Baseline Report of Clean Cooking Fuels in the East African Community

Submitted by Project Gaia
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List of Abbreviations

ADB- Africa Development Bank
AFREA- Africa Renewable Energy Access Program
ARGeo- African Rift Geothermal Facility
ARTI- Energy 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 Mechanisation 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 Organisation for Development Cooperation
ICS- Improved Cookstoves
ICT- Information and Communication Technology

IEA- International Energy Agency
IGAD- Inter-Governmental Authority on Development
IP- Investment Plan
IRST- 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
MDG- Millennium Development Goals
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 (NAIVS).
NBP- National Biogas Program
NBS- National Bureau of Statistics
NEMC- National Environment Management Council
NFA- Ugandan National Forestry Association
NGO- Non-Governmental Organization
NIRS- 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- Rural Energy Technologies
RURA- Rwanda Utilities Regulation Agency.
RWF- Rwandan Frank

SADC- Southern Africa Development Cooperation
SCT- Single Customs Territory
SE4ALL- Sustainable Energy for All
SLCP- Short-Lived Climate Pollutants
SME- 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 Organisation
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

I. Executive Summary

Ethanol fuel production represents a significant opportunity for economic and social development in the East African Community (EAC) region. Ethanol can be produced locally using a variety of feedstocks that can be selected based on unique local conditions. Farmers can grow fuel feedstocks 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 for cooking fuel, transportation fuel, or small-scale power generation. 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 distributing 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 can be harvested several times in a year. More biomass can be grown and processed into a fuel that burns readily and cleanly, while pressure is reduced on forests for fuelwood and charcoal production. Families will have healthier homes with cleaner indoor and courtyard air.

The United Nations Industrial Development Organization commissioned Project Gaia for this study following a successful pilot study in Zanzibar from 2014-2015. The pilot study demonstrated that ethanol produced from the Zanzibar Sugar Factory was a preferred cooking fuel and could be competitive on the market. Project Gaia has been examining the potential for alcohol fuels in developing markets for 20 years and during the past 10 years has sought to encourage cookstove and ethanol fuel businesses in Sub Saharan Africa and elsewhere. Its experience is drawn from 29 pilot studies in 13 countries to date. Project Gaia has developed benchmarks and guidelines for beginning ethanol microdistillery, stove, and fuel distribution projects or businesses. This study draws from Project Gaia's experience to analyze the potential for small-scale ethanol production for cooking in Uganda, Rwanda, Kenya, Tanzania, Burundi, and Ethiopia.

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, laws from the time of colonialism tax ethanol heavily as an alcohol beverage. No tax treatment may 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 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 production and is including ethanol in their expansion plans. Although progress is being made to develop ethanol as a fuel, more work must be done with governments to encourage them to develop supportive tax structures for ethanol as fuel and create standards for quality of fuel ethanol for cookstoves as well as for other purposes such as automotive fuel blending. This report reviews the six EAC countries that are the subject of this study and examines the market potential of ethanol fuel, current and projected fuel production, government policies that may affect the production and sale of ethanol fuel, and the potential for small-scale distributed production of ethanol for cooking fuel.

Several feedstocks were selected for review, 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*), prickly pear cactus (*Opuntia* *ficus-indica* or *Opuntia polycanta*), 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 that are or could be available; the list of potential feedstocks is much longer. But the feedstocks selected for examination do show the diversity of what is available. Molasses from sugar manufacture is one of the best feedstocks to use in either large- or small-scale fuel production. In all of the surveyed countries, although to a lesser extent in Ethiopia and Kenya, molasses is currently a waste product that is either dumped or used for livestock feed. But where sugar manufacture exists, the amount of molasses produced greatly exceeds what can be fed to livestock. Many of the other feedstocks examined are best suited for small-scale ethanol production that happens 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 a 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 that a project begin with a microdistillery in the range of 1,500 to 5,000 liters 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 liters 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 be dependent upon 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.

II. Introduction to Study

Each day, three billion people cook their meals on polluting biomass fuels, including fuelwood, charcoal, dung, and agricultural residues. This causes vast public health, environment, and global climate change issues. Over four million people die each year from diseases caused by Household Air Pollution (HAP) from the smoke of cooking fires. The reliance on biomass for cooking leads to large-scale deforestation and high opportunity costs for the women who must gather the 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% of black carbon emissions, 84% of which are from developing countries. Black carbon is a more potent Green House Gas (GHG) compared to carbon dioxide and is estimated to contribute the equivalent of 25 – 50% of carbon dioxide warming globally.[1]

Addressing biomass cookstoves with a truly clean alternative fuel not only provides a solution to these health, social, and environmental issues, but also presents an opportunity for economic growth and poverty reduction. Ethanol is a truly clean fuel and uniquely suited to household use. When used in the proper stove, ethanol cannot explode, burns cleanly and efficiently, and cooks meals quickly. 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 is opportunity for livelihood generation in the construction, distribution, and sale of ethanol stoves. Employment can also be created in the distribution and sale of the fuel. Perhaps the greatest opportunity for job creation is in the cultivating of feedstocks and their conversion into ethanol. Agriculture is the backbone of many developing countries. In Africa, agriculture employs 65% of the labor force and accounts for 32% of the gross domestic product.[2] According to the Food and Agriculture Organization of the United Nations (FAO), gross domestic product (GDP) growth in agriculture is at least twice as effective in reducing poverty as growth originating in other sectors.[3] Agriculture has an important role to play in development; it represents 1) economic activity, 2) livelihood creation, and 3) a provider of environmental services.[4] With integrated food and energy systems, agriculture can also provide crucial sources of energy through the production of ethanol.[5]

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,

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[1] Global Alliance for Clean Cookstoves, 'Environment', last modified 2015, accessed August 27, 2015,
[2] World Bank, 'Africa - Fact Sheet: The World Bank And Agriculture In Africa', accessed August 27, 2015, http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/AFRICAEXT/0,,contentMDK:21935583~pagePK:146736~piPK:146830~theSitePK:258644,00.html.
[3] Food and Agriculture Organization of the United Nations, 'Investment In Agriculture', accessed August 27, 2015, http://www.fao.org/investment-in-agriculture/en/.
[4] Anne Bogdanski et al., *Making Integrated Food-Energy Systems Work For People And Climate: An Overview* (Rome: Food and Agriculture Organization of the United Nations, 2010), accessed August 23, 2015, http://www.fao.org/docrep/013/i2044e/i2044e.pdf.
[5] *Agriculture For Development* (Washington DC: World Bank, 2008), accessed August 27, 2015, http://siteresources.worldbank.org/INTWDR2008/Resources/WDR_00_book.pdf. Pg. 2.

locally produced fuel can provide rural communities and their urban neighbors with much needed energy for cooking, lighting, refrigeration, and power generation.

It should be emphasized that there are plenty of wasted or underutilized 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 byproducts, and other crops of interest that grow abundantly in the wild and are available for use. One example is 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. According to the FAO, 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.[6] 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 to both large-scale (>5,000 liters per day) and small-scale ethanol (1,000-5,000 liters 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 labor costs. However, large-scale biofuels production requires large areas of land, which can be particularly burdensome in areas of Africa where plots of land 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 well suited to the region.

Small-scale distilleries can take advantage of existing waste or underutilized feedstocks that are or 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, fitted to a community context, 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 become 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 microdistillery 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

[6] Jenny Gustavsson et al., *Global Food Losses And Food Waste* (FAO, 2011), accessed September 21, 2015, http://www.fao.org/docrep/014/mb060e/mb060e00.pdf.

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 – Microdistilleries must be located close to their feedstock source to keep transportation costs at a minimum. Some feedstocks also have a short window from the time of harvesting until 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 able to 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 easy transport 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.

<u>Food vs. Fuel</u>

One of the biggest misconceptions regarding biofuels is that the production of ethanol causes food prices to rise and takes food out of the mouths of the hungry.[7] What this fails to recognize is that, if done correctly, food and fuel production are not mutually exclusive and can be produced together.[8] José Graziano de Silva, Director-General of the FAO said, “Given

[7] Tim Searchinger and Ralph Heimlich, *Avoiding Bioenergy Competition For Food Crops And Land* (World Resources Institute, 2015), accessed August 12, 2015, http://www.wri.org/publication/avoiding-bioenergy-competition-food-crops-and-land%20.

[8] John Urbanchuk, *The Renewable Fuel Standard And Consumer Food Prices* (Agriculture and Biofuels Consulting Economics, 2013), accessed August 12, 2015, http://ethanolrfa.3cdn.net/281d77a62939896ba8_8nm6bevpj.pdf.

the right conditions, biofuels can be an effective means to increase food security by providing poor farmers with a sustainable and affordable energy source."[9]

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.”[10] 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 products have been removed. By using material that would otherwise be discarded, fuel can be made with no impact on food production.[11]

Farmers in developing markets often only have access to inefficient shipping networks and must go without refrigeration. About 40% of food is lost in developing countries before it can reach the market.[12] This waste can be used in efficient microdistillery systems that are located close to farmers’ fields. Currently, the cost of food is largely connected to the cost of oil. According to a World Bank Report, more than 50 percent of food price increases are due to oil prices.[13] In some inland African countries, gasoline costs three times the global average.[14] 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 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.[15] For example, certain feedstocks could be regulated

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[9] José Silva et al., 'Food In The Age Of Biofuels', *Project Syndicate: The World's Opinion Page*, last modified 2015, accessed August 12, 2015, http://www.project-syndicate.org/commentary/biofuels-food-security-climate-change-by-jose-graziano-da-silva-2015-06.
[10] Irina Utkina, 'Reducing Poverty By Growing Fuel And Food', *United Nations Food And Agriculture Organization*, last modified 2011, accessed August 12, 2015, http://www.fao.org/news/story/en/item/51165/icode/%20/.
[11] Paul Christakopoulos, *Utilization Of Household Food Waste For The Production Of Ethanol At High Dry Material Content* (Biotechnology for Biofuels, 2014), accessed August 12, 2015, http://www.biotechnologyforbiofuels.com/content/7/1/4.
[12] Food and Agriculture Organization of the United Nations, 'Seeking End To Loss And Waste Of Food Along Production Chain', last modified 2015, accessed August 12, 2015, http://www.fao.org/in-action/seeking-end-to-loss-and-waste-of-food-along-production-chain/en/.
[13] John Baffes and Allen Dennis, *Long Term Drivers Of Food Prices* (World Bank Development Prospects Group, 2013), accessed August 12, 2015, http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2013/05/21/000158349_20130521131725/Rendered/PDF/WPS6455.pdf.
[14] José Silva et al.
[15] Ibid.

depending on varying agricultural production. When production is high, regulation could allow for ethanol production from food crops. When it 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 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.[16]

Water Use

In the 1990s and early 2000s, a good deal of water was needed to produce one liter 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 liters of water per liter of ethanol in 1987, but today, their plants average 2.6 liters of water per liter.[17] For corn ethanol, water consumption rates have dropped within the last ten years from an average of 6.8 liter/liter to 3.0 liter/liter. To put this in context, it currently requires about 34 liters of water to produce a can of vegetables, a substantially larger amount than a liter of ethanol.[18] 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."[19]

Water use in crops irrigation is also similarly overestimated. About 90% 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.[20] 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 need for irrigation.

Most of the information available regarding water use focuses on the use of water in industrial production of corn ethanol in the United States. However, more information is being developed regarding the use of water at microdistilleries for alternative feedstocks. Green Social Bioethanol, a microdistillery provider based in Brazil, has built small-scale 2,500 liter per day distilleries in Guyana, Brazil, and Nigeria. According to their numbers, 19.24 liters of water are required to produce one liter of ethanol from cassava; 4.54 liters of water are required to produce one liter of ethanol from sugarcane; and 14.46 liters of water are needed to produce one liter of ethanol from molasses.[21] It is also possible to use

[16] UNDP, UNIDO, *Energy Poverty: How To Make Modern Energy Access Universal?* (Paris: International Energy Agency, 2015), accessed August 12, 2015, http://www.se4all.org/wp-content/uploads/2013/09/Special_Excerpt_of_WEO_2010.pdf.
[17] POET, 'Sustainability', accessed September 18, 2015, http://www.poet.com/sustainability.
[18] Sara Schoenhorn, 'Water Use For Ethanol Production: Where Are We Today', *Agri-View*, last modified 2012, accessed August 18, 2015, http://www.agriview.com/news/crop/water-use-for-ethanol-production-where-are-we-today/article_d0f5ef58-c0a2-11e1-af53-0019bb2963f4.html.
[19] Ethanol RFA, 'Policy Positions: Ethanol And Water', last modified 2015, accessed August 18, 2015, http://www.ethanolrfa.org/pages/policy-positions-ethanol-and-water.
[20] Ibid.
[21] Bruno Mallmann, email message with Project Gaia, September 1, 2015.

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 of harm should accidents occur.[22] 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 East African Community (EAC) region, including Kenya, Rwanda, Uganda, Burundi, Tanzania, and the associate country, Ethiopia. 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 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 fuel, and lists current ethanol production capacities in each country. 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 third and final section will give recommendations for how to develop distilleries and ethanol cooking programs in the EAC region. This report was directed and managed by Project Gaia. The country specific sections were researched and written by local consultants with expertise in clean, alternative energy, cookstoves, and their selected country. An international feedstock expert specializing in tropical agriculture was responsible for the feedstock profiles and assisted with the recommendations for developing successful, sustainable ethanol cooking fuel distillery programs.

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[22] Forrest Jehlik, 'Five Ethanol Myths, Busted', *WIRED*, last modified 2011, accessed August 18, 2015, http://www.wired.com/2011/06/five-ethanol-myths-busted-2/.

III. Overview of the EAC Region

EAC Country Group Outline

Geographically Eastern Africa is made up of the 13 Sub-Saharan countries of Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Seychelles, Somalia, Sudan, Tanzania, Uganda, and, as of 9 July 2011, the newly independent Republic of South Sudan. Within Eastern Africa, there are two subgroups, including the East African Community (EAC), which now comprises the five countries of Kenya, Tanzania, Uganda, Rwanda, and Burundi; and the Horn of Africa, made up of Somalia, Djibouti, Eritrea, and Ethiopia.

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.

During the last decade, the EAC in its present form, comprising Burundi, Kenya, Rwanda, Tanzania and Uganda, has become one of the most integrated regional markets in Africa, consisting of a Customs Union and a Common Market. The EAC is now moving into a Monetary Union with the Protocols for the Establishment of the EAC Monetary Union signed on 30 November 2013.

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%[23] during the last decade. Furthermore, it is one of the largest regional economic blocs in the African continent with a total population of 145 million and a total combined GDP of USD 98 billion. The total Foreign Direct Investments (FDI) inflow in the EAC region has tripled from USD 1.3 billion in 2005 to USD 3.8 billion in 2012.[24]

Against this backdrop of significant socioeconomic change in the region, including a growing middle class, larger consumer markets, improved business environment, and an integration process underway, the EAC partner states present ample investment opportunities in various sectors from agriculture to manufacturing, tourism, financial services, and information and communications technology (ICT).

Why Invest in the EAC?

The geographical region has a total population of 143.5 million, with average annual growth rate of remaining at the 2.6 percent over the last three consecutive years.[25] This poses a

[23]African Development Fund, *Foreword To EAC Investment Guidebook* (East African Community, 2013), accessed August 21, 2015, http://www.invest.eac.int/index.php?option=com_docman&task=doc_download&gid=26&Itemid=70.
[24] Ibid.
[25]East African Community Portal, 'EAC Quick Facts', last modified 2013, accessed August 21, 2015, http://www.eac.int/index.php?option=com_content&view=article&id=169&Itemid=157.

significant regional market for trade and investments. There are a number of factors that distinguish the EAC as investment opportunity:

- It has a growing middle class and demand for fairly sophisticated products
- It has a diversified economy offering a variety of business and investment opportunities
- It has a business-friendly environment
- It has a stable economic and political environment
- There is a harmonized tariff structure within the EAC
- It has great market access to Africa, the Middle East and Asia, and preferential market access to the United States, the European Union and some other developed countries
- It has English as an official business language
- It has a relatively large pool of educated and skilled workers.

These features are the result of the cooperation among the EAC member countries to establish a favorable economic and political climate. The economic integration instituted by EAC has resulted in:

- 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 stocks
- 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 also a number of other significant integrational initiatives that have already succeeded, further unifying the region. These include initiatives to increase the mobility of the labor 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, defense 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.

A significant regional investment bank in the region, the African Development Bank (ADB)[26], is also targeting a number of key improvements in regional transport and trade infrastructure that will further enhance economic opportunity in the EAC:

- Addressing the equipment shortages in the regional railway system.
- Improving regional seaports in Mombasa and Dar es Salaam.
- Improvement of water and air transportation to island countries.
- Design and construction of One Stop Border Posts (OSBPs) along 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.

The prospects for green energy generation are especially encouraging. The Eastern 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. Geothermal energy 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.

Common Environmental Considerations

East Africa is well-endowed with a variety of ecosystems that are of great economic value as well as being habitats for a wide range of species[27].

The Kenyan coastline is characterized by a rich diversity of flora and fauna, including fish, coral reefs, and mangrove forests. The rangelands 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

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[26] The African Development Bank is a multilateral development finance institution established to contribute to the economic development and social progress of African countries

[27]East African Community Portal, 'Biodiversity & Forestry', last modified 2014, accessed August 21, 2015, http://www.eac.int/environment/index.php?option=com_content&view=article&id=183&Itemid=195.

some 40% 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).[28]

Burundi has thirteen protected areas covering 100,000 hectares of land. About 172,000 hectares (or 6.7%) of Burundi is forested. These ecosystems harbor 2,500 higher plant species, 145 bird species, 107 mammal species, 79 reptile species, 18 amphibian species, and 5 fish species.[29]

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).[30]

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.[31]

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 to have a rain surplus, while large parts of Kenya are considered to have a very large water deficit.[32]

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

- Lake Tanganyika - the greatest single reservoir of fresh water on the continent and second deepest in the world.[33]
- The Nile River Basin - source of the Nile, the longest river in the world.
- 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 East African Community has designated Lake Victoria and its basin as an "area of common economic interest" and a "regional economic growth zone" to be developed jointly by the Partner States[34]. With a

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[28] Ibid.
[29] Ibid.
[30] Ibid.
[31] Ibid.
[32] East African Community Portal, 'Water Resources', accessed August 21, 2015, http://www.eac.int/environment/index.php?option=com_content&view=article&id=177&Itemid=197.
[33] Ibid.
[34] *Proposal For Review: Lake Victoria Environmental Management* (General Environment Facility, 1996), accessed August 22, 2015, http://www.thegef.org/gef/sites/thegef.org/files/gef_prj_docs/GEFProjectDocuments/International%20Waters/Regional%20-%20Lake%20Victoria%20Env.%20Manag/Project%20Document%20for%20WP.htm.

surface area of 68,800 km2 and an adjoining catchment of 184,000 km2, 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 percent of the lake surface, respectively. The gross economic product of the lake catchment is in the order of USD 3-4 billion annually, and supports an estimated population of 25 million people at incomes in the range of USD 90-270 per capita per annum.

