distillation. Because there is only one tank, distillation can only take place every three or four days after fermentation is complete. This type of system is easy to run, simple in design, and can be established and run by one farmer, one operator, and one ethanol sales agent (Blume, et.al., 2007). In some cases, this could be just one person or one family of several persons providing fuel for themselves and their neighbours. A smaller team and less equipment require a smaller upfront investment; this makes it easier to establish initial operations.

Blume's small plants require more equipment since the cooking, fermentation, and distillation all occur simultaneously in different tanks. The plant can thus run at least one distillation per day since the fermentation vessel does not double as a distillation vessel. This process and the equipment for small plants are more involved than a micro plant and the upfront costs are much higher. However, the greater production capacity and streamlined processes make small plants more economical and the cost per liter of ethanol per dollar invested is much lower. In Blume's discussion, both the micro plants and small plants are batch distillation processes. As plants scale up, they can move from batch to continuous distillation and the continuous distillation process can be more or less automated so that it does not require the constant attention of an operator.

Micro distilleries can be modular. Initial plans could leave room for eventual expansion and even for transition from batch to continuous distillation. One argument for scaling up from very small plants to somewhat larger micro distilleries is the experience and capacity building that comes with operating a very small plant. One way to address the need for upfront capital is to add one component at a time and to grow incrementally as capital becomes available. There are challenges and certainly there are expenses and less efficiency involved in starting very small, but there may be some advantages as well. Unique to producing alcohol fuel by fermentation, it is possible to start at any size.

This report recommends beginning with a distillery of 1,500 litres to 5,000 litres per day. This is less of an artisanal approach and more of a business approach. While smaller projects may be feasible under the right conditions, this size, while still small, allows the operation to be monetized by a not insignificant output. A distillery of 1,500 litres per day will support cooking for up to 2,000 households. Furthermore, this production level makes it possible to generate power for the distillery from ethanol.[30] It also allows for a more efficient boiler that can burn low grade biomass clean and efficient. If starting smaller than 1,500 litres per day, it is best to have scale-up plans prepared so that it will be possible to expand production without duplicating costs more than necessary or causing bottlenecks in the expanded plant.

Micro plants may be economical as a part of an artisanal system where ethanol is produced at a very small-scale with cheap or no-cost feedstocks and labour close to farms with rudimentary equipment representing almost no investment, and with the artisanal ethanol shipped to a more sophisticated distillery for further refinement. Such a system was explored by Professor Juarez de Sousa e Silva in his 2011 book, Produção de Álcool na Fazenda (Silva, 2011). The alcohol produced in the artisanal distilleries would be of lower strength, perhaps 80 per cent, thus requiring less energy to produce. It would be upgraded to 95 per cent at the central plant.

The central plant would not expend energy to produce the ethanol delivered in this fashion, but only to remove the remaining water. Ultimately, the size of the artisanal plants and the central plant must depend upon the feedstocks and other required inputs available. But a system such as this could prove quite resilient because it is distributed across many small catchment areas. Ethanol made in one micro plant from mango drops and in another micro plant from cashew apples would essentially be indistinguishable at the central distillery.

The central plant would be receiving its water supply from the artisanal ethanol and thus would not need much additional processing water. If ten artisanal plants are feeding a

[30] Personal communication between Gaston Kremer, Green Social Bioethanol, and Hilary Landfried, September 2015.

central plant and two or three go down, the central plant is still being supplied by the remaining micro plants. This concept was also explored in 2001 by Marcello Guimarães Mello in Biomassa: Energia dos Trópicos em Minas Gerais (Mello, 2001). This approach to the production of fuel ethanol remains unproven, although there are many examples of successfully operating micro plants of various descriptions.

Selecting Feedstocks

When selecting the feedstocks, the facility to be used for ethanol production, seasonality, yields, preparation requirements, labor costs, water requirements, and the types of yeasts and enzymes readily available must all be taken into account. The size of the micro distillery should be determined in light of the feedstock constraints to ensure that the plant production capacity matches feedstock availability.