The lake catchment 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 capital of Uganda, 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 are a significant part of those nations' 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 a deterioration of Lake Victoria that resulted in a 5 percent reduction in productivity of the region would result in consequent losses in the order of USD 150 million annually.

Important regional issues[35]

It is clear that the region has significant volumes of water and that these volumes could be enhanced by the preservation and restoration of the region's water towers. However to achieve water security, there is 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 catchments 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.[36]
- 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.[37]

The main challenges to achieving water security are therefore:

- The destruction of the ecosystems underpinning the region's water towers;

[35] East African Community Portal, 'Water Resources'.
[36] Ibid.
[37] Ibid.

- 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;[38]
- Poor waste management;
- High rates of evaporation particularly of Lake Victoria;
- Lack of systematic knowledge, data and monitoring of groundwater aquifers.

An Overview of Climate Change

As such 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.

Customs Unions and Common Markets

Eastern Africa has the largest number of Regional Economic Cooperation (RECs) and intergovernmental regional bodies in Africa.[39] 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, labor, services, and capital, which will significantly boost trade and investments, make the region more productive and prosperous,[40] and simply enable the free movement of people, capital and services, and abolish import duties. The 8 other countries in Eastern 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 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.

Economy

The total aggregate output (at current prices) for the EAC amounted to USD 110.3 billion in 2013, compared to USD 99.3 billion in 2012. The per capita GDP for the region in 2013 ranged from USD 294.20 in Burundi to USD 1,055.20 in Kenya. The dominant sector in the EAC in 2013 was agriculture, followed by wholesale and retail trade and manufacturing.

Table 1 EAC member country population and GDP figures[41]

State	Population in Millions	GDP in US$ Billion	GDP Growth %	Inflation %	Total a
Burundi	10.16	2.718	4.5	8.0	25.0
Tanzania	49.25	33.23	7.0	7.9	886.3
Uganda	37.58	21.48	5.8	5.5	200.5

[38] Ibid.
[39] *Eastern Africa Regional Integration Strategy Paper 2011 – 2015* (African Development Bank, 2011).
[40] East African Community Portal, 'EAC Common Market: Overview', last modified 2015, accessed August 21, 2015, http://www.eac.int/commonmarket/index.php?option=com_content&view=article&id=80&Itemid=117.
[41] Trademark East Africa, 'EAC', last modified 2015, accessed August 22, 2015, https://www.trademarkea.com/countries/eac/.

Rwanda	11.78	7.452	4.6	4.2	24.2
Kenya	44.35	44.10	4.7	5.7	580.7
EAC Total	**153.12**	**108.98**	**5.32**	**6.26**	**1716.7**

The EAC integration stands as the single most significant opportunity cluster for the region, giving all five Partner States immediate access to a market of approximately 154 million people. This integration will only 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 USD 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[42]. 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 of work permits that vary among EAC Partner States

Agriculture in the Region

The agricultural sector accounts for about 34% of the GDP in Burundi, 29% in Kenya, 32% in Rwanda, 25% in Tanzania and 23% in Uganda, (2014 figures), although agriculture's percent contribution to these economies is slowly declining. Since agriculture employs over 80 percent 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

[42] *Status Of Elimination On Non-Tariff Barriers As Per March 2013* (Arusha: East African Community, 2015), accessed September 21, 2015, http://www.tradebarriers.org/octo_upload/attachments/download/521dc987-b194-4bf0-ba2d-0d63c0a80d02/EAC%20STATUS%20OF%20ELIMINATION%20OF%20NTBS%20%20AS%20PER%20MARCH%202013%20SUMMARY.pdf.

sustainable manner. Agriculture also contributes to foreign exchange earnings, employment and provides raw materials for agro-based industries.[43]

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. Aquacultural 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 increasing 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.

[43] Edward Ssekalo, 'EAC's Agenda For Agriculture', *East African Community*, last modified 2015, accessed September 24, 2015,
http://www.agriculture.eac.int/index.php?option=com_content&view=article&id=73&Itemid=117.

IV. Country Reports

This section provides baseline reports on energy and cooking in the five EAC countries and Ethiopia. Each report outlines the demographics and basic information about 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.

A. Uganda

Political, Population and Demographics

The country is divided into 112 districts across four regions: Northern, Eastern, Western and Central regions. Each district is further divided into counties, sub-counties, parishes and villages. Uganda is a relatively easy place to do business by sub-Saharan Africa standards although it is quite challenging by international norms. Uganda has a population of about 35 million people with 16,935,456 males and 17,921,357 females. 28,430,800 (81%) live in rural areas and 6,426,013 live in urban areas.[44] Uganda has the second highest birth rate in the world with an annual Population Growth Rate of 3.2%, increasing the demand on the available energy resources. The majority of the population relies almost exclusively (96%) on biomass for cooking. The population projection for 2025 is 46.7 million.[45] Uganda has many tribes that speak different languages. Fifty six tribes and about nine indigenous communities are recognized in the 1995 constitution amendment of 2005. The Baganda tribe of the Bantu ethnic group, which is the biggest in the country, is found in the Central region and is the largest tribe in the country with 16.2% of the population. The other Bantu tribes include Basoga (7.7%), Bagisu (5.1%) found in the Eastern region, Banyoro (2.9%), Banyarwanda (5.8%), the Banyankore (8.0%), Batoro (3.2%) and the Bakiga (7.1%) in the Western and Southwestern parts of the country. The other tribes include the Karimojong (2.0%), Langi (5.6%), Iteso (8.1%), Acholi (4.4%), Lugbara (3.6%), and others (20.3%) living in the Northern, Western and Eastern regions.[46] English is the official language with Luganda widely spoken in most parts of the country. Swahili is spoken by mainly the business (trading) community.

Current Energy Situation

Uganda is richly 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.[47] In addition, petroleum reserves estimated at 6.5 billion barrels have been discovered in the western part of the country.[48] The national total primary energy consumption is 1,125,528 ktoe.[49] Biomass is the most important source of energy contributing about 90% of the total primary energy consumption with firewood contributing (78.6%), charcoal (5.6%) and crop

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[44] Bureau of Statistics, *Uganda Housing And Population Census* (Kampala: Government of Uganda, 2014).
[45] Ibid.
[46] George Kurian, *The Encyclopedia Of The Third World Volume III* (New York: Facts on File, 1987).
[47] Rural Electrification Agency, *Renewable Energy Policy* (Government of Uganda, 2007).
[48] Elias Biryabarema, 'UPDATE 2-Uganda Ups Oil Reserves Estimate By 85 Pct, Finds Natural Gas', *Reuters*, last modified 2014, accessed September 21, 2015, http://www.reuters.com/article/2014/08/29/uganda-oil-idUSL5N0QZ1EW20140829.
[49] Ministry of Energy and Mineral Development, *Statistical Abstract* (Government of Uganda, 2013).

residues (4.7%). Electricity contributes only 1.4% to the total energy balance while hydrocarbon-based fuels contribute 9.7%.[50] Forest wood biomass demand is estimated 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.[51]

The total installed power generation capacity is 822 MW with the overall national access to electricity at 14% while less than 5% (2013 figures) of households in the rural areas are connected to the grid.[52] 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.[53] The energy sector is key to the 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 satisfy the cooking energy needs of the urban population. Between 2005 and 2008 the charcoal prices rose at an enormous nominal rate of 14% per year owing to decline in supply of the biomass resource.[54] 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% of its forest cover between 1990 and 2005 mainly to meet fuel wood demand for household cooking and industrial use.[55] 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 to 12%.[56] Coupled with inefficient cooking methods of efficiencies less than 40% 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.

Economic

Uganda is blessed with substantial natural resources. Agriculture is the mainstay of the economy, employing over 71.9% of the working population.[57] GDP stands at US $20 billion, growing at 5.2% per annum.[58] The GDP per capita is 509 USD, 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% in 2007 to 20.9% in 2013.[59] The major food crops include bananas, cassava, maize and sweet potatoes. Although the country produces substantial amounts of

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[50] Ibid.
[51] Ministry of Energy and Mineral Development, *Biomass Energy Strategy Uganda* (Government of Uganda, 2015).
[52] Ministry of Energy and Mineral Development, *Rural Electrification Strategy And Plan For Uganda 2013-2022* (Government of Uganda, 2012).
[53] *Creating Certainty: Uganda'S FY 2013/14 Post Budget Analysis* (PricewaterhouseCoopers, 2013), accessed July 17, 2015, http://www.pwc.com/ug/en/assets/pdf/uganda-budget-2013.pdf.
[54] Ministry of Energy and Mineral Development, *Biomass Energy Strategy Uganda*
[55] National Environment Management Authority, *State Of The Environment Report For Uganda* (Government of Uganda, 2008).
[56] Ministry of Energy and Mineral Development, *Biomass Energy Strategy Uganda*
[57] Bureau of Statistics, *Statistical Abstract* (Kampala: Government of Uganda, 2014).
[58] Ibid.
[59] Ibid.

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.[60]
The biomass industry is such an important sector to the economy contributing 74.8 million USD to GDP, with firewood contributing 48 million USD and charcoal 26.8 million USD per annum.[61] 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.[62]

Although Uganda is blessed with plenty of rainfall, good weather and high productivity 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.[63]

Agriculture[64]
About 86% of the population relies on agriculture to earn a living.[65] 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 have over the years been coffee, tea, cotton, and tobacco. Two kinds of coffee that is Robusta and Arabica are grown with the Robusta type produced in much higher quantity compared to Arabica coffee. 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 gown 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% from 2013. This figure is expected to increase to 508,500 MT in 2015 to meet expected increase in consumption of the rising population.[66]

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[60] Andrew Cleary, David Jung and Nicole Noyes, 'Feasibility Analysis For Commercial Biofuels Business In Uganda', *Slideshare*, last modified 2014, accessed September 21, 2015, http://www.slideshare.net/AndrewCleary/final-biofuels-report.
[61] *Uganda Country Action Plan* (Global Alliance for Clean Cookstoves, 2012).
[62] Food and Agriculture Organization of the United Nations, 'Imports: Commodities By Country - Uganda', last modified 2015, accessed July 15, 2015, http://faostat.fao.org/desktopdefault.aspx?pageid=342&lang=en&country=226.
[63] Food and Agriculture Organization of the United Nations, 'Exports: Commodities By Country - Uganda', accessed July 15, 2015, http://faostat.fao.org/desktopdefault.aspx?pageid=342&lang=en&country=226.
[64] Bureau of Statistics, *Statistical Abstract.*
[65] Bureau of Statistics, *Uganda Census Of Agriculture, 2008-2009, Vol. 3, Agricultural Household And Holding Characteristics Report* (Kampala: Government of Uganda, 2010).
[66] *Seventeenth Annual Report* (Kampala: Uganda Sugar Manufacturers Association, 2014), accessed July 23, 2015, http://www.ugandasugar.org/pdf/The%2017th%20USMA%20Annual%20Report%202014.pdf.

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% of the total number of households (total number of households is 7 million).[67] 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.[68] 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% of poor households' expenditure is spent on cooking and lighting fuels while the rich households' expenditure is about 9% on the same[69]) are incurred in fuel costs for those that purchase the fuels. Women are therefore deprived of valuable time to engage in income generating activities and children are denied opportunity to go to school and study.

Social
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% 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 Information for Cooking Fuels and Cookstoves[70]
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 neighboring 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 centers is low. LPG receives no government subsidy. Kerosene is used by a small percent of the population mainly smaller families in urban areas.

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[67] Bureau of Statistics, *National Household Survey 2012-13* (Kampala: Government of Uganda, 2014).
[68] *Uganda Market Assessment: Sector Mapping* (Global Alliance for Clean Cookstoves, 2015), accessed July 15, 2015, http://cleancookstoves.org/resources_files/uganda-market-assessment-mapping.pdf.
[69] *State Of The Clean Cooking Energy Sector In Sub-Saharan Africa* (World Bank, 2012), accessed July 15, 2015, http://siteresources.worldbank.org/EXTAFRREGTOPENERGY/Resources/717305-1355261747480/ACCES_State_of_the_Clean_Cooking_Energy_Sector_in_SubSaharanAfrica_Report_DRAFT_Dalberg.pdf.
[70] *Uganda Market Assessment: Sector Mapping*.

The government recently removed subsidies on electricity and very few households can afford to cook with this fuel.

Types of charcoal and briquettes cookstoves on the market[71]

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.

Types of firewood cookstoves on the market[72], [73]

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.

Approximate upfront cost of cookstove, efficiency and distribution channel used[74], [75]

Cookstove[76]	**Cost (dollars)**	**Efficiency**	**Distribution channels**
Three stone fire	$0	Unknown	Home
Traditional metal charcoal stove	$2-$4	Unknown	Direct sales and retailers
Improved charcoal stove with ceramic liner	$7-$15	30-40%	Direct sales, network of stove vendors, retailers
Improved wood stove	Various	Various	Direct sales, retailers and

[71] Ibid.
[72] *State Of The Clean Cooking Energy Sector In Sub-Saharan Africa*.
[73] *Uganda Country Action Plan*.
[74] *Uganda Market Assessment: Sector Mapping*.
[75] *Uganda Country Action Plan*.
[76] Ibid.

			middlemen
Imported wood stove	$15-$20	33%	Direct sales and network of salesmen
Gasifier stove	$18-20	30-40%	Direct sales and network of salesmen
LPG Stove	$28	Unknown	Direct sales and network of vendors

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. 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 the biogas plant. The Renewable Energy Policy has a target of 100,000 biogas units installed by 2017.

Consumer Behavior

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 purchasing behavior of fuels and cookstoves, 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 whilst in urban areas households use both firewood, charcoal and a few households use LPG and briquettes. Many households in rural areas can 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 of the 30,000 hectares of Mabira forest to SCOUL, one of the major sugar producers in the country to double 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 about the dangers imposed by 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% for firewood, charcoal and briquettes if improved cookstoves are used.[77]

Fuel	Purchase Unit	Usage	Cost (dollars)
Firewood	1 bundle	3 days	$2.1
Charcoal (urban)	40kg sack	2 weeks	$30
LPG	13kg cylinder	3 weeks	$38.5[78]

[77] Ibid.

Cooking Costs Per Week Using Traditional Cooking Methods[79]
(Costs will reduce by about 20%-30% for firewood, charcoal and briquettes if improved cookstoves are used).

Fuel	Purchase Unit	Usage	Cost (dollars)
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[80]
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.

	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
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

From the table below (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 times and convenience. Households are unlikely to switch to electricity because of the associated high tariffs of energy use from this source.

	Segment 3: Peri-urban Charcoal	Segment 4: Urban Charcoal	Segment 5: Urban Charcoal $>3/d
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	Moderate to high (already pays for	Moderate to high (already pays for

[78] This does not include the cost of the cylinder for LPG. One cylinder will cost between 30 and 50 USD.
[79] *Uganda Market Assessment: Sector Mapping*.
[80] Ibid.

	charcoal)	charcoal)	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

Potential Market

Given that clay cookstoves have a lifetime of six months to 2 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.[81] 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% despite the various government and donor interventions.[82] The majority of rural Ugandan households live on less than US$3 per day and spend more than US$8 per month on biomass fuels to use on traditional cookstoves. 36% of rural households spend a significant amount of their monthly incomes on firewood.[83] About 15% of poor households' expenditure is spent on cooking and lighting fuels while the rich households' expenditure is about 9% on the same.[84] 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 into the sector in the past have been 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.

The Major Actors

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

[81] *State Of The Clean Cooking Energy Sector In Sub-Saharan Africa.*
[82] Bureau of Statistics, *Uganda National Household Survey 2009/10: Socioeconomic Module.*
83 *Uganda Market Assessment: Sector Mapping.*
[84] *State Of The Clean Cooking Energy Sector In Sub-Saharan Africa.*

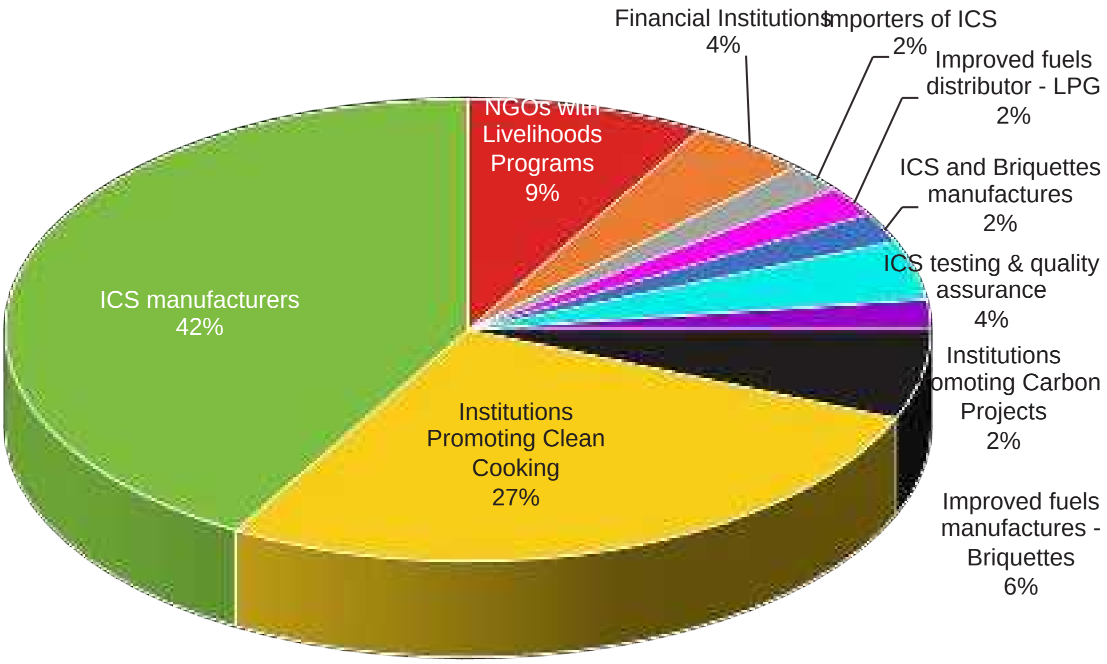
Organisation Name:	Area of operation:	Areas of intervention	Clean cooking interventions being implemented
Ministry of Energy and Mineral Development	Countrywide	Supporting the development of all renewable energy including biomass; charcoal, briquettes, firewood, clean cookstoves, biogas technologies	• 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 technologies	• Supports Ministry of Energy to promote and develop policy for renewable energy development • Training and capacity building of rural stove artisans to build 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, 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
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
ICCO – Inter Church Organisation for development cooperation	Lango, Acholi, Teso, and Karamoja Sub region	Improved stoves and biogas technologies	• Promotion campaigns for afforestation (wood lots) to mitigatefirewood shortages and time spent on firewood collection • Awareness campaigns to reduce Household Air Pollution • Promotional activities to generate carbon credits from household clean cooking
BEETA – Biomass Energy Efficient Technologies Association	All regions except Karamoja region	charcoal, firewood clean cookstoves	• Capacity building of members • Awareness raising and market promotions for households and institutional cookstoves
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.