Seasonality:

Bioethanol can be stored during periods when feedstocks are not available and the plant cannot produce. However, extensive storage represents an expense, so it is better to produce and distribute in a continuous cycle, with storage at the plant reasonably sized to assure smooth operation of the fuel supply chain. Molasses, a byproduct of sugar production, can often be obtained year around, and can be stored for long periods. Other feedstocks may be obtainable year around, such as the juice of prickly pears cactus. In most regions, both cassava and elephant ear leaves can be harvested during the entire year. It is possible to use two or three different feedstocks with different harvest seasons to supply the plant for a round the year production. A good feedstock plan would be desirable to enhance the likelihood that a multiple feedstock approach could be executed successfully.

The international feedstock and tropical agriculture specialist for this study recommends mixing starch and sugar feedstocks. By mixing milled sun-dried roots and the juice from fruits, a distillery may be able to increase yield by 50 per cent without using more equipment and without increasing fuel for the boiler, assuming that the ethanol concentration in the mash be kept high, e.g. 12 per cent, rather than a more normal concentration of 8 per cent (Gaia study, 2015). If this approach is taken, it will be necessary to experiment with feedstocks and run tests to make sure that the mixture of feedstocks works and the process is feasible and efficient.

Regardless of the primary feedstock selected, it may be best to have the flexibility to diversify across several feedstocks. If feedstocks can be supplied from both centralized sources such as molasses from a sugar factory and from decentralized sources such as sugarcane from growers, this may be desirable. Feedstocks should also be sourced from different localities and ecosystems to reduce the risk of dimatic factors that could wipe out one area's entire crop. Thus, wild crops or forest crops could supplement field crops.

Storage:

Some types of feedstocks can be stockpiled and stored until ready for processing. Molasses and dry chips (tubers of sweet potato, roots of cassava, and rhizomes of elephant ears and other aroids) can be stored from three months to a year or more. Other feedstocks must be processed immediately.

Ethanol can be stored for any period of time without deteriorating, although it may absorb some water from the environment. Ethanol is energy dense and thus an efficient way to store energy as fuel. However, any storage is expensive therefore, a large amount of ethanol storage associated with a distillery represents an added expense to the operation. Storage should be sized to handle the efficient running of a fuel supply chain but should not perhaps be sized larger than that, unless there is some other reason to build and store ethanol fuel (such as to cover spikes in demand or occasional bulk sales).

Water Management:

In many cases, production of feedstocks that require irrigation is not recommended, unless water supply is not a constraint. This is because, in dry climates, land that can be irrigated may be necessary to produce food. Land without access to irrigated water but only rainwater, can support a variety of fuel feedstocks. Examples are prickly pear cactus, sweet potato, cassava, and melons. Deep rooted plants in the grass family (Poaceae) such as sweet sorghum and milo are also appropriate for non-irrigated land. If water is not a constraint and if the location has adequate rainfall or access to irrigation channels or wetlands, sugarcane and rhizomes from elephant ear leaf-shaped crops (aroids) can be successfully grown in lowlands and even on hillsides and other normally uncultivated areas.

The amount of water required to process a feedstock into ethanol is also important. Certain crops require less water and other crops more. The following crops require, as a rule of thumb, 1.2 m^3 of water per metric ton of feedstock: roots unfit for human consumption, tubers from sweet potato, roots from cassava, and rhizomes from elephant ear leaf-shaped crops. Molasses requires 5 m^3 of water per MT. Other feedstocks (like fruits) require only 0.2 m^3 water per MT (Shanavas, et.al., 2010; Arumugam and Manikandan, 2009; Zhang, et.al., 2011; Thorsson, 1989). Fruits like melons can be used to add water to the fermentation process and may also add simple sugars as well (Suszkow, 2009).

Ethanol Yield Per Metric Ton:

The yield that can be obtained per metric ton of each feedstock must also be taken into consideration because it has a large effect on the capacity and efficiency of the micro distillery. If this yield rate is high, less feedstock may be needed. If the yield rate is low, more feedstock will be required. The highest rate of conversion of feedstock to ethanol is molasses from sugarcane, which yields 200 Liters of ethanol per MT.

After molasses, high yielding feedstocks include fresh roots, tubers and rhizomes, which yield 140 Liters of ethanol per MT; fresh fruits and seeds such as fallen mangoes and other fruits unfit for human consumption, which yield 100 Liters of ethanol per MT; and prickly pear, melons, and fresh stems of sugarcane and sweet sorghum, which all yield 80 Liters of ethanol per MT. It is also important to consider the availability of especially high yielding varieties of various feedstocks, which have been bred to produce consistently high amounts of bioethanol per metric ton.

Crop Yield Per Hectare:

In most cases, high crop yields are more effective than lower yields, because high yields reduce the cost of planting material and the management of erosion, nutrients, weeds, diseases and pests. Inter-planting crops also increase yield per hectare. Planting prickly pear cactus as a fence protects other crops and also contributes to yield since they can be converted to ethanol along with the main crop. The establishment of other living fences of such species as petroleum plant (pencil plant, milk bush, *Euphorbia tirucalli*) and devil's backbone (*Pedilanthus tithymaloides*) can reduce overall production costs because while they are not useful as feedstocks, their stems and leaves (biomass) can fuel boilers used in the distillation process. Disease and pest management practices also greatly influence crop yield, so the presence of certain pests and the cost of controlling them are important considerations as well.

Table 23. Yields of the production of bioethanol from the feedstocks

Raw material	**Yield (MT/Ha per year)**		**Yield bioethanol**				**Ha/UBM of 400 L bioethanol /day**	
	Min.	**Max.**	**L/MT**		**L/Ha per year**		**Min.**	**Max.**
			Min.	**Max.**	**Min.**	**Max.**		
Molasses from sugarcane	-	-						
Collected fruits and seeds from under mango trees								

Raw material	Yield (MT/Ha per year)		Yield bioethanol				Ha/UBM of 400 L bioethanol /day	
	Min.	Max.	L/MT		L/Ha per year		Min.	Max.
Sweet sorghum (stems)	19	24	21		3,990	5,040	34	27
Prickly pear cactus	10	40	40		400	1,600	86	343
Sweet potatoes (tubers)	7	40	150		1,073	6,000	23	128
Cassava (roots)	8	25	110	222	859	5,550	25	160
Taro and other related elephant ear leaves shaped crops (rhizomes)	7	20	60	139	907	2,780	49	151
Melons (fruits)	20		50		1,168	1,400	98	118
Sugarcane (stems)	32	71	68	82	2,135	5,814	24	64
Sweet sorghum (grain)	2	6	360		720	2,160	64	191

Source: Based on John Loke's field work

Other Considerations

Besides the feedstock(s) used for ethanol production, other factors will influence the economic feasibility and efficiency of an ethanol micro distillery.

Labor costs:

Labor costs affect the cost of ethanol by affecting the cost of the feedstock. High yields will reduce the cost of labor to grow crops. Labor costs can also be mitigated by the use of such simple devices as two-wheel or walking tractors that increase productivity.

Availability and Cost of Enzymes and Yeasts:

The fermentation of sugar feedstocks only require yeast to break down the six carbon sugars. Sugar feedstocks do not require enzymes. Avoiding enzymes lowers the cost of production; however, feedstocks that are starch based often have higher production yields with enzymes. Feedstocks that do not require enzymes include: molasses from sugarcane, juice from prickly pear, fruits unfit for human consumption, carrots, fruits from prickly pear, melons, and juice from sugarcane and sweet sorghum.

To obtain ethanol from starch feedstocks both enzymes and yeasts are needed. Feedstocks requiring enzymes include: root crops unfit for human consumption, collected fruits and seeds below mango trees, tubers from sweet potato and cassava, and rhizomes from elephant-ear-leaf-shaped crops.

Location of the Micro distillery:

The site for a new micro distillery should be chosen only after considering proximity to farms where the feedstock is to be grown, proximity to fuel supply, power supply, availability of water, and availability of transportation networks. Proximity to the market where the products of the distillery will be sold should also be considered.