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
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

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 centers for improved cookstoves, briquettes and LPG are super and local markets and retailing kiosks attached to large producers.

The figure below shows the distribution of actors in the clean cooking sector[85]



[85] *Needs Assessment And Sector Mapping Of UNACC Members* (Kampala: Uganda National Alliance on Clean Cooking, n.d.).

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 favor 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 subsector 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 here below:

The Renewable Energy Policy

The Renewable Energy Policy has an overall goal of increasing the use of modern renewable energy from the 4% in 2007 to 61% 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 to 2,500,000 and increase the adoption of efficient fuelwood stoves from 170,000 to 4,000,000 by 2017. The cumulative number of all types of cookstoves disseminated/installed up to 2013 was 223,977.[86] 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.[87] The policy also advocates for a blend of biofuels with conventional fossil fuels up to 20% and recommends the development of a biofuels policy to promote the industry.

Biofuels Bill[88]

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 amount of biofuels to be blended in petroleum products

[86] Ministry of Energy and Minerals, *Annual Report 2013* (Government of Uganda, 2013).

[87] Bureau of Statistics, *Statistical Abstract*.

[88] Ministry of Energy and Mineral Development, *Biomass Energy Strategy Uganda.*

- 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.[89]

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 liters of hydrocarbon-based fuels per day, 70 million liters every month.[90]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 liters per year.[91] However, this would be a rather ambitious target with a lower less strenuous blend of 2% preferred in 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 liters of petrol, diesel, kerosene, and aviation fuel every month.[92]

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) through which a joint coordination framework, the inter-ministerial dialogue composed of 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 for the promotion and use of biofuels in a sustainable and well-harmonized approach in view of other competing interests like agriculture and agroforestry.

National Sugar Policy[93]

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 at bringing harmony among all the key players in the sugar industry to promote and sustain steady industrial growth of the sector. It is intended to

[89] Rural Electrification Agency, *Renewable Energy Policy*.
[90] “Izael Pereira Da Silva, 'Biofuels: Food From The Poor's Mouth Into The Tank Of My Car!', *Daily Monitor*, 2009, accessed August 21, 2015, http://www.monitor.co.ug/OpEd/Commentary/-/689364/832414/-/ak58m9z/-/index.html.
[91] Ibid.
[92] Samuel Sanya, 'Vivo Energy Explains Fuel Pricing', *New Vision*, 2015, accessed September 22, 2015, http://www.newvision.co.ug/news/667030-vivo-energy-explains-fuel-pricing.html.
[93] Ministry of Tourism, Trade and Industry, *National Sugar Policy* (Kampala: Government of Uganda, 2010).

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 apparatus used for 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 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 as the Biofuel Act and by laws have not been passed. 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%) and locally manufactured ones (60%), the majority of local distillers who control about 70% of the market share will try as much as possible to evade the taxes.[94] In the 2015 budget the Ministry of Finance has proposed to increase the taxes for imported spirits to 100% or more for some spirits. The leading spirits distiller (East African Breweries Limited) who has an estimated 30% market share contributes 70% of tax revenues from spirits.[95]

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 purposes of taxation and investment in the sub-sector.[96]

[94] *The Road Map To Alcohol Policy And Regulation In Uganda* (Uganda Youth Development Link, 2010), accessed July 28, 2015, http://www.uydel.org/downloads/The%20Road%20Map%20to%20Alcohol%20Policy%20in%20Uganda%20booklet-20110706-161532.pdf.

[95] Ibid.

[96] Ministry of Energy and Mineral Development, *Biomass Energy Strategy Uganda*.

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% Import duty, 18% VAT and 6% withholding tax. VAT is refundable, that leaves 31% 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% peasants who currently contribute 22% of GDP from subsistence to commercial agriculture to move out of poverty and attain food security using land as the major resource input.[97] 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: National Land Cover Statistics[98]

Table 1.1.1: National Land Cover Statistics (sq km)

Type of land cover	1990	2000	2005
Built-Up Areas	365.7	365.7	365.7
Bush lands	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	99,018.6
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	36,902.8	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 1992 satellite imagery

Source: NFA

[97] Ministry of Agriculture, Animal Industries, and Fisheries, *National Agricultural Policy* (Government of Uganda, 2013).

[98] 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 kilometers to 99,000 square kilometers an increase of 18%, while tropical forests and woodlands substantially decreased by 25% from 1990 to 2005 mainly for 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 one hundred 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.[99] 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 liters 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 liters of pure alcohol are consumed per capita every year in Uganda which is the highest for the East African region.[100] 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 liters 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

[99] *The Road Map To Alcohol Policy And Regulation In Uganda.*
[100] *Global Status Report On Alcohol And Health* (World Health Organization, 2014), accessed July 21, 2015, http://www.who.int/substance_abuse/publications/global_alcohol_report/en/.

million liters 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.[101] 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 a 60,000 liters per day, 20 million liters 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 liters 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;

(i) The construction of two low cost, scalable and modular bioethanol production plants with an estimated capacity of 200,000 liters/year at the Kaliro Sugar Factory;
(ii) Introduction of sustainable use of bioethanol as a cooking fuel in Kaliro District;
(iii) 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 liters 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:

[101] Ministry of Energy and Minerals, *Annual Report 2013.*

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*	Green	Yellow	Green	Yellow
2	*Sweet potatoes*	Green	Yellow	Green	Yellow
3	*Maize*	Green	Yellow	Yellow	Yellow
4	*Bananas (food)*	Red	Green	Red	Yellow
5	*Bananas (beer)*	Red	Green	Red	Yellow
6	*Bananas (sweet)*	Red	Green	Red	Yellow
7	*Sorghum*	Yellow	Red	Yellow	Red
8	*Irish potatoes*	Red	Green	Red	Red
9	*Finger millet*	Yellow	Red	Red	Red
10	*Coffee*	Green	Green	Red	Green
11	*Sugar molasses*	Green	Yellow	Red	Yellow
12	*Sugar bagasse*	Green	Yellow	Red	Yellow
13	*Rice*	Red	Red	Red	Red

Key

Green	*High crop production and high probability of crop waste*
Yellow	*Medium crop production and moderate supply of crop waste*
Red	*Low crop production and low supply of crop waste*

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. 19,700 deaths occur each year, the majority children 17,800 who suffer from pneumonia, mental impairment and cardiovascular diseases caused by the noxious gases.[102] 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.[103] 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 while 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

[102] Ministry of Energy and Mineral Development, *Biomass Energy Strategy of Uganda.*
[103] National Environment Management Authority, *State Of The Environment Report For Uganda*.

improved cookstove. Affordability is a significant factor influencing purchasing behavior 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 easily transportable and distributable.

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 neither does it receive 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% to 61% by the year 2017 which will partly be achieved by blending biofuels with conventional fossil fuels up to 20%.

The biofuels law which provides for the provision of 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 and will support the development of the industry especially if the 80% to 20% 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 self-sufficiency in food crop production and environment sustainability.

An alcohol policy is under development to replace the old enguli (ethanol) act which was intended to regulate the manufacture, sale, possession and consumption of ethanol its manufacture is under review. The policy will welcome alternative uses of ethanol to deter its population from consuming very high quantities of alcoholic products.[104]

Taxation

The biofuels law provides for the provision of 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 favorable 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 catalyze investments in the biofuels sub sector.

[104] *The Road Map To Alcohol Policy And Regulation In Uganda.*

B. Rwanda

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 kilometers square. It is densely populated (435 persons per Sq km), with a population of 12,337 million people. 80.26% live in the rural areas, and 19.74% are in urban areas. The country borders Burundi for 290km, the Democratic Congo for 217km, Tanzania for 217km, and Uganda for 169km. The largest ethnic groups are the Hutus (85%), the Tutsis (14%), and the TWAs (1%). 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% of the people living in Rwanda. The Rwanda National languages are Kinyarwanda, English and French, Kiswahili is spoken.by some of the population. [105]

The Rwanda population growth rate trend in the last 25 years has been inconsistent. In 1980 the growth rate was on the increase at 3.3%. By 1987, the growth rate was at 5.5%. Following the genocide, the growth rate declined to the negative. After 1994, the growth rate grew up rapidly to 10% in 1998, started stabilizing in 2003, and by 2014 was estimated to be 2.63%.[106]

Rwanda's Economy

90 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 7-8% annually with reduced inflation. 45 percent of the population lives below the poverty line, compared to 57% 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 and pursuing transportation linkages to other countries continue to handicap private sector growth.[107] The Rwandan government is seeking to become a regional leader in information and communication technologies.[108]

Although still poor and mostly agricultural, the nation has made significant progress in recent years in growth. The economic growth rate of Rwanda's economy is growing at 8.3%, and the government is targeting to achieve an annual growth rate of 11.5% over the period of 2017/2018.[109] 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.[110]

Rwanda's Health Indicators

Rwanda's infant mortality rate is 59.59 deaths per 1,000 live births The maternal mortality rate is 340 deaths per 100,000 births. Low birth weight rate is 11.7%[111] According to the

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[105] Index Mundi, 'Rwanda - Country Profile - 2014', accessed August 28, 2015, http://www.indexmundi.com/rwanda/#Demographics.

[106] Ibid.

[107] Ibid.

[108] Economy Watch, 'Rwanda Economic Statistics And Indicators', last modified 2015, accessed August 28, 2015, http://www.economywatch.com/economic-statistics/country/Rwanda/.

[109] Ministry of Infrastructure, *Rwanda Rapid Assessment And Gap Analysis Energy Sector* (SE4ALL, 2014).

[110] *Second Economic Development And Poverty Reduction Strategy: 2013-2018* (Government of Rwanda, 2013).

[111] Index Mundi, 'Rwanda - Country Profile – 2014.'

Global Disease Burden (2010), the profile of Rwanda indicates that HAP is a leading risk factor through disability adjusted life years (DALYs), resulting in total annual deaths of 5,680 people due to HAP, greater than the deaths attributed to malaria. [112]

Baseline Information for Fuels and Cookstoves
More than 90% of Rwanda's primary energy needs are met by biomass in the form of wood, charcoal, and agricultural wastes.[113] 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% of Rwanda's population, as of 2009, it consumed 20.7 % of the entire woody biomass consumption and 60% of the national charcoal consumption.[114] National managed supplies provide not for all biomass demand. The supply under management is 69.3%. 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.[115]

Households are the dominant consumers of energy (91%), followed by the transport sector (4%), industry (3%), and public services (2%). Households are also the dominant consumers of electricity (51%), which is primarily used for lighting. The second largest consumer is the industrial sector (42%), which mainly comes from motor-drivers and lighting. Public sector consumption (6%) is largely due to public buildings, street lighting and water pumping[116].

<u>Fuelwood</u>
There are various types of woodstoves. In the rural areas, 48-49% of the households use the traditional stoves, mainly three-stone fires. 52% use mud stoves, which are considered improved stoves following the government initiative after the genocide as well as recent initiatives. About 4% 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- 8.16 USD) 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. 51% of households in the rural areas live in poorly ventilated houses leading to high risks of exposure to smoke leading to 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 widely for making family food or foods to sell by the food kiosks or food vendors. The main staple food is beans, which are cooked in almost

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[112] Institute for Health Metrics and Evaluation, *GBD Profile: Rwanda* (Institute for Health Metrics and Evaluation, 2010), accessed September 24, 2015, http://www.healthdata.org/sites/default/files/files/country_profiles/GBD/ihme_gbd_country_report_rwanda.pdf.
[113] *Biomass Energy Strategy (BEST) Rwanda*, Partnership Dialogue Facility (European Union Energy Initative, 2015), accessed August 28, 2015, http://www.euei-pdf.org/sites/default/files/files/field_pblctn_file/EUEI%20PDF_BEST_Rwanda_Executive%20Summary_Jun%202009_EN.pdf.
[114] Rudi Drigo et al., *Rwanda Supply Master Plan For Fuelwood And Charcoal* (Rwanda Ministry of Natural Resources, 2013).
[115] Rudi Drigo and Vital Nzabanita, *WISDOM Rwanda* (Food and Agriculture Organization of the United Nations, 2011), accessed September 24, 2015, http://www.fao.org/docrep/013/ma223e/ma223e00.pdf.
[116] Ministry of Infrastructure, *Energy Sector Strategic Plan* (Government of Rwanda, 2013).

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 on the domestic stoves.

Charcoal

More than 90% of the households living in the major urban areas, Kigali, Butare, 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, 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 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. This varies by district.[117]

Both traditional and improved cook stoves are used to burn charcoal. A bag of charcoal costs RWF 7000- 10000 (USD 9.52-13.60) 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- 5000 (USD 3.40-6.80), and the traditional charcoal stoves cost about RWF 500-1000 (USD 0.68-1.36). More than 90% of the urban households use charcoal stoves as their primary stoves for cooking all their meals. At the same time more than 90% of the rural households rely on biomass for meeting their cooking needs.[118]

Crop Residue/Animal Dung

Crop residues are widely used mainly 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 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% of households in Rwanda are connected to the grid.[119] Rwanda uses diesel engines for generation of electricity. Currently Rwanda generates electricity from hydropower. 55MW is currently generated and is expected to grow to over 120MW by 2018.[120]Electricity is typically used for lighting, industrial processing, and other commercial activities. About 5% of the households in Kigali use electricity for cooking. This represents about 25MW as of 2009.[121]

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[117] Courtney Blodgett, *Charcoal Value Chain And Improved Cookstove Sector Analyses*, SNV Rwanda Positioning Document (SNV Rwanda, 2011), accessed August 28, 2015, http://cleancookstoves.org/resources_files/charcoal-value-chain-and.pdf.
[118] *Biomass Energy Strategy (BEST) Rwanda*.
[119] Ministry of Infrastructure, *Rwanda Rapid Assessment And Gap Analysis Energy Sector*.
[120] Ibid.
[121] *Biomass Energy Strategy (BEST) Rwanda*.

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% tax. According to RURA, Rwanda imports all its oil products either through the central or north (via Kenya) corridors. Kerosene costs RWF 674 (USD 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.[122] 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 10-15% per year under current conditions, but this rate could be much higher if some form of subsidy is put into 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%[123]

The LPG bottles come in various sizes and refill prices vary with size of the bottle. The 20kg bottle costs RWF 32,000 (USD 43.53), 13kg costs RWF 20,000 (USD 27.21) and 6kg bottle costs RWF 10,000 (USD 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.[124] 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 land scarcity for crops and competition for food sources as issues hindering biodiesel'sproduction. 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. [125]

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[122] Rudi Drigo et al., *Rwanda Supply Master Plan For Fuelwood And Charcoal*.
[123] *Biomass Energy Strategy (BEST) Rwanda*.
[124] Ministry of Infrastructure, *Rwanda Rapid Assessment Gap Analysis Energy Sector*.
[125] *The Potential Of Sustainable Liquid Biofuel Production In Rwanda. A Study On The Agricultural, Technical And Economic Conditions And Food Security* (GIZ, 2011), accessed August 22, 2015, https://www.dbfz.de/fileadmin/user_upload/Berichte_Projektdatenbank/GIZ_2011_Potential_liquid_biofuels_Rwanda.pdf pp 116.

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 SNV Board showed that there were fewer uptakes than expected of biogas, and 10% 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. 25% of biogas digester owners were dissatisfied. Despite these professed downsides, 80% of users still reported benefits from using biogas. [126]

The cost of a digester for a household is RWF 300,000 (USD 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. [127] Biogas stoves are manufactured locally with a cost of RWF 2000-4000 (USD 2.72-5.44). 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.[128] 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 of peat and solar.[129]

Improved Cookstove Initiatives

The Rwandan government initiated an Improved Cook Stove (ICS) program in the late eighties/early nineties to combat deforestation. Various ICS programs have been implemented since then, which have led to a stove penetration rate of over 40-50% nationwide by 2012.[130] The largest initiative was of Darfur stoves, a mud stove with pieces of bricks forming the firebox, after the genocide. The Rwanda Defense Forces led the initiative. MININFRA also initiated an ICS dissemination program in the rural regions of Rwanda in 2011-2012. 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

[126] *SNV Managing Board'S Response To The Impact Evaluation Of Rwanda's National Domestic Biogas Programme* (SNV, 2013) pp. 1.
[127] Ibid.
[128] Ministry of Infrastructure, *National Energy Policy And National Energy Strategy 2008-2012* (Government of Rwanda, 2009) pp. 51-52.
[129] Ministry of Infrastructure, *Rwanda Rapid Assessment and Gap Analysis Energy Sector.*
[130] *Biomass Energy Strategy (BEST) Rwanda*.

cookstoves, and their production process allows for standards 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 initative with the Ministry of Health. They intended to distribute 600,000 Ecozoom stoves and 600,000 water filters to 30% of 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.[131] 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:

a) The National Biogas Program (NDBP): Started in 2007 and follows the principles of supporting the poorest while leveraging private sector involvement and developing a commercial and sustainable domestic biogas sector by ensuring companies know how to maintain and install digesters. Since initiation roughly 3,700 digesters have been disseminated with the support of a 50% 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 USD 37.3 million.
b) 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 developed.

Stakeholders

Government initiatives involve a wide 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, Africa Development Bank, European Union, Belgium, France, Germany, Japan, the Netherlands, South Korea, the United Kingdom, and the United States 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.

[131] Delagua, 'Project Rwanda', accessed August 28, 2015, http://www.delagua.org/#home-mid-section-rwanda.

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.[132]

Platform for Improved Cookstoves Stakeholders.
Recently the 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 an energy policy and energy efficiency is one of the key pillars.[133] The Electricity Policy was enacted in July 2011 and the key principles of the law are:

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

Key principles likely in linkage to biofuel programs are:

a) Maximize use of indigenous energy resources
b) Improve energy access
c) Promote efficient utilization of energy resources
d) 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.[134]

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[135].

Rwanda Development Board (RDB) plays a lead role in investment, mobilization, and promotion for the energy sector. It promotes private sector participation. The RDB also issues environmental impact assessments or exemptions for energy projects.[136]

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

[132] FONERWA, 'Home', accessed September 24, 2015, http://www.fonerwa.org.
[133] Ministry of Infrastructure, *National Energy Policy And National Energy Strategy 2008-2012.*
[134] Ministry Infrastructure, *Rwanda Rapid Assessment and Gap Analysis Energy Sector.*
[135] Ibid.
[136] Ibid.

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 80-90% alcohol from other countries, and the Rwanda Bureau of Standards allows the wine and spirit companies to dilute the imported alcohol to 45%. 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 would need 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 plan stages. 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 currently. The factory produces under capacity because of floods that affect sugarcane production adversely. Rwanda imports a large portion of its sugar demand annually. Currently the company sells all of its molasses to dairy farmers. Molasses is sold at RWF 190,000 (USD 259) per ton.[137]

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% 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 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.[138]

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 wasted, there may be more potential for ethanol than commonly

[137] An Ansoms, *Privatization's Bitter Fruit: The Case Of Kubuye Sugar Works In Rwanda* (Chronique Politique du Rwanda, 2009), accessed September 24, 2015, http://www.ua.ac.be/objs/00245644.pdf pp. 1-2.
[138] Personal conversation between Rwanda Revenue Authority official and Hellen Owala, July 2015.

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.[139]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 good waste 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. In December, Practical Action and the Global Alliance for Clean Cookstoves conducted a National Stakeholders Meeting to identify barriers for dissemination of ICS in Rwanda.[140] A three-pronged strategy was developed: enhancing demand, strengthening supply, and fostering an enabling environment.[141]With more education and raising 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. Thus far, there is no biofuels policy, making this a highly innovative area. The government may need support to develop ideal policies and regulations in this area.

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[139]*The Potential Of Sustainable Liquid Biofuel Production In Rwanda. A Study On The Agricultural, Technical And Economic Conditions And Food Security* (GIZ, 2011), accessed August 22, 2015, https://www.dbfz.de/fileadmin/user_upload/Berichte_Projektdatenbank/GIZ_2011_Potential_liquid_biofuels_Rwanda.pdf pp 116.

[140] *Understanding And Building Energy Access Markets: A Framework And Analysis Of Key Market Systems* (European Union, 2014), accessed August 24, 2015, https://cleanenergysolutions.org/sites/default/files/documents/value_chain_analysis_of-key_energy-market_systems_mf.pdf.

[141] Accenture Development Partnerships, *Rwanda Market Assessment: Intervention Options* (Global Alliance for Clean Cookstoves, 2012), accessed August 24, 2015, https://cleancookstoves.org/binary-data/RESOURCE/file/000/000/169-1.pdf pp. 7.

Any initiatives in bioethanol production would need a detailed feasibility study. There is likely a big opportunity 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 centers, 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.

C. Burundi

Country and Demographic Information
Burundi is a small landlocked African Country with territorial total area of 27,834 sq. km out of which land area is: 25,680 sq. km and water occupies 2,150 sq. km. Burundi is surrounded by Rwanda to the North, Tanzania to the East and South, Lake Tanganyika to the Southwest, and the Democratic Republic of the Congo to the West. Burundi is administratively divided into 18 provinces and further into 117 Communes and 2639 Collines. The population is 10.75 million and this results to a population density of 250 - 400 people per square kilometer making it one of the dense Countries in Africa. Approximately 90 percent of the population lives in rural areas with agriculture as their main economic activity. The population of Burundi has annual growth rate of 2.8% and the growth rate in cities is higher than in rural areas. 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 and that is Hutu 83%, Tutsi (14%) and Twa (3%). 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. This historical war lasted for 12 years from 1993 to 2005 claiming 300,000 lives of people and displacing approximately 1,200,000 people or 16 percent of the population. The current ongoing political instability in Burundi due to disputable extension of presidential term is an indicator of Burundi's precarious state of affairs. The ongoing dispute is likely to diminish the gains of Arusha Peace and National Reconciliation Accord signed in 2000 and the Government of Burundi's endeavor in consolidation of peace, national reconciliation and economic reform.

There exist widespread poverty in Burundi. This is illustrated by 90-95% of the population living on less than USD 2 day. This is common in rural areas. The economic growth has been dynamic as characterized by negative GDP for several years, 5.9 % in 2006, 3.9% in 2010, and associated per capita GDP of USD 210 in 1990 and USD 110 in 2002. Likewise 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, and eight out of ten Burundians live below the poverty line.[142] The critical food insecurity situation in Burundi captures vividly the poverty situation in the country; 70 percent of the population is living in food insecurity and 35 percent of children under five are suffering from moderate to severe underweight.[143]

In terms of land-use, agricultural land is 73.3% out of which arable land is 38.9%; permanent crops 15.6%; permanent pasture 18.8%, forest 6.6% and others 20.1%[144] Burundi experiences two rainy seasons; a long rainy seasons in February-May and short rainy season in September-November. Additionally it has very short rainy season in January. The rainfall

[142] Government of Burundi, *Poverty Reduction Strategy Paper II* (Bujumbura, 2012).
[143] Patrick Vinck et al., *Comprehensive Food Security And Vulnerability Analysis (CFSVA) Burundi* (World Food Programme, 2008), accessed August 20, 2015, http://catalog.ihsn.org/index.php/catalog/4095/download/55182.
[144] Ir Henri Niyongabo, *Best Practices For Water Harvesting And Irrigation: Burundi Report* (Nile Basin Initative, 2008), accessed August 18, 2015, http://nileis.nilebasin.org/system/files/burundi_best_practices_print.pdf.

ranges from 2,000 mm in higher altitudes to 1,000 mm in low-lying areas. The average temperature is 16-23^oC.

The economy is predominantly agricultural. Agriculture accounts for just over 40% of GDP and employs more than 90% 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% of total cultivated area and 44% 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.[145]

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.[146]

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 labour, 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.[147]

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.[148] The country has an interesting landscape with an altitude that ranges from 772 metres (Bujumbura) to 2,670 metres (Mont Heha). The average altitude of the country is 1,700 metres. 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% of energy consumption in Burundi. Access to electricity for the Burundian population is very low (10%) compared with other countries in the East African

[145] Nathan Associates Inc., *The Link Between Land, Environment, Employment, And Conflict In Burundi* (USAID, 2006), accessed August 17, 2015, http://pdf.usaid.gov/pdf_docs/Pnadg059.pdf.
[146] Mary Hobbs and Walter Knausenberger, *Burundi Environmental Threats And Opportunities Assessment* (USAID, 2003), accessed August 17, 2015, http://pdf.usaid.gov/pdf_docs/pnaea331.pdf.
[147] Mark Curtis and David Adama, 'Walking The Talk: Why And How African Governments Should Transform Their Agricultural Spending Policy Breif', *Actionaid*, last modified 2013, accessed August 15, 2015, http://www.actionaid.org/sites/files/actionaid/walking_the_talk_full_report_final.pdf.
[148] Fintrac Inc., *BEST Analysis: Burundi*, Bellmon Estimation Studies for Title II (USAID, 2012), accessed August 22, 2015, http://pdf.usaid.gov/pdf_docs/PBAAB954.pdf.

Community. According to GOB (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.[149]

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%, and national forest cover is below 6%.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. [150]

Baseline Energy Information

The energy sector in Burundi should be appraised in the context of political instability and war leading to neglect and inadequate investment in energy sector, climate constraints such as recurrent drought hampering the full potential of hydropower, low consumption and purchasing power leading to highly subsidized electricity, landlocked nature, 2000km for transport of 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.

The following energy needs and uses are active in Burundi: heating, lighting, commercial, agricultural, and industrial purposes. Traditional biomass such as wood, solid wastes, charcoal and bagasse provide 96% of energy needs in Burundi. Biomass energy is composed of 70.8% fuel wood, 18.35% agricultural residues, 5.82% charcoal, and 0.978% bagasse. Additionally other energy sources participating in energy balance are 2.5% petroleum products (crude oil, liquefied petroleum gas), 2.5% flowing water (hydropower), 0.04 % peat, and 0.01 % 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 % of Burundi's supply of commercial energy is imported (petroleum products and electricity), the other 23 % being domestically produced in the form of hydroelectric power and peat.[151]The challenges of energy sector in Burundi include:

- Investment costs are very high and difficult to mobilize.
- The lack of new investment for instance 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,

[149] Government of Burundi, *Investment Opportunities In Renewable Energy In Burundi Report* (Bujumbura, 2012).
[150] Ibid.
[151] Godefroy Hakizimana, *Burundi Country Baseline Report And Workplan*, EAC Strategy to Scale-Up Access to Modern Energy Services (Bujumbura: East African Community, 2008), accessed August 15, 2015, http://eac.int/energy/index.php?option=com_docman&task=doc_download&gid=63&Itemid=70.

- The destruction or the abandon 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,
- An over-exploitation of traditional energy resources and the low rate of regeneration of natural forests,
- No access of the country to ocean (all petroleum products are imported),
- High prices of oil products and lack of strategies to reduce those prices,
- Lack of measures to promote renewable energies among others.

Fuelwood

Fueldwood dominates energy consumption in Burundi, and its uses include lighting, cooking, water heating, household heating and home enterprises. 96% of households use wood, farm residues, and charcoal. Biomass and farm residues are mainly used in rural areas with 94% of the households as compared to 2% of 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[152]. 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 cost USD 0.46 - 0.50 per kg. For urban areas, it is the lowest income households who depend on firewood the most. Trends have showed that 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.[153] 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% of the population in urban areas and peripheral zones. The use stands at 30.2% urban, 7.7% rural, and 13.3% national[154]. The cost of charcoal is at 10-15 $USD per sack however it varies depending on production zone, season and location of demand. Charcoal production is commercial and raw materials 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% of high-income groups regularly use charcoal as well[155].

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152 Ibid.
153 Ibid.
154 Ibid.
155 Ibid.

Crop Residue/Animal Dung

Burundi has immense forest and agricultural resources that can be converted into energy. Additionally Burundi generates a lot of agricultural residues from its agricultural dominated economy and this can be converted into energy. Farm residue is mainly used for cooking, water heating, ironing, lighting, and home business. 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 to 58 million tons.[156] The National Office of Peat (ONATOUR) is responsible for 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, installation cost, and the poor technology availabile 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% are not in working condition.[157] The notable cause is the civil war. The most notable biogas technology promotion effort was 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%) compared with other countries in the East African Community or Sub-Saharan Africa[158]. 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.[159]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 as back up, 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 East Africa region. This stands at 0.04

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[156] Government of Burundi, *Investment Opportunities In Renewable Energy In Burundi Report.*
[157] Godefroy Hakizimana, *Burundi Country Baseline Report And Workplan.*
[158] Shonali Pachauri et al., *Access To Modern Energy: Assessment And Outlook For Developing And Emerging Regions* (IIASA Energy Program and the UNIDO, 2012), accessed September 24, 2015, http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/IIASA-GEF-UNIDO_Access-to-Modern-Energy_2013-05-27.pdf.
[159] Government of Burundi, *Investment Opportunities In Renewable Energy In Burundi Report*

USD/kWh, 0.3 USD/kWh and 0.48 USD/kWh for hydropower plans, thermal power and diesel generators respectively[160]. The average production costs for the energy mix are consequently estimated at 0.062 USD/kWh for 2012[161]. 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 0.06 USD/kWh to 0.18 USD/kWh[3]. The potential for increased electrical consumption is substantial; the average household consumption is quite low, around 23 kWh/year per household, relative to the African average of 150kWh/year[162]. 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 infrastructural projects.

Solar Energy

Solar is increasingly being exploited in Burundi for off-grid rural electrification. This is donor driven as opposed to market driven 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 as only two mechanic 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 its commercial viability.

Kerosene

Kerosene is imported from the Middle East via Kenya and Tanzania. It is part of 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, appliances, and the poor infrastructure available for delivery.

Biofuels

There is no experience of biofuels in Burundi. There is potential for biofuels in Burundi as implied through availability of 1st and 2nd 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 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 developed to tap into this

[160] Government of Burundi, *Investment Opportunities In Renewable Energy In Burundi Report.*
[161] Ibid.
[162] Ibid.

energy niche.

The country sugar belt in eastern Burundi holds promise in sizeable production of this fuel. It is imperative to note that the region has been mobilizing by the private sector to implement a Vanilla-Jatropha Development Project, which is going to establish out grower farming activities of the Jatropha crop with the aim of producing biodiesel. Nothing substantial has resulted from this self-mobilization.

Gross Energy Supply in Burundi[163]

N°	Type of Energy	Quantity	Toe	%
1	**Biomass**			
1.1.	Fuel wood	6,400,000 m	1,216,000	70.8
1.2.	Agricultural residues	900,000 tons	315,000	18.35
1.3.	Charcoal	346,617 tons	100,000	5.82
1.4.	Bagasse	48,000 tons	16,800	0.978
2.	**Petroleum Products**	(40,500 tons)	(42,000)	2.5
3.	**Hydroelectricity**	180 GWh	45,580	2.5
4.	**Peat**	8,000 tons	2.276	0.04
5.	**Solar and biogas**	n.a.	n.a.	0.01
	TOTAL			100

Current Initiatives For Clean Cooking

Cooking in Burundi is heavily dominated by fuelwood, charcoal, and peat in order of prominence. This results Household Air Pollution, environmental degradation, and loads of time in collection due to overdependence and increasing scarcity especially by women and girls. The amount of time spent collecting fuelwood varies from 30 minutes to two hors 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 1980s through Improved Cook Stoves (ICS). Development partners, donors, civil society and Government drive these projects.[164] 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% of the digesters are not in use. The poor

[163] Godefroy Hakizimana, *Burundi Country Baseline Report And Workplan.*
[164] Oliver Johnson et al., *From Theory To Practice Of Change: Lessons From SNV'S Improved Cookstoves And Fuel Projects In Cambodia, Kenya, Nepal And Rwanda* (Stockholm Environment Institute, 2015), accessed September 22, 2015, http://www.sei-international.org/mediamanager/documents/Publications/SEI-WP-2015-09-SNV-cookstove-market-transformation.pdf.

penetration is attributed to the civil war of 1993-2005, poor capacity of use, repair and construction, poor development of milk or livestock industry, and high installation cost.[165]

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 of 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 environmentally 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 CO2 equivalent per annum.[166]

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 biofuel in Burundi.[167] 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
- National Plan for Agricultural Investment (*Plan National d'Investissement Agricole)* for 2012-17

[165] Godefroy Hakizimana, *Burundi Country Baseline Report And Workplan*
[166] *Poa 9634 : Renewable Biomass Fired Improved Cookstoves Programme For Households In Burundi By BQS*, Programme Design Document Form for Small-Scale CDM Programmes of Activities (United Nations Framework Convention on Climate Change, 2015), accessed August 10, 2015, http://cdm.unfccc.int/ProgrammeOfActivities/poa_db/1L6JS9B25W078EXKGFCTQHP3AZN4VM/view.
[167] *Burundi Energy Policy, Laws And Regulations Handbook Volume I Strategic Information And Regulations* (Washington DC: International Business Publications, 2015).

No	Enabling Institutional Instrument	Impact on Biofuel Sub-Sector
1.	National Energy Policy 1998	The policy aims to facilitate supply and demand for energy by 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 role of private sector and other stakeholders in the Energy Sector
3.	Document on Investment opportunities in renewable energy Burundi	Outline Priority Renewable Energy Investment Opportunities in Burundi
4.	Law N° 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	This 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. Thus excellent reference point for facilitative biofuel sector initiatives though biased on 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
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 percent to about 33 percent, by 2025. Bias on 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	Enabling environment for private investment thus application for Biofuel Sub-sector. Likewise additional associated Law such as 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 six regional communities: (i) the East African Community (EAC); (ii) the Nile Basin Initiative (NBI); (iii) the Economic Community of the Great Lakes Countries (CEPGL); (iv) the Common Market for Eastern and Southern Africa; (v) the Economic Community of Central African States (CEEAC), and (vi) 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.[168] 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.[169]

Additionally donor interest matters in energy sector and biofuel production in Burundi since 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.

[168] Nathan Associates Inc., *Burundi: Expanding External Trade And Investment* (USAID, 2015), accessed August 16, 2015, http://pdf.usaid.gov/pdf_docs/Pnadg055.pdf.
[169] *Strategy For The Development Of Regional Refineries* (East African Community, 2008), accessed August 23, 2015, http://www.eac.int/energy/index.php?option=com_docman&task=doc_download&gid=13&Itemid=70.

Overview Of Ethanol Production In Country

There is no current ethanol fuel production in Burundi, except artisanal processing of local alcoholic drinks for consumption from local crops such as sorghum.[170] 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 Agricultural Ecological Zones (AEZ) of 1 and 5 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.

Crop Production in 2006-2009[171]

Food crops (in millions of 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-tradtitional crops	-	246	763	727

The only sugar factory, La Société Sucrière du Moso (SOSUMO), in Burundi 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 at 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% of sugar and has a fibre of 12.5%. The company is aiming to:

[170] Espérance Habindayyi, 'Morphological Characterization Of Sorghum (Sorghum Bicolor) Diversity In Burundi' (CBM Master Theses Series, Swedish University of Agricultural Sciences, 2009).
[171] International Monetary Fund, *Burundi, Growth And Poverty Reduction Strategy Framework: Performance And Impact Assessment* (Government of Burundi, 2010), accessed September 24, 2015, https://www.imf.org/external/pubs/ft/scr/2011/cr1153.pdf pp.38.

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

There was feasibility study contracted by 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 22,000t to 35,000t of sugar per year with a production of ethanol of 1,500,000 liters per year.[172] However, these plans have yet to be implemented. The only alcohol and soft drink company is Brarudi Brewery. It is owned by the government (40%) and Heineken International Netherlands (60%) and could be source for waste for ethanol production.