For each micro distillery, there should be enough land nearby, generally within a haul distance of no more than three to four hours but preferably less than one hour, to grow all of the feedstock that will be needed. This can be computed based on local experience and will be determined by yield per acre times yield per feedstock ton divided by the size of the plant, times desired number of days of operation. For a 1,000 liter/day plant using sugarcane that provides yields under local conditions of 60 tons per acre, and assuming an ethanol yield of 60 liters per ton, this would require approximately 1,000 hectares of growing stock. In the case of sugarcane, the crushed stalks provide the fuel that is needed for the boiler. The roads between fields, the distillery and markets for distillery products should be accessible during the entire year by trucks with a loading capacity of a minimum of 5 MT. The time of transport between the fields and micro distillery should ideally be not more than one hour because the transport of feedstocks, vinasses (the affluent of the bio-digesters), and biomass can be a major cost of operation and therefore must be kept as low as possible. The maximum time required to transport ethanol between the distillery and households where it is to be used is less critical, because ethanol is efficiently transported, but the shorter the supply chain, the more economical it is.

Distilleries also require access to electricity of at least 220 volts. The use of biogas produced from vinasses in biodigesters can act as a backup fuel for power generation if grid power fails for short periods (no more than 12 hours). An ethanol generator can also be used to provide power. If sugarcane or sweet sorghum are crushed for juice, an electrical supply of at least 380 volts will be needed. Therefore, an animal-driven means of crushing may be more economical.

Project Gaia recommends a fuel quality of 90-95 per cent ethanol for use in the CLEANCOOK stove. To achieve this quality, an efficient distillation column is needed. A micro distillery has the following major pieces of equipment:

(1) Equipment for processing feedstocks – A peeler/grater is used for cassava and sweet potato; a crusher is used for sugarcane and sweet sorghum. A conveyor system is useful to move processed feedstock into the fermentation unit.
(2) Sterilization tank – This is where the feedstock is heated to kill bacteria.
(3) Fermentation tanks – This is where the processed feedstock is fermented. These tanks should not be made of carbon steel as these will have a life of only 7 to 10 years. Tanks should be made of polypropylene or stainless steel.
(4) Boiler – The boiler must be carefully chosen. It is important use a certified, pressure-tested boiler.
(5) Cooling tower
(6) Distillation columns – Ethanol stoves burn best without ethanol containing fuel oil or higher alcohols. These impurities can be removed during the distillation process. Columns should be used that have the ability to extract these impurities during distillation.
(7) Storage for feedstocks and for finished ethanol
(8) Various pumps and piping

This report also recommends investing in a generator should grid power supply be unreliable. Ethanol-powered generators are available and can be economically used at distilleries producing over 1,500 litres per day. A control module with thermometers, pH equipment and hydrometers are also recommended. Boilers, fermentation tanks, and cooling towers should be easily sourced in country. Other equipment should be sourced from certified and experienced micro distillery providers. Based on direct experience, we recommend the following companies; however, there are many manufacturers of micro distilleries:

(1) Green Social Bioethanol
(2) Blume Distillation
(3) Spectrum Technology

Byproducts:

Ethanol is not the only product of value derived from the distillation process. There is also potential revenue to be generated from biogas and bio-fertilizer. Vinasse, the liquid that drains from the distillation columns, is characterized by high acidity, high concentration of nutrients and a high temperature (100° C). If stored in an open system it will be smelly. Application of hot, untreated vinasses to farmers' fields will affect the environment negatively and depress crop production. However, biological treatment of vinasse in polyethylene plug and flow biodigesters for an average of 30 days under anaerobic conditions will transform vinasse into a valuable liquid bio-fertilizer for crops.

During this process biogas is also produced, which can serve as fuel for electrical generators, which normally run only on gasoline or diesel fuel (biogas can corrode iron and therefore it may not be desirable for use as a fuel in the distillery boiler). For starch feedstocks, a high-protein animal feed can be produced for livestock from the solids recovered from the fermentation process. Feedstock plant residues, such as peels and stalks, can be composted and wetted with vinasse to produce a rich, organic soil amendment for the fields. This compost can also be used as a medium for growing fungi, worms or snails.

Management:

Each micro distillery will require an organized team and good management. There are many variables involved in running a successful and profitable micro distillery. In Project Gaia's experience, it is important to have a focused and motivated entrepreneur responsible for managing the plant and marketing the fuel. A plant manager is necessary to oversee the day-to-day activities of the micro distillery. It is also recommended that the distillery operator work closely with farmers of a farmers' cooperative to develop a strong relationship between the growing of the feedstock and its processing in the distillery.

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