Conclusions 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 urbanizing hubs, industries, transportation, fishing, commerce, agricultural activities, health, education, and tourism. This necessitates energy sector reforms in terms of refurbishment of infrastructure, improvement of efficiency, cost recovery mechanisms, diversification of energy sources, enabling of private sector investment, and energy resources studies for potential and feasibility mapping. Additionally, reduction of use of fossil fuels due to over 2000 km transport difficulty from the coast of Kenya and Tanzania is recommended by the EAC.[173]

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 1st and 2nd 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% of the workforce and do 70% of farm work. Yet women have few rights; under customary law, they are not allowed to own land or livestock.[174]

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.[175] Burundi is no exception and may be worse off in these

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[172] Godefroy Hakizimana, *Burundi Country Baseline Report And Workplan.*
[173] Ibid.
[174] Mark Curtis and David Adama, 'Walking The Talk: Why And How African Governments Should Transform Their Agricultural Spending Policy Breif'.
[175] B. Amigun, R. Sigamoney and H. von Blottnitz, 'Commercialization Of Biofuel Industry In Africa: A Review', *Renewable and Sustainable Energy REviews*, no. 12 (2008): 690-711.

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 offer opportunities for rural employment, alternative markets for agricultural commodities, and economic returns from ethanol industry in terms of profits.[176] 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 of 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 securing 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 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 USD 140 per year hampering investment capacity in biofuel production.

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

[176] B. Amigun and H. von Blottnitz, 'Operating Cost Analysis Of An Annexed Ethanol Distillery In A Rural, Landlocked African Country', *Environ. Prog. Sustainable Energy* 30, no. 3 (2010): 500-515.

D. Tanzania

Population and Social Profile

The total land area of mainland Tanzania is 883,343 km^2.[177] According to the 2012 census, the population of Tanzania is estimated to be 43.6 million people, of which 70.9% was considered rural.[178] Currently, the proportion of the country's urban population grows at a rate of approximately 5% per year. As with population growth, urbanization can have both positive and negative implications for human development. The average annual population growth rate (2002-2012) has been 2.7%.[179] 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. Female life expectancy at birth in 2012 is higher (63 years) than that of males (60 years).

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 economical priorities.

Economic Profile

Tanzania's economic is predominantly rural-based, with relatively low levels of manufacturing and value addition of the commodities produced. According to the Bank of Tanzania (BoT), the Gross Domestic Product (GDP) in 2013 grew by 7.0 percent in real terms compared with 6.9 percent in 2012.[180] GDP at constant prices amounted to TZS 20.5 trillion (13.04 billion USD) compared with TZS 19.2 trillion (12.2 billion USD) 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%), followed by agriculture (13.7%), communication (12.7%) and manufacturing (10.9%). In terms of share to GDP in 2013, agriculture, hunting, forestry, and fishing activities had the largest share of 22.2%, followed by trade and repairs 15.0%, and real estates and business services 10.2%. Annual headline inflation remained at single digit over the course of 2013/14, averaging at 6.3%.[181]

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

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

[178] National Bureau of Statistics, *Tanzania Census: 2012 Population And Housing Census General Report* (Dar es Salaam: Government of Tanzania, 2013).

[179] Ibid.

[180] Bank of Tanzania, *Annual Report 2013/14* (Dar es Salaam: Bank of Tanzania, 2014).

[181] Ibid.

(USD 651.9) in 2012.[182] Additionally, Tanzania is characterized by low levels of both HDI and national income. Tanzania's GNI per capita in 2013 was $1,702 (constant 2011 PPP$), compared to $2,126 which is the average for the least developed countries and $13,723 which is the average for the world.[183]

According to BoT, in 2013/14, the value of imported goods increased by 8.3 percent to USD 11,347.1 million from the amount recorded in 2012/13.[184] Import categories were capital, intermediate, and consumer goods. The value of goods exported was USD 5,619.1 million, being 4.1 percent higher than the 2012/2013. Composition of exported commodities was coffee (2.6%), Cotton (1.9%), Sisal (0.4%), tea (1.0%), tobacco (7.3%), cashew nuts (2.7%), cloves (1.2%), gold (33.9%), other minerals (2.7%), manufactured goods (26.5%) fish and fish products (3.4%), horticultural products (0.6%), and other export products (12.2%).

About 28.2% of Tanzanians are poor, and 9.7% are extremely poor.[185] 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% to 28.2% over a period of five years from 2007 to 2012[186].

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% of the total energy demand while petroleum and gas accounts for 8% and electricity is only 2%.[187]

According to the International Energy Agency (IEA), the domestic residential sector consumes about 73% of the total energy in all productive sectors of the economy (industry – 14.4%, agriculture – 4.2%, transport – 5.8%, other sectors-3.1%). This high residential proportion of the total energy depends on mainly the use of firewood and charcoal for cooking using rather inefficient stoves.[188]

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 demand for petroleum products is estimated to be over 1.8 million metric tons per year.[189] According to BoT, the country spends significant amount of foreign currency on oil

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182 *Sustaining Human Progress: Reducing Vulnerabilities And Building Resilience*, Human Development Report (New York: United Nations Development Programme, 2014), accessed July 25, 2015, http://hdr.undp.org/sites/default/files/hdr14-report-en-1.pdf.
183 Ibid.
184 Bank of Tanzania, *Annual Report 2013/14*.
185 *Sustaining Human Progress: Reducing Vulnerabilities And Building Resilience*.
186 Ibid.
187 Bank of Tanzania, *Economic Bulletin For Quarter Ending September 2013, Vol XLV, No. 3* (Dar es Salaam: Bank of Tanzania, 2013).
188 *Tracking Clean Energy Progress 2013* (International Energy Agency, 2013).
189 Ministry of Energy and Minerals, *Draft Energy Policy* (Dar es Salaam: Government of Tanzania, 2015).

imports. For example, between March 2014 and March 2015, fuel imports nationwide were 1,886.10 million USD.[190]

Also, the level of access to electricity in Tanzania is still low. As of May 2014, about 24 percent of the mainland Tanzanian population was connected with electricity services, of which 7 percent is in rural areas.[191] This means the vast majority of rural populations 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%.[192] The government plans to increase the connectivity level to 30 percent by 2015; 50 percent by 2025 and at least 75 percent by 2033.[193] 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.[194]

Nearly 95% of the population uses biomass in the form of firewood and charcoal as their primary fuel for cooking[195]. It is estimated that only 1.2 million households out of 9.359 million households are using improved cookstoves in Tanzania.[196] Poor households spend a considerable share of household resources (up to 35%) to meet their domestic energy needs through the use of biomass fuels.[197] 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.[198]
- 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 natural biomass resources available, 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 are attributable to unsustainable charcoal production.[199]

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

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190 Bank of Tanzania, *Economic Bulletin For The Quarter Ending March 2015, Vol. XLVIII, No. 1* (Dar es Salaam: Bank of Tanzania, 2015).
191 Ministry of Energy and Minerals, *Electricity Supply Industry Reform Strategy And Road Map 2014-2025* (Dar es Salaam: Government of Tanzania, 2014).
192 Ministry of Energy and Minerals, *Scaling Up Renewable Energy Program* (Dar es Salaam: Government of Tanzania, 2013).
193 Ibid.
194 Ibid.
195 National Bureau of Statistics, *Tanzania Census: 2012 Population And Housing Census General Report* (Dar es Salaam: Government of Tanzania, 2013).
196 *Country Action Plan For Clean Cookstoves And Fuels* (Dar es Salaam: SNV Tanzania, 2012).
197 *Household Energy Survey In The Lake Zone Region* (Dar es Salaam: SNV Tanzania, 2012).
198 Gwénaëlle Legros et al., *The Energy Access Situation In Developing Countries* (New York: UNDP, WHO, 2009), accessed September 22, 2015, http://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/Sustainable%20Energy/energy-access-situation-in-developing-countries.pdf.
199 *Enabling Reforms: A Stakeholder Based Analysis Of The Political Economy Of Tanzania'S Charcoal Sector And The Poverty And Social Impact Of Proposed Reforms.* (Washington DC: World Bank, 2010).

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; 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 on Fuels and Clean Cookstoves
According to the National Agriculture Survey (2012), the most prevalent source of energy for cooking is firewood, which was estimated at 94.5% of all rural agricultural households, followed by charcoal (3.9%), and crop residues (0.7%), electricity (0.3%), LPG (0.2%), kerosene (0.1%), solar (0.1%), biogas (0.1%) and dung (0.1%).[200]

It is estimated that about 8 million households in Tanzania cook with firewood and/or charcoal on traditional cookstoves.[201] In a 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 of the health risks of HAP in 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.[202] 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%; whereas in other urban centers adoption is about 20%; and less than 3% of households at national level are using improved cookstoves.[203]

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.[204] 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.

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

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[200] Ministry of Agriculture, Food Security, and Cooperatives, *National Sample Census Of Agriculture, Small Holder Agriculture Vol. II* (Dar es Salaam: Government of Tanzania, 2012).
[201] *Country Action Plan For Clean Cookstoves And Fuels.*
[202] Ministry of Energy and Minerals, *Status Of Energy In Rural Tanzania And Implications To Poverty Reduction* (Dar es Salaam: Government of Tanzania, 2006).
[203] *Tanzania Country Report And Implementation Workplan*, EAC Strategy to Scale-Up Access to Modern Energy Services (East African Community, 2008).
[204] Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division, *National Woodfuel Action Plan* (Dar es Salaam: Government of Tanzania, 2009).

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 centres 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% of rural households depend on firewood for cooking. In urban areas, less than 19% of households cook with firewood. In places with abundant firewood supply, firewood is collected free of charge. Time spent in collecting firewood ranges between 1 to 8 hours.[205] In areas with scarcity of firewood, rural people buy firewood. Three-stone fires dominate in the rural areas – made at no cost. The three-stone firewood stove is very inefficient (less than 10% efficiency) and wastes a lot of wood.[206] For general domestic use, per capita firewood consumption ranges between 1 to 1.5 m^3 per year. Therefore, for a household with five members, consumption is between 5 and 7.5 m^3 per year.[207] 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.[208]

Improved firewood stoves in rural areas have a significant role to play in terms of reducing HAP (approximately 40%), saving time, and reducing wood wastage (about 70 percent).[209] Field observations show that a typical locally manufactured household stove costs between TZS 1,000 (USD 0.5) to TZS 10,000 (USD 5). Imported improved firewood stoves costs around TZS 60,000 (USD 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% 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.[210] Charcoal and commercial fuel wood generated approximately TZS 1.6 trillion (approximately USD 1 billion) in revenues for actors along the chain.[211] Charcoal

[205] Ibid.
[206] Francis Songela, *Improved Stoves Promotion And Impacts* (Dar es Salaam: TaTEDO, 2001).
[207] Ministry of Natural Resources and Tourism, *Woodfuel Consumption In Selected Urban Areas Of Tanzania* (Dar es Salaam: Government of Tanzania, 2001).
[208] Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division, *National Woodfuel Action Plan*.
[209] F. Songela et al., *Indoor Air Pollution (IAP) Reduction Efforts In Tanzania -Some Lessons And Options From Tatedo Experience* (Dar es Salaam: TaTEDO, 2006).
[210] Ministry of Energy and Minerals, *Biomass Energy Strategy* (Dar es Salaam: Government of Tanzania, 2014).
[211] Ibid.

demand has nearly doubled over the past ten years.[212] 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[213]; this will significantly contribute to the loss of forests. A World Bank report on the charcoal situation in Tanzania informs that around 100,000-125,000 hectares of annual forest loss are attributable to unsustainable charcoal production – roughly about 0.3 – 0.4% of the total forest cover.[214] 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 urbanisation 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 in Tanzania 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 from 11 – 30 percent[215]; however in other studies, the efficiency of traditional kilns was reported to range between 10 – 20 percent[216]. Field tests by TaTEDO in the Coast region showed that traditional kilns produce between 1 – 1.5 bags[217] of charcoal for each cubic metre of wood. The carbonization process for the traditional kiln takes between 7 – 14 days. In addition, the charcoal-harvesting guide issued by the Forestry and Beekeeping Division in 2007 directs all charcoal 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%. 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 30-40%.[218] These stoves are up to 35% more expensive than traditional stoves. According to MNRT, a typical household consumes approximately 1 ton of charcoal per year when using a traditional stove, equivalent to TZS 125,000[219] (USD 62.5) per month.[220] This falls to 0.4 tonne when using an efficient charcoal stove, TZS 50,000 (USD 25) per month.

An Enviroft charcoal stove (CH5200 model) costs more than other improved charcoal cookstoves, TZS 75,000 (USD 35), but saves more. CARE and ARTI have distributed more than 800 firewood stoves (M500 model) in rural and peri-urban areas.

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[212] National Bureau of Statistics, *Tanzania Census: 2012 Population And Housing Census General Report*.
[213] Ministry of Energy and Minerals, *Biomass Energy Strategy*.
[214] *Enabling Reforms: A Stakeholder Based Analysis Of The Political Economy Of Tanzania'S Charcoal Sector And The Poverty And Social Impact Of Proposed Reforms.*
[215] *Charcoal Potential In Southern Africa*, EU INCO_DEV Project (European Union, 2002).
[216] *Annual Report 2002/2003* (Dar es Salaam: TaTEDO, 2003).
[217] Weight of a bag of charcoal was 28kg
[218] Francis Songela, *Improved Stoves Promotion and Impacts*.
[219] Current price of a kilo of charcoal in Dar es Salaam is TZS. 1500.
[220] Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division, *National Woodfuel Action Plan*.

Forest Wastes

The major source of forest residues is from wood harvesting and processing industries. In general, the main source of forest residues is from wood industry activities and 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 normally 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 exception of a small percentage 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.[221]

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 use 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).[222]

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. 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 mills (wastes include rice husk, coffee husks, bagasse, coconut husks, coconut shells, groundnuts and cashew nut shells, and corn cobs). The main advantages of agro-processing residues is on their uniform physical-chemical properties (particle size, calorific value, moisture, and ash contents), and 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 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 amounts of residues generated from major crops in Tanzania to be about 15 million tons per year. Since that time, no other estimates have been published. Since that time no other estimates have been published. However, crop-residue ratios can be used to estimate current amounts of residues generated.

There 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

[221] Personal communication between Biomass Unit Lead person and Francis Songela, August 2015.
[222] Personal communication between Senior Electrical Engineer and Francis Songela, August 2015.

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 the factories operate below their capacities due to low demand caused by low awareness of this energy type by most of the Tanzanians.[223] Field observations revealed that a factory owned by ARTI Energy in the Coast region produce 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 (USD 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 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% of national electricity generation.[224]

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.[225] Mkonge Energy System, a subsidiary company of Katani Limited[226] 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.[227] 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 utilising of the total plant instead of the current 2%. The 98% biomass – the so-called "waste" hitherto thrown away is now known to be more valuable than the 2% if 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 ton of animal waste per year mainly from cattle, goats and sheep.[228] 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 of the dissemination of 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.[229] Two independent feasibility studies were carried out in 2007, and both indicated that there was a potential

[223] Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division, *National Woodfuel Action Plan*.

[224] Fred Gwang'ombe, *Renewable Energy Technologies In Tanzania: Biomass Based Cogeneration* (African Energy Policy Research Network, 2004).

[225] Ministry of Energy and Minerals, *National Energy Policy* (Dar es Salaam: Government of Tanzania, 2003).

[226] The Company owns three sisal estates in Tanga region.

[227] Hale Sisal Estate in Korogwe District, Tanga Region.

[228] Ministry of Energy and Minerals, *National Energy Policy*.

[229] *Narration For Tanzania Domestic Biogas Programme* (Dar es Salaam: SNV Tanzania, 2009).

market for around 165,000 bio-digesters in Tanzania.[230] 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.[231]

Electricity

Electricity is a source of power for lighting in urban areas and is also used as energy for cooking by upper class households.[232] According to NBS, by 2012, only 0.4% of households in Tanzania were using electricity for cooking (0.2% in rural and 1% in urban). The cost of electricity for this customer category is TZS 306 (USD 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 (USD 0.92), monthly consumption of electricity for cooking would approximate TZS 55,080 (USD 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.[233]

Kerosene

Kerosene use is 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 percent of households were using kerosene as domestic energy for cooking. By 2012, about 2.1% of households (7% of urban and 0.4% of rural) were cooking using kerosene.[234]Decreased use of kerosene for cooking has been influenced primarily by price increases.[235] 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 liter[236].

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 all over 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,

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[230] Fred Marree and Marloes Nijboer, 'Biogas: Viable Or Not? An Explorative Study To The Feasibility Of Introducing Biogas And The Impact On Hhs' Livelihoods In The Northern Regions Of Tanzania' (Master, University of Utrecht, 2007).

[231] Tanzania Domestic Biogas Programme, 'Monthly Production Figures', accessed July 28, 2015, http://www.biogas-tanzania.org/tdbp/about/category/archievements.

[232] Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division, *National Woodfuel Action Plan*.

[233] Ibid.

[234] National Bureau of Statistics, *Tanzania Census: 2012 Population And Housing Census General Report*.

[235] Ministry of Energy and Minerals, *Draft Energy Policy* (Dar es Salaam: Government of Tanzania, 2015).

[236] Revenue Authority, *The Finance Act* (Government of Tanzania, 2011).

but in 2012, the MNRT estimated that household expenditure on kerosene for cooking is about TZS 20,000 per month.[237]

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 exonerating LPG cylinders and gas from all forms of taxation.[238] However, all taxes remain on LPG cookers and other accessories. Tax exemption decision has accelerated the penetration of LPG market.

LPG is sold retail in 6, 15, and 38kg bottles, 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.[239] However, according to Alternative Energy, a LPG retailing company, the market grew by 30-40 percent for the last three years.[240] 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 6kg cylinder plus stove and other necessary accessories suited for an average household costs approximately TZS 150,000 (USD 75), making start-up costs for LPG substantially higher than those for charcoal.[241] However, monthly refills of the cylinder cost TZS 28,000 (USD 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 operation in Tanzania. 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 (USD 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 (USD 27) per stove. SAFI is currently getting ethanol

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[237] Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division, *National Woodfuel Action Plan.*

[238] 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 subsidised 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.

[239] National Bureau of Statistics, *Tanzania Census: 2012 Population And Housing Census General Report*.

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

[241] Ministry of Natural Resources and Tourism, Forestry and Beekeeping Division, *National Woodfuel Action Plan.*

from Kilombero Sugar and stores it in two tanks (10,000 liters each). The company does the packaging and denaturing of the ethanol before it is retailed. Ethanol is retailed in one liter bottles, which cost about TZS 2,350 (USD 1.1). According to SAFI, one liter can last for 1.5 days, making the monthly fuel costs less than the average amount spent on charcoal by a typical family.

Between 2014 – 2015, UNIDO commissioned Project Gaia to implement an ethanol cooking fuel pilot project in Zanzibar.[242] 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 2-3 liters of ethanol fuel each week at TZS 1,600 per liter. 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 additional, 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 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 a disagreeable 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 (USD17.5) and a typical household spends TZS 45,000 (USD 22.5) on ethanol gel per month.

Local NGOs such as TaTEDO, Jatropha Tanzania, and KAKUTE have been the first to promote biodiesel straight 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 consumer expectations.

Liquefied Natural Gas (LNG)

LNG was first found in Tanzania in the 1970’s. Currently the two areas in the southern part of the country (Mnazi Bay and Songo Songo) have the capacity for two million standard cubic feet per day and 100 million standard cubic feet per day respectively.[243] Current main off-takers are Songas power plant, TANESCO, Twiga Cement Company and other small customers.

LNG is the liquid form of the natural gas that can be used in homes for heating and cooking. As local content strategy to 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 into significant savings on utilization of forest resources for cooking energy.

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[242] Project Gaia, *Zanzibar Pilot Study Final Report* (United Nations Industrial Development Organization, 2015).
[243] Ministry of Energy and Minerals, *Draft Energy Policy*.

Coal

Tanzania has significant quantities of coal. The MEM revised its estimates of coal reserves from 1.5 billion to 5 billion tons in July 2013.[244] 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 the lack of analysis related to health and cooking habits. The Ministry of Energy and Minerals and Tanzania Commission for Science and Technology are exploring coal as a household charcoal substitute and investigating health impacts related to coal usage.

Solar Energy

Solar cookers are extremely limiting 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. One company, 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 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[245]

- *ARTI Energy Limited:* ARTI Energy Limited *(*www.arti-africa.org*)* is a commercial enterprise established in 2011 with the 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 have been sold across Tanzania. The retail cost of the stoves is between TZS 65,000 to 85,000, energy efficiency level is 60% and saves energy up to 3 times less compared to the traditional stoves. (example a bag of charcoal which will be used for 3weeks on a traditional stove will be used for 3 months on the improved stove).
- *Biomass Briquettes*- ARTI has established a biomass briquettes small-scale factory in the Coast region, about 65km from Dar es Salaam. The factory produces up to 5tonnes a day. Main customers are both domestic institutions/industries.

CARE's Clean Energy Programme[246]

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

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[244] Ministry of Energy and Minerals, *Draft Energy Policy*.
[245] Personal communication between Sales Manager, ARTI Energy and Francis Songela, July, 2015.
[246] Personal communications between Programme Manager, CARE, and Francis Songela, July, 2015.

designed as a supply enhancement model where women at the bottom of the pyramid become entrepreneurs for solar lanterns and clean cookstoves by participating in a market driven process through linkage with respected global/local manufacturers or suppliers of clean energy products.

In Tanzania, CARE implements wPOWER project in 19 districts of the following regions: Dar es Salaam, Tanga, Arusha, Manyara, Morogoro, Mwanza, Shinyanga. wPOWER trained more than 200 entrepreneurs who sold more than 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[247]

The overall objective of the TICS Programme 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.

Tanzania Domestic Biogas Programme[248] (TDBP)

The Centre for Agricultural Mechanisation and Rural Technology (CAMARTEC) in Arusha is a parastatal 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 Organisation (SNV) and MEM in implementing the Tanzania 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. The second phase is targeting 20,700 plants

Country Action Plan for Clean Cookstoves and Fuels[249]

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% in half of the fuelwood consuming households and all the institutions by 2020.

Key interventions in the Country Action Plan include:

- Supporting and lobbying 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.

[247] Personal communication between Renewable Energy Advisor, SNV, and Francis Songela, July 2015.
[248] Tanzania Domestic Biogas Programme, 'Monthly Production Figures'.
[249] *Country Action Plan For Clean Cookstoves And Fuels*.

- Establishing a 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 ISO standard.
- 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 with a focus to identify 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 awareness rising.
- 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 to action. CCFAT calls for the financial support from the Government of Tanzania and other development partners.

Tanzania Traditional Energy Development Organization[250] (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[251]

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 use pellets as fuel, which are made from grounded agricultural waste with jatropha cake binder, whereas Jiko Safi use jatropha whole seeds as fuel.

[250] *Annual Report 2002/2003*.

[251] Oliver Johnson et al., *From Theory To Practice Of Change: Lessons From SNV'S Improved Cookstoves And Fuel Projects In Cambodia, Kenya, Nepal And Rwanda* (Stockholm Environment Institute, 2015), accessed September 22, 2015, http://www.sei-international.org/mediamanager/documents/Publications/SEI-WP-2015-09-SNV-cookstove-market-transformation.pdf.

Government and Public Institutions Initiatives

Rural Energy Agency[252] (REA)
The Rural Energy Agency was established in 2005 as an autonomous agency subordinated to the MEM. REA funds a range of rural energy activities. The fund 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)
TPDC is a public company formed in 1969, mandated to spearhead, facilitate, and undertake oil exploration and development in Tanzania. In 2014[253], TPDC in collaboration with BQ Constructors Limited launched a pilot project of gas distribution services for domestic and industrial use in Dar es Salaam. So far, distribution pipelines have been connected to 57 initial homes in Mikocheni area. 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 more cheaply. TPDC has engaged Exim Bank of India to fund completion of the project that will make all city residents enjoy cheap natural gas. About $8 million (over Sh12.8 billion) was needed to finance the project to supply gas to residents of Sinza, Mikocheni, University of Dar es Salaam, Ardhi University, Mbezi Beach, and Mikocheni Coca-Cola.

Tanzania Commission for Science and Technology[254] (COSTECH)

COSTECH is a public institution established in 1988 charged with the task of advising the government on the matters pertaining to scientific research and innovations, formulation of policy briefs on research and development, and coordination of research, and dissemination of scientific information.

In 2013, COSETCH and Tanzania Renewable Energy Association (TAREA) signed a three-year Memorandum of Understanding with 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[255] (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

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[252] Ministry of Energy and Minerals, *Biomass Energy Strategy*.
[253] Saumu Mwalimu, '57 Homes Connected To Gas Pipeline', *The Citizen*, 2015, accessed September 24, 2015, http://www.thecitizen.co.tz/News/57-homes-connected-to-gas-pipeline/-/1840392/2398988/-/60mb8d/-/index.html.
[254] TAREA Events, 'National Renewable Energy Day 2015', last modified 2015, accessed September 24, 2015, https://sites.google.com/site/tareatzevents/red2015.
[255] Personal communication between Assistant Commissioner for Renewable Energy, MEM, and Francis Songela, July 2015.

wider adoption of Rural Energy Technologies (RETs). Clean cookstoves and fuels is one of the key interventions of the programme.

Government Regulations for Biofuels

Petroleum Act of 2008[256]

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. 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[257].

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 contract agreements and encourage them to be more involved in the value adding activities.
- To ensure that biofuels production has a positive impact on food production, all investors/developers shall set up to 5% (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.

[256] *Petroleum Act* (Dar es Salaam: Government of Tanzania, 2008).
[257] Ministry of Energy and Minerals, *Guidelines For Sustainable Liquid Biofuel Development In Tanzania* (Dar es Salaam: Government of Tanzania, 2010).

Other Relevant Policies

Energy Policy[258]
The new Energy Policy was drafted in 2014. The policy promotes fuel switching from wood fuel 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[259] (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, August 5, 2015[260], EWURA published retail prices for diesel, kerosene and petrol. It indicates that retail prices for diesel and kerosene have decreased by TZS 18/liter or 0.86% and TZS 29/Liter or 1.47% respectively, while petrol price has increased by TZS 92/liter or 4.19%. Similarly compared to the last month publications, wholesale prices for diesel and kerosene have decreased by TZS 17.50 /liter or 0.90%, and TZS 29.27/liter or 1.55% respectively, while petrol price has increased by TZS 92.07/liter or 4.40%. These changes have been caused by changes in prices of petroleum products in the world market.

Tanzania Biomass Energy Strategy[261] (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[262] (1991) and amending Cereals and Other Products Act[263](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 acts establishing and regulating the commodity specific board. These include cashew nuts, coffee, cotton, pytherym, sugar, tobacco, tea, and sisal. The original acts

[258] Ministry of Energy and Minerals, *Draft Energy Policy*.
[259] *The Energy And Water Utilities Regulatory Authority Act Cap 414* (Dar es Salaam: Government of Tanzania, 2001).
[260] Energy and Water Utilities Regulatory Authority, 'Cap Prices For Petroleum Products With Effect From 5Th August 2015', last modified 2015, accessed September 24, 2015, http://www.ewura.go.tz/newsite/index.php/fuel-prices/257-cap-prices-for-petroleum-products-with-effect-from-5th-august-201.
[261] Ministry of Energy and Minerals, *Biomass Energy Strategy*.
[262] *The Food Security Act* (Dar es Salaam: Government of Tanzania, 1991).
[263] *Cereals And Other Products Act* (Dar es Salaam: Government of Tanzania, 2009).

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[264] (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[265] (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 be obtain a license from TFRA. Additional supportive legislation was developed as the Public–Private Partnership Act of 2010[266], 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.

Land Act

The Land Act came into force in 2001, and it consists of The Land Act No. 4 of 1999[267], and The Village Land Act No. 5 of 1992[268]. 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% 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 Acts place 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.

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[264] *The Seed Act* (Dar es Salaam: Government of Tanzania, 2003).
[265] *The Fertilizer Act* (Dar es Salaam: Government of Tanzania, 2009).
[266] *Public-Private Partnership Act of 2010* (Dar es Salaam: Government of Tanzania, 2010).
[267] *The Land Act No. 4* (Dar es Salaam: Government of Tanzania, 1999).
[268] *The Village Land Act No. 5* (Dar es Salaam: Government of Tanzania, 1992).

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 percent, and since then, the market has subsequently stabilized.[269] Additionally, in 2014, the government decided to subsidize electricity connection charges to TANESCO's customers.[270] For example, connection charges for a customer who is 30m away from an electric pole dropped from TZS 512,000 to 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.[271]

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[272]. 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.

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 nuts. This initial targeting has since been expanded to cover sorghum, sunflower, cotton, cashew nuts, coffee, and tea. 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.[273]

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[269] Ministry of Natural Resources and Tourism Forestry and Beekeeping Division, *National Woodfuel Action Plan*.

[270] *Personal communications between Senior Manager Distribution, TANESCO, and Francis Songela, August 2015*.

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

[272] Mustafa Haidi Mkulo, 'The Estimates Of Government Revenue And Expenditure For The Fiscal Year 2011/2012', 2011.

[273] *Liquid Biofuels For Transportation In Tanzania: Potential And Implications For Sustainable Agriculture And Energy In The 21St Century* (German Technical Cooperation, 2005).

According to GTZ, potential ethanol production from these crops is 4000-8000s/Ha (sugarcane), 3000-6000 liters/Ha (sweet sorghum) and 1750-5400 liters/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 based company, is investing over USD 500 million (TZS 800 billion) into a sugarcane plantation and a factory producing sugar in Bagamoyo, approximately 60km 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% 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 was 62,569Ha but harvested area was 44,194 Ha of which 35% 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.[274]
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 smallholder farmers and 10 commercial farmers, and offer farming contracts to produce and sell their cassava to the factory. The factory is expected to be operational early 2016.
3. *Sweet Sorghum* is grown almost entirely by small-scale farmers on small plots of land between 1.5 - 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, British-based energy firm, CAMS Group, had a plan to produce 240 million liters 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.

[274] Tanzanian Sugar Board, 'Production Data For 2011/12', accessed July 29, 2015, http://www.sbt.go.tz/index.php/production-datas.

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 liters per year.[275] 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 liters of ethanol per year. Most of this ethanol 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 liters[276] of ethanol from Kilombero Sugar. Based on the current consumption trend, SAFI expects that stock will last until September 2015. Ethanol is taxed like any other alcoholic beverages. The Tanzania Revenue Authority has imposed the following taxes on alcoholic beverages – VAT (18%), import, excise, and import duties. For example excise duties for wine is TZS 820/liter and spirit is TZS 1,216 per liter.

Kilimanjaro Biochem Ltd has set-up a bioethanol plant with 22,000 liters per day capacity 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%) and technical grade alcohol (94%) for medicinal use and fuel.

Also, EcoEnergy Africa AB’s investment into sugar factory intends to produce 10 million liters 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:

- *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.

- *Availability 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.

- *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

[275] *Liquid Biofuels For Transportation In Tanzania: Potential And Implications For Sustainable Agriculture And Energy In The 21St Century*.
[276] Wholesale price at Kilombero Sugar is TZS 1970/liter (USD 0.99/liter). SAFI is retailing in 1 liter bottle at TZS 2350 (USD 1.1)

development, a good number of end-consumers have low purchasing power, and most of them have limited access to credit facilities.

- *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.[277] 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 in the 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% 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.[278]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.[279]

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

[278] *Gender And Clean Energy Profiling Study* (CARE International, 2014).
[279] Ibid.

exempted LPG from all from of taxes. One of the impacts of this exemption was market growth for LPG. In addition, solar energy products receive exoneration 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

E. Kenya

Country And Demographic Information
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: *Bantu* (Kikuyu, Meru, Gusii, Embu, Akamba, Lyhya, Swahili and Mijikenka), *Nilotic* (Luo, Masai, Turkana, Samburu, and the Kalenjin) and *Cushite* (Somali, El Molo, Boran, Burji, Dassenich, Gabbra, Orma, Sakuye, Boni, Wata, Yaaka, Daholo, Rendille, and Galla).[280]

No ethnic group constitutes a majority of Kenya's citizens; the largest ethnic group, the Kikuyu, make up only 20% of the nation's total population, The five largest - Kikuyu, Luo, Luhya, Kamba and Kalenjin; account for 70%. 97.58% of Kenya's citizens are affiliated with its 32 major indigenous groups. Of these, the Kikuyu, who were most actively involved in the independence and Mau Mau movements, are disproportionately represented in public life, government, business and the professions. The Luo people are mainly academics, traders and artisans[281]. The Kamba are well-represented in defense and law enforcement. The Kalenjin are mainly farmers. While a recognized asset, Kenya's ethnic diversity has also led to disputes. Interethnic rivalries and resentment over Kikuyu dominance in politics and commerce have hindered national integration.

The principal non-indigenous ethnic minorities are the Arabs and Asians. Almost all the Kenyan Arabs live in Coast Province, more than half of them in Mombasa. Over 99% of the Arab residents have Kenyan citizenship, speak Swahili rather than Arabic, and generally see themselves as Africans.

The total number of households in Kenya was reported to be 8,767,954 during the 2009 national census. Kenya has a total population of 44,354,000 persons, of which 42% are under the age of 15 while 4% are above the age of 60 years old. The median age is 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.[282]

25% of the total population of Kenya lives in urban areas; in the region as a whole an average of 38% of the population lives in urban areas, and globally the average is 50%, though the county urbanization rate stands at 32.3%. The total national urban population stood at 10,990,850 in 2013[283]; the rural population (2010) was 33,979,200. The population growth rate is 2.462%. Average household size is five persons, and the literacy rate is 87% (among females the literacy rate in 2002 was 82%) and the average life expectancy is 55 years. The population below the poverty line (2009) was 50%.[284]

The informal sector had the largest share of employment accounting for 82.7%of the total jobs. Public administration, compulsory social security, and education sectors were the largest employers in the public sector. The Kenyan economy is primarily agriculture based,

[280] George Kurian, *The Encyclopedia Of The Third World Volume III* (New York: Facts on File, 1987) pp. 970.
[281] Ibid.
[282] World Health Organization, 'Global Health Observatory (GHO) Data', last modified 2015, accessed August 22, 2015, http://www.who.int/gho/countries/ken/country_profiles/en/.
[283] Index Mundi, 'Kenya - Urban Population', accessed August 22, 2015, http://www.indexmundi.com/facts/kenya/urban-population.
[284] World Health Organization, 'Global Health Observatory (GHO) Data'.

with farming and fishing contributing 30% of the total GDP for 2014[285]. Other significant GDP contributors are manufacturing whose share edged downwards to 10% from 10.7% 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. However, in 2014, the agricultural sector recorded mixed performance mainly attributable to erratic rains with some regions experiencing depressed rainfall. The lower levels of rainfall resulted in a decrease in production for some crops as well as decreased pasture regeneration for livestock. The country experienced depressed rainfall during first quarter of 2015 while long-range weather forecasts point to a possibility of insufficient long rains in parts of the country later in the year as well. Performance of the agriculture sector is therefore likely to remain close to the 2014 level due to its over-reliance on rain-fed water.

Socioeconomic Indicators

Kenya's economy is estimated to have expanded by 5.3% in 2014, compared to a growth of 5.7% in 2013. From the demand side, government and private final consumption increased by 2.7% and 5.5%, respectively[286].

Key Economic Indicators: GDP (2010) was $31,408,632,915; GDP Per Capita (PPP) (2010) was $775; GDP Growth Rate (2010) was 5.3%; Inflation Rate (2011 est.) 11%; Unemployment (2008 est.) 40%; Household income by percentage share – lowest 10% earned just 1.8% while the household income by percentage share – highest 10% earned 37.8%.

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% in exports of goods and services.

From the supply side, the major drivers of the economy were agriculture, forestry and fishing, construction, wholesale and retail trade, education, and finance and insurance. However, accommodation and food services (hotels and restaurants) sector contracted for the second year in a row.

Gender Issues: Although Kenya is traditionally a patriarchal society, women are increasingly taking on more empowered roles and gender mainstreaming initiatives are taking place. However barriers to equality still exist especially within rural areas.

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% of the agriculture labor force. They are also involved in the informal sector and make up almost ½ of Micro, Small, and Medium Enterprises (MSMEs). Men are dominant in the formal and modern sector and 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

[285] Kenya National Bureau of Statistics, *Economic Survey* (Nairobi: Government of Kenya, 2015).
[286] Ibid.

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% 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% of households are male headed and 29% female headed.[287] 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 areasthat are neither cities nor municipalities nor town councils. On average farm workers have lower education and income than non-farm workers.
The minimum wages are paid as follows;

i. KES 97.90 per hour ($0.99 USD); KES 527.10 ($5.38 USD) per day and KES 10,954.70 ($111.78 USD) per month for cities;
ii. KES 89.50 ($0.92 USD) per hour; KES 484.30 ($4.94 USD) per day and KES 10,107.10 ($103.13 USD) per month for municipalities;
iii. KES 54.70 ($0.56 USD) per hour; KES 296.20 ($3.02 USD) per day and KES 5,844.20 ($59.63 USD) 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;

i. KES 228.30 ($2.33 USD) per day and KES 5,436.90 ($55.49 USD) per month for unskilled workers;

[287] Ministry of Planning and National Development, *Kenya Integrated Household Budget Survey (KIHBS) 2005/06* (Government of Kenya, 2005).

ii. Between KES 236.30 ($2.41 USD) and KES 337.70 ($3.45 USD) per day for the lower cadres of the semi-skilled to skilled cadres, and a monthly wage of between KES 6,278.80 ($66.11 USD) for stockmen, herdsmen, and watchmen, and KES 7,966.80 ($81.30 USD) 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% of the land in Kenya is considered arable.[288,289]

World Bank Indicators - Kenya -Land Use[290]	
Agricultural land (sq. km) in Kenya	266,710.0
Agricultural land (% of land area) in Kenya	46.9
Arable land (hectares) in Kenya	4,891,000.0
Arable land (hectares per person) in Kenya	0.2
Arable land (% of land area) in Kenya	8.6
Permanent cropland (% of land area) in Kenya	0.8
Forest area (sq. km) in Kenya	35,820.0
Forest area (% of land area) in Kenya	6.3

Key Population Health Indicators

Malaria and pneumonia continued to be the leading causes of death each accounting for 11.6% and 10.9% 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% of the total in 2014.[291]

Household Air Pollution (HAP) Impact in Kenya[292]

Group	Numbers Exposed
1. Households using traditional open fires in built kitchens	9.9 million
2. Female cooks	2.48 million

[288] World Bank Data, 'Arable Land (% Of Land Area)', last modified 2015, accessed August 22, 2015, http://data.worldbank.org/indicator/AG.LND.ARBL.ZS.

[289] 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.

[290] Trading Economics, 'Agricultural Land (Sq. Km) In Kenya', last modified 2015, accessed August 22, 2015, http://www.tradingeconomics.com/kenya/agricultural-land-sq-km-wb-data.html.

[291] Ibid.

[292] Global Village Energy Partnership International, *Kenya Market Segmentation Study* (Global Alliance for Clean Cookstoves, 2012), accessed August 22, 2015, http://www.gvepinternational.org/sites/default/files/resources/kenya-consumer-segmentation.pptx.

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

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 13-19 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.[293]

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% of children with ARI symptoms are taken to a health center, yet they are the second largest cause of death. 26% 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% of children under age five show symptoms of ARI at any given time.

Baseline Energy Information

19.2% of the Kenyan population has access to grid electricity, compared to 100% in the USA[294]. Overall, 68% of all energy needs in Kenya are met by traditional biomass, comprising mainly woodfuel and charcoal. The balance of 32% is met by fossil fuels (crude oil, liquefied petroleum gas), geothermal power, flowing water (hydropower), wind, and solar radiation.[295]

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% of total consumption (rural—87.5%; urban—10%)[296]. The total sustainable biomass supply from all sources is estimated at 15 million tons. Firewood comes from three main areas: rangelands

[293] Ibid.

[294] World Bank, 'Kenya Data On Readiness For Investment In Sustainable Energy', last modified 2015, accessed August 22, 2015, http://rise.worldbank.org/data/exploreeconomies/kenya/2014.

[295] Ashington Ngigi, *Kenya Country Baseline Report And Workplan*, EAC Strategy to Scale-Up Access to Modern Energy Services (Nairobi: East African Community, 2015), accessed August 21, 2015, http://www.eac.int/energy/index.php?option=com_docman&task=doc_download&gid=64&Itemid=70.

[296] Kenya National Bureau of Statistics, *Economic Survey* (Nairobi: Government of Kenya, 2015).

(25%), government forests (28%), and small farmlands (47%). 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% 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% to 9,138.7 GWh in 2014. Hydro and geothermal power accounted for the bulk of power with a total share of 71.0% during the period. Domestic demand for electricity registered a growth of 3.8% to 7,768.6 GWh in 2014 from 6,928.1 GWh in 2013.[297] Renewable electricity sources account for 69.5% of the total electricity output, compared to just 10.1% in the USA.

The sale of petroleum fuels by consumer category between 2010-2014 was dominated by road transport (2,791.0 K tons and 71%), aviation (530.4 Ktons and 13%), industrial, commercial and others (451.2 Ktons and 11%), power generation (98.9 Ktons and 2%) and agriculture (36.4 Ktons and 1%)[298].

Main Energy Sectors: Households, Business And Commercial, Industrial, Government

The electricity sector grew by 6.8% compared to a growth of 9.8% in 2013. The performance was determined by a number of factors among them: suppressed long rains that led to a contraction of 19.5% in hydro generation. On the contrary, there was an increase of 63.8% in geothermal power generation, primarily due to expanded installed capacity. In addition, thermal electricity production increased significantly by 19.6% during the review period. This culminated in an overall increase of 8.2% in electricity generation in 2014 compared to an increase of 7.6% 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% 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 average, electricity prices might fall slightly in 2015 due to increased 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 will be undertaken. Peak electricity demand is expected to rise from 1,350 MW in 2013, to 3,400 MW by 2015 and 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 opportunity for bioenergy to contribute significantly towards meeting this demand. According to the Ministry of Energy Survey

[297] Ibid.
[298] Ibid.

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.[299] 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% 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% of that community have 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 have been recent increase of geothermal generated electricity in Kenya, the cost of electricity is yet to reduce to the extent that mirrors the recent developments. This is due to the fact that 40% of the cost of one unit of electricity is in the form of taxes and to not form part of the production costs. There are myriad taxes levied on the electricity, as follows:

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

[299] Patrick Magenya, *Opportunity For Bioenergy Solutions In The Kenyan Sugar Industry* (Nairobi: GIZ, 2014), accessed September 22, 2015, https://www.giz.de/fachexpertise/downloads/2014-de-pep-informationsveranstaltung-bio-kenia-mugenya.pdf.

		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%.[300] The units for retailing fuels such as charcoal have been further reduced, such that there are intermediary units between the 30 to 40 kg sack and the 2 kg tin, with options for troughs at 10 kgs, half sacks at 25 kgs and larger 5 kgs tins. The cost per unit falls as the units increase in weight, such that the 2 kg unit is $0.5 USD while the sack is $10 USD but for which only 75% 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 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% of rural households and 6.4% 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 centers and is subject to seasonal fluctuations. Access to modern fuels in Kenya is higher than in other parts of East Africa especially in urban areas where 58.4% 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 rises 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

[300] 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.

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 $2 USD to $12 USD, depending on size. Most of the brands available are imported from China and India, though there are a few locally manufactured brands.

Fuel cost per week using traditional cooking methods[301]

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

Fuelwood

Nearly 400,000 households relied on fuelwood for lighting as of 2009.[302] Apart from households, there are many 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% 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.[303]

These examples show that it is time to acknowledge the important role that firewood plays in meeting energy needs in Kenya, and not simply view it in terms of negative environmental impacts. Indeed, shifting from firewood to charcoal or kerosene does not automatically lead to positive impacts as historically presumed. Recent studies and press show 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, prunings, 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.

[301] Global Village Energy Partnership International, *Kenya Market Assessment: Sector Mapping*.
[302] Kenya Open Data, 'Main Lighting Energy Sources Averaged To Districts In 2009 | Open Data Portal', last modified 2015, accessed August 22, 2015, https://www.opendata.go.ke/Distribution-and-Consumption/Main-Lighting-Energy-Sources-averaged-to-Districts/u77w-ifgt.
[303] *Sustainable Firewood Access And Utilization: Achieving Cross Sectoral Integration In Kenya* (Stockholm Environmental Institute, 2014), accessed September 22, 2015, http://www.sei-international.org/mediamanager/documents/Publications/ICRAF-SEI-2014-techbrief-Sustainable-firewood.pdf.

With a current enrollment rate of about 1.5 million, the Homegrown 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 kgs 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.[304] 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 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 4 times more expensive than buying it in bulk.

Cost of fuel in Kisumu market, based on Vincent Okello's primary research

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

Charcoal is used by 82% of urban and 34% 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.[305]

Electricity

1,989,740 households were reported as having electricity during the 2009 census, which was 22.7% of the total national number of households[306].

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[304]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

[305]Practical Action Consulting, *Small-Scale Bioenergy Initiatives: Brief Description And Preliminary Lessons On Livelihood Impacts From Case Studies In Asia, Latin America And Africa* (Rome: Food and Agriculture Organisation of the United Nations (FAO) and Policy Innovation Systems for Clean Energy Security (PISCES), 2009), accessed September 22, 2015, http://ftp://ftp.fao.org/docrep/fao/011/aj991e/aj991e.pdf.

[306] Kenya Open Data, 'Main Lighting Energy Sources Averaged To Districts In 2009.

Electricity contributes only 9% of the total energy needs in Kenya, after biomass (68%) and petroleum (22%).[307] It is costly in Kenya due to the high costs of generation, currently estimated at $11.30 USD. Commercial/industrial tariff is at $0.14 USD and domestic tariff is at $0.20 USD. 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 National Census of 2009, 2,670,387 (30.5%) and 3,373,126 (38.5%) 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 a poor quality light when used in a lantern, causes frequent accidents through explosions after gas buildup 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 households goods in homes that use it.
Kerosene is also a lucrative retail trade good, and its highly developed supply chain means that the liter that is purchased for just below $0.65 USD at the pump, ends up costing double the amount by the time it is distributed in smaller quantities of 0.2 liters among poor households. Kenya does not subsidize kerosene, but removed the value added tax (VAT) of 16% from the pump prices in May 2011. Kerosene is often regarded as a “poor man’s fuel” and is used by approximately 92% of all households (rural, 94%; urban, 89%).[308]

Liquid Petroleum Gas (LPG)

Kenya consumes about 2.1 kg per capita of LPG. LPG demand 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 more costly, retailed in bottles of 6 kgs, 12 kgs, and 13kgs for domestic use, at KES 1300 and 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% of households) and 0.1 million rural households (1% of households) at an average price of $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 of as little as 50 KES ($0.60 USD). 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 are been trialed in the LPG sector to target low income households by reducing the upfront cost of LPG hardware and refilling costs.

[307] Ibid.
[308] Global Village Energy Partnership International, *Kenya Market Assessment: Sector Mapping*.

Valve incompatibility across gas bottles from different retailers locked in customers to specific brands, but once the Kenyan government gazetted requirements 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 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.[309] 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."[310]

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[311]. 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.[312]

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 Labeling 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).

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309 *Energy Act* (Nairobi: Government of Kenya, 2006).
310 Kate Langford, 'What Really Happened With Jatropha In Kenya', *Agroforestry World Blog*, last modified 2015, accessed September 25, 2015, http://blog.worldagroforestry.org/index.php/2014/03/31/what-really-happened-with-jatropha-in-kenya/.
311 UNDP in Kenya, 'Piloting Bioethanol As An Alternative Cooking Fuel In Western Kenya', accessed September 22, 2015, http://www.ke.undp.org/content/kenya/en/home/operations/projects/environment_and_energy/bioethanol.html#.
312 Safi International, 'The Kibera Project', last modified 2015, accessed August 22, 2015, http://safi-international.com/project/project-2/.

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 funders, 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 below in the table.

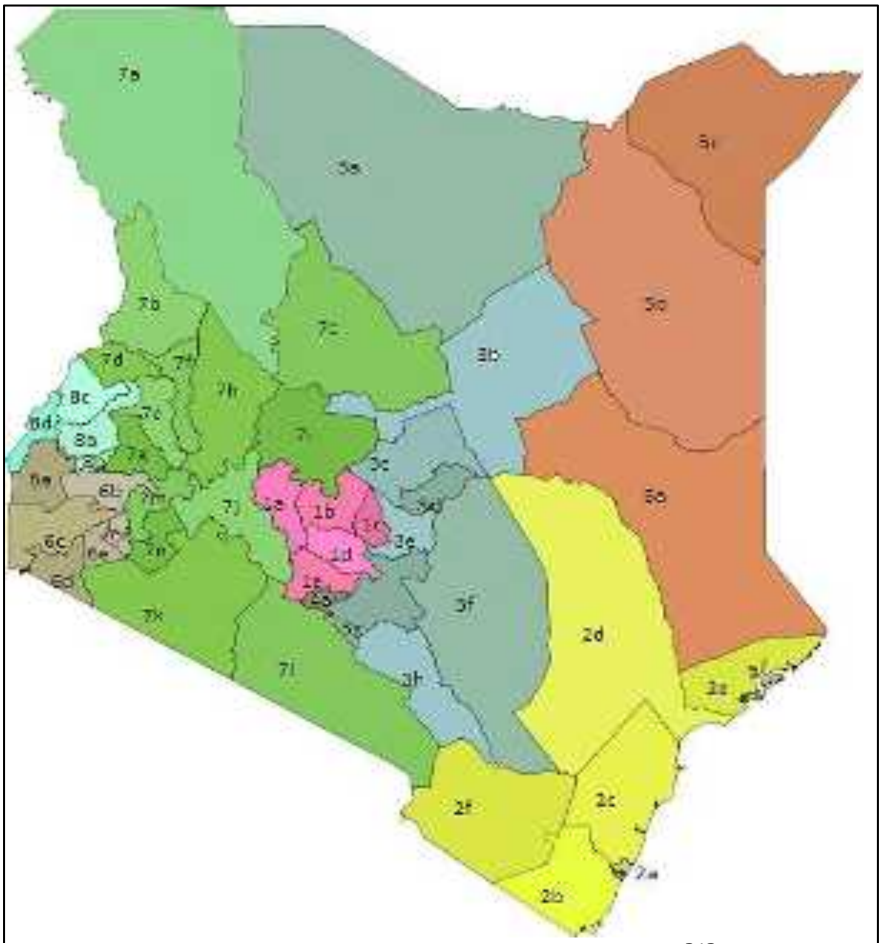
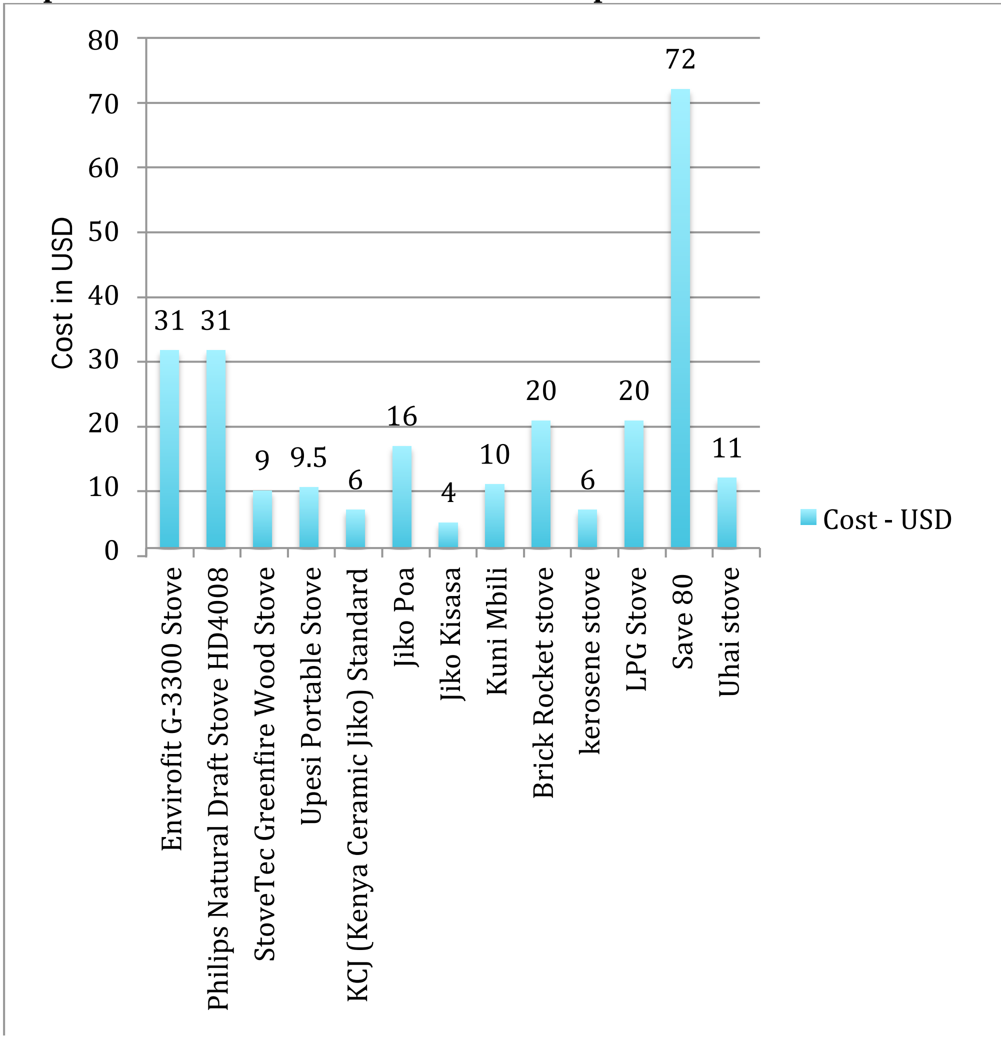


Table Map of Kenya, Market Segmentation Study[313]

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%

313 Global Village Energy Partnership International, *Kenya Market Segmentation Study*.

Improved Cook Stoves Current Market– Upfront Costs[314]



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

Modern ethanol gel fuel stoves cost $30 USD in supermarkets for a single burner stove and about $0.90 USD for a liter 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.[315] 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[316] in Sub-Saharan Africa, GLPGP aims to transition

[314] Ibid.

[315] *Energy Access Among The Urban And Peri-Urban Poor In Kenya* (Nairobi: Global Network on Energy for Sustainable Development, 2008).

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

50-70 million people to LPG for cooking, create 150,000+ new jobs, and offset more than 18 million metric tons of wood used for cooking per year.[317]

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 then thereafter it will go 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[318].

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
(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:[319]

- Regulate, develop and promote the sugar industry.
- Coordinate the activities of individuals and organizations within the industry.
- 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.[320]

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.'

[317] *Kenya Market Assessment*, Market Assessments (Global LPG Partnership, 2013), accessed September 22, 2015, https://cleancookstoves.org/binary-data/RESOURCE/file/000/000/234-1.pdf.
[318] Ibid.
[319] Kenya Sugar Board, 'Our Mission, Vision Values And Roles', last modified 2015, accessed August 22, 2015, http://www.kenyasugar.co.ke/new/index.php/about-us/mission-vision-values-roles.
[320] Ibid.

Molasses enjoys a lucrative underground market especially since sugar factories are not obligated to dispose of their supplies in a formal manner, and there exist 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.[321] Media reports estimated that producers and other supply chain players lost about US $50,000,000 during the crackdown.[322] 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). COMESA, a regional economic cooperation organization, has been 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 liters/day of ethanol from molasses as a byproduct of sugar production.[323] All factories generate the steam and power required for their own operations from sugar cane waste, known as bagasse. Only one factory (Mumias) 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.

Sugar Company	**Tons Crushed per Day (TCD)[324]**
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

[321] Magdalene Mukami, 'Kenya Declares War On Illicit Alcoholic Brews', *Anadolu Agency*, 2015, accessed August 20, 2015, http://www.aa.com.tr/en/world/kenya-declares-war-on-illicit-alcoholic-brews/29120.
[322] Anthony Gitonga, 'Crackdown On Illicit Brew To Cost Kenya Sh50 Billion', *Standard Media*, 2015, accessed August 22, 2015, http://www.standardmedia.co.ke/thecounties/article/2000168698/crackdown-on-illicit-brew-to-cost-kenya-sh50-billion.
[323] Kwale International Sugar Company, 'KISCOL Products', last modified 2015, accessed August 22, 2015, http://www.kwale-group.com/product.html.
[324] *Strategic Plan* (Kenya Sugar Board, n.d.), accessed September 25, 2015, http://www.kenyasugar.co.ke/downloads/KSI%20Strategic%20plan.pdf.

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 and 4.1 million liters of petrol and automotive diesel respectively per day by 2014. By 2030, fuel consumption will be 2.7 and 6.5 million liters of petrol and automotive diesel respectively per day. Currently, Kenya requires 85 million liters of ethanol per year for a national 10% (E10) blend. At current consumption levels, this would need to grow to 93 million and 148 million liters by 2014 and 2030 respectively. It is estimated that a ton of molasses can be converted into 220 liters of ethanol.[325]

Sony Sugar Company completed a feasibility study fora 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 distills approximately 60,000 liters of ethanol daily, which is less than half its capacity of 175,000 liters per day[326]. 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% excise duty and 16% 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% and 65% 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% alcohol concentration) of 4,000 liters for every eight-hour shift, expected to rise to 22 million liters 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 liter. 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 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 liters 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.

[325] Ibid.
[326] Sugar Online, 'Kenya: Molasses Shortage Boosts Local Prices For Ethanol Producers', last modified 2011, accessed August 22, 2015, http://www.sugaronline.com/website_contents/view/1181002.

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 and certified B-Corp 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 Center, 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 set out 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 actor 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 2-3 days per week on average, selling 510 stove liners/year (per person working); receive incomes of $175 USD annually per woman in each producer group with stove promoters earning an average of $200 USD annually; and saving cook stove users up to $82 USD annually with fuelwood savings of up to 43%. Additionally, time savings of about 10 hours/month were reported along with smoke reduction of 60%. Additional reported achievement was the reduction of acute respiratory infections in children by 60%, and in mothers by 65%.[327]

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 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.

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[327] Beatrice Njenga, *Upesi Rural Stoves Project,* Generating Opportunities - Case Studies on Energy and Women (United Nations Development Programme, 2001), accessed August 22, 2015, http://www.bioenergylists.org/stovesdoc/Kenya/05_Kenya.pdf.

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 government 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[328], 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 government. Vision 2030 as a key government policy framework positions the agricultural sector as a key driver for delivering the 10% annual economic growth rate envisaged under the economic pillar

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

of Vision 2030. The sector has set itself a goal of achieving an average growth rate of 7% 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 in 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 recognized 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 liters 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, 6 biomass, and 1solar) have been approved for development. The tariff ranges from \$0.06 USD/kWh to \$0.12 USD/kWh, with a special rate of \$0.85 USD/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.

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 (Impact Assessment and Audit) Regulations	2006	
Environmental Management and Coordination (Water Quality) Regulations	2006	Water Quality Regulations outline Standards for effluent discharge into the environment; and 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 all waste categories, and disposal of waste by NEMA licensed company.
The Sugar Act	2001	Governs the operations of the Kenya Sugar Board.
The Agriculture Act (Cap 318)		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 good husbandry. It permits “Fixing of prices for scheduled crops” and formation of agricultural committees and boards.
The Water Act	2002	
The Public Health Act (Cap 242)		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, Smokey chimneys, Dirty dwellings, Premises used without sanitation, Factories emitting smoke or smell.
The Forest Act	2005	Pursuant to Section 90 and Section 116 (B) of the Customs and Excise Act, CAP 472 of the Laws of Kenya, Kenya Revenue Authority (KRA) See table 8 below.
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.

<u>Exemptions:</u> 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 businesses forecasting. [329]

Table of Excise Duty Rates[330]		
Goods	**Description or Usage**	**Rate of Duty €**
Electricity	Business use	0.50 per megawatt hour
	Non-Business Use	1.00 per megawatt hour
Spirits		42.57 per liter 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 hectoliter% of alcohol in the beer
	Exceeding 2.8% volume	22.55 per hectoliter% of alcohol in the beer
Wine	Still and sparkling, not exceeding 5.5% volume	141.57 per hectoliter
	Still, exceeding 5.5% volume but not exceeding 15% volume	424.84 per hectoliter
	Still, exceeding 15% volume	616.45 per hectoliter
	Sparkling, exceeding 5.5% volume	849.68 per hectoliter

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 liter of spirit.
- Ethanol is classified as a spirit. Spirits attract KES 120 per liter or 65% 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.[331]

[329] UNDP in Kenya, 'Piloting Bioethanol As An Alternative Cooking Fuel In Western Kenya'.
[330] 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.
[331] Kenya Revenue Authority, *The Customs And Excise Act (Chap 472)* (Government of Kenya, n.d.).

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 fall 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 benefits 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, for their cooking, lighting, and commercial use purposes, and 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. 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% of the total. In 2010, this was 67.4%; in 2011 it rose to 70%, dropped marginally to 68.9% in 2012, and rose again to 69.9% 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%, then another 12% in 2012 and another 21% in 2013, for a sustained growth trend.[332]

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

While several reports exist that analyze and investigate the importance of effectively integrating women into energy initiatives through gender mainstreaming practices, 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 developed its resource, *Scaling Adoption of Clean Cooking Solutions through Women's Empowerment.*[333] The Global Alliance for Clean Cookstoves 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 the global target of

[332] Kenya National Bureau of Statistics, *Economic Survey* (Nairobi: Government of Kenya, 2015).
[333] Global Alliance for Clean Cook Stoves, 'Scaling Adoption Of Clean Cooking Solutions Through Women'S Empowerment', accessed September 25, 2015, http://www.cleancookstoves.org/gender.

reaching 100 million households with clean stoves and fuels, the GACC 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 exacted 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[334]. 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,

> "*(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…*"[335]

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[334] UNDP in Kenya, 'Piloting Bioethanol As An Alternative Cooking Fuel In Western Kenya'.

[335] 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.

It also creates a plethora of regulatory bodies all of which have different incorporation identities such as an “Agency” (the Center 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 in trying to streamline energy regulation and ensure that red-tape is eliminated. In addition to the above mentioned 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 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.[336]

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 liter, it also attracts VAT at 16% and excise duty at KES 120.00, raising the total cost per liter to KES 220.00. A pilot study conducted in Kisumu, Kenya by UNDP[337] reported a 98% 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 ($20 to $40 USD) for the CLEANCOOK stove piloted. They were willing to pay between KES 50 - 100 per liter 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 favorable reviews and test results.

[336] Ibid.

[337] UNDP in Kenya, 'Piloting Bioethanol As An Alternative Cooking Fuel In Western Kenya'.

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. Also, convenience and reduced need for electricity were factors.[338] 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 liter 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.

[338] *Energy Access Among The Urban And Peri-Urban Poor In Kenya* (Nairobi: Global Network on Energy for Sustainable Development, 2008).

F. Ethiopia

Introduction

Ethiopia is the second-most populous country in Sub-Saharan Africa, with a population of 94.1 million, a 2.6% growth rate, and an area of 1.1 million square kilometers.[339] Ethiopia is a diverse state with eighty-three ethnicities and languages, although Oromo and Amhara constitute more than 60% of the population.[340] Amharic serves as the national language. The country has a GDP (2014) of 54.80 billion USD, representing 0.09% of the world economy. Ethiopia's per capita income is substantially low, at 470 USD; nevertheless, the government aspires to reach middle-income country status over the next decade. Over the past decade, the country's economy has recorded an average 10.8% growth. Economic growth has yielded positive results towards poverty reduction, reducing it by 9.1 percentage points as measured by the national poverty line. The country has achieved the MDGs for child mortality and water and has made promising progress in gender parity in primary education, HIV/AIDS, and malaria.[341]

Ethiopia has a predominantly agricultural economy, and 84% of the population lives in rural areas directly or indirectly employed in agriculture and other related activities.[342] The economy depends on the agriculture and the service sector, which contribute 46% and 44% to the GDP respectively, while industry contributes less than 10%.[343] Ethiopian agriculture is primarily subsistence and rain fed farming, despite the fact that it is the backbone of the economy.[344] The industry sector remains underdeveloped despite the fact that the Ethiopian economy has enjoyed rapid growth for the past decade, with an average of 10.6% annual GDP growth, compared to the regional average of 4.9%.[345] As a result, most of the Ethiopian energy demand is for agriculture and residential use, which are largely met by human and animal power and biomass fuels respectively.

In Ethiopia, domestic energy requirements are mostly met with wood, animal dung, and agricultural residues.[346] About 63.3% of the estimated 3.5 million urban households of Ethiopia use firewood, 17.5% use charcoal, and the rest, 12.2%, use electricity, kerosene, and LPG for cooking.[347] In rural Ethiopia 99.5% of energy demand for cooking is met by wood, dung, crop residues, and sawdust.[348] The continued traditional energy use has endangered the country's remaining very low forest coverage.[349] Deforestation and forest degradation must be reversed to support the provision of economic and ecosystem services and the growth in GDP.

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[339] World Bank, 'Ethiopia Overview', last modified 2015, accessed September 25, 2015, http://www.worldbank.org/en/country/ethiopia/overview.
[340] Ethiopian Government Portal, 'Policies And Strategies', last modified 2015, accessed September 25, 2015, http://www.ethiopia.gov.et/policies-and-strategies1.
[341] World Bank, 'Ethiopia Overview'.
[342] Ethiopian Government Portal, 'Policies And Strategies'.
[343] Ministry of Finance and Economic Development, *Growth And Transformation Plan* (Addis Ababa: Federal Democratic Republic of Ethiopia, 2010).
[344] Farm Africa, 'Farm Africa's Work In Ethiopia', last modified 2015, accessed September 25, 2015, http://www.farmafrica.org/ethiopia/ethiopia.
[345] Ministry of Finance and Economic Development, *Growth And Transformation Plan.*
[346] Climate and Clean Air Coalition, 'Ethiopia', last modified 2015, accessed September 25, 2015, http://www.unep.org/ccac/Partners/CountryPartners/Ethiopia.aspx.
[347] Central Statistical Agency, *Welfare Monitoring Survey-2011 Summary Report* (Addis Ababa: Federal Democratic Republic of Ethiopia, 2012).
[348] Ibid.
[349] Ethiopian Government Portal, 'Policies And Strategies'.

Ethiopia consumed a total 1.3EJ of energy during 2010, of which biomass fuels generated energy constituted 92% of the total energy supply while hydrocarbons and electricity contributed only 7% and 1% of the supply respectively.[350] The residential sector accounted for 93% of the total energy consumed, transport for 5%, industry for 1%, and others for the remaining 1%.[351] Biomass fuels are used in the residential and service sectors mainly for cooking while petroleum fuels are used for transport and industrial applications. Simultaneously, demand for energy is growing rapidly in Ethiopia: 6% for biomass fuels, 8% for electricity, and 11% for petroleum products.[352] Average Ethiopian household spends 9% of income on energy; out of which cooking fuels account for 40% of the expenditure.[353] The share of expenditure on fuelwood and other cooking fuels is greater for low income households compared to better-off households.

The social, economic, health and environmental implication of cooking fuel acquisition and consumption is very high. Over thirteen million households collect their cooking fuels. A typical household spends 500 hours annually on fuel collection.[354] Women and girls are discriminately affected with the adverse impacts of cooking fuel collection and use. Household Air Pollution (HAP) is responsible for approximately 4.9% of the total burden of disease among all age groups in Ethiopia.[355] Excessive exposure to smoke due to burning of dry biomass for cooking is one cause of respiratory diseases, which is responsible for up to 12% of total deaths in Ethiopia.[356]

Heavy dependence and unsustainable use of biomass is a severe burden to the biomass resource base. The amount of wood consumed for cooking is estimated at 76.5 million tons; charcoal is interpreted as a fuelwood equivalent of 28.6 million tons annually; and the amount of animal dung and crop residues consumed are 22.8 and 19.7 million tons annually.[357] Such heavy reliance and inefficient use of biomass fuels make consumption exceed the sustainable yields.

In response to these energy problems the government and non-government organizations took various measures to promote energy efficiency and alternative fuels since mid-1980s. The most prominent of these programs are the cooking efficiency programs by the Ministry of Water, Irrigation and Energy (MoWIE), German Technical Cooperation (GIZ), and SNV. As a result, a variety of improved wood and charcoal stoves have been disseminated in the country despite limited success. Though there is a significant interest by the government to shift to cleaner fuel burning stoves, clean fuel stove programs remain low.

[350] Ethio Resource Group, *Solar Energy Vision For Ethiopia: Opportunities For Creating A Photovoltaic Industry In Ethiopia* (Addis Ababa: International Solar Energy Institute, Solar Energy Foundation, Solar Energy Development Association, 2012), accessed September 25, 2015, http://www.sun-connect-news.org/fileadmin/DATEIEN/PV-Industry-ET-04-09-12_final.pdf.
[351] Ibid.
[352] Ministry of Finance and Economic Development, *Growth And Transformation Plan.*
[353] Central Statistical Agency, *Welfare Monitoring Survey-2011 Summary Report.*
[354] Ibid.
[355] World Health Organization, 'WHO | Household Air Pollution And Health', accessed September 25, 2015, http://www.who.int/mediacentre/factsheets/fs292/en/.
[356] Ibid.
[357] Ministry of Water and Energy, *Energy Sector Mapping And Database Development - Draft Ethiopian Energy Policy Framework* (Addis Ababa: Federal Democratic Republic of Ethiopia, 2011).

Cooking Fuels and Stoves in Ethiopian Households

Ethiopian households energy use for preparation of food can be broadly categorized into two, cooking and baking. Cooking includes cooking, water boiling, re-heating and coffee/tea boiling. Biomass is used to meet 94% energy demand of the country, which is mostly for cooking.[358] Cooking energy consumption shows similar trends both in rural and urban areas of the country with high reliance on biomass fuels.The biomass fuels used for cooking include; fuelwood, charcoal, branches, dung cakes and agricultural residues. Biomass reliance to meet households cooking energy need is causing massive deforestation and land degradation. Though the dependence is recognized to have significant harmful health hazards and negative economic consequences as well, the problem is aggravated by the population's high growth rate.[359]

Cooking Fuels and Stoves in Rural Households

Biomass dependence is higher in rural parts of the country compared to urban areas. Recently completed energy studies show that the Ethiopian rural population is almost completely dependent on biomass fuels for cooking. The major fuels used for preparation of food in the rural households are fuelwood, charcoal, BLT (branches, leaves and twigs), and dung. A recent national cooking fuel survey by a local NGO, Gaia Association, shows fuelwood to be the major fuel used by 96% of the rural households out of which 43% use it for cooking while the remaining 57% is for baking. The survey also shows charcoal is the second highly used fuel by about 40% of households, mostly for cooking. However, modern clean fuel use in rural households is almost non-existent.[360]

Fuelwood is the most widely used fuel for cooking and baking in rural Ethiopia. However studies show there is variation in the type of fuels that are in use throughout the regions of the country. One of the major reasons for the variations is availability and price of the fuel. For example, charcoal is found to be the second most common fuel in the rural households. But, the national survey found charcoal usage by the rural households is highest in Tigray region (77%) and lowest in Oromia region (33%). Most rural households obtain charcoal from the left over embers of firewood burning which is used mostly to make either coffee or tea. Crop residues and branches, leaves and twigs (BLT) are used almost by a third of the rural households even though use of crop residues is seasonal. The survey showed average use of dung in rural households of all regions is only 13%, while more than a third of the households in Tigray region use dung.[361]

The vast majority of rural households that are dependent on traditional fuels use primitive and inefficient technologies. The national study conducted showed the cooking stoves that are widely in use in rural areas are open fire wood stoves and all clay charcoal stoves. Ownership and use of improved cooking stoves, such as Upesi, Tikikil, and electric stoves for cooking in rural areas is very small. Upesi, Tikikil, and electric stoves are owned by only 5%, 0.1% and 1% of the households respectively. Upesi stoves are promoted in the rural areas of Tigray, Oromia, and Amhara regions for cooking and are owned by 14%, 11% and 6% households respectively.[362]

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[358]Horn of Africa Regional Environment Centre and Network, 'Overview', accessed September 25, 2015, http://www.hoarec.org/index.php/en/107-hoarec/docs/Energy/Energy%20Brochure.pdf.

[359] World Bank, 'Ethiopia Overview'.

[360] Gaia Association, *The Holistic Feasibility Study* (Addis Ababa: Project Gaia, 2015), accessed September 25, 2015, https://projectgaia.com/our-approach/resources/.

[361] Ibid.

[362] Ibid.

The most widely used baking stove in rural areas of all the regions except Tigray is open fire wood stove. About 72% of the rural households use open fire stoves for baking. In Tigray, traditional enclosed stoves are the most common baking stoves (98%). Ownership of other improved stoves such as Gonzie, Mirt and electric mitad by the rural households is limited. Flexibility of Open fire in terms of space utilization, ability to adjust for various end uses and sizes, and that it is a no-cost and accessible stove makes it easier for households to own and use it. When affordable alternative cookstoves are not available, Open fire is usually the only known solution for most of the households.[363]

Cooking Stoves and Fuels in Urban Households

The national fuel survey found stove stacking is a widely exhibited behavior in urban households with more than 90% charcoal, 70% firewood, and about 33% electricity users for cooking/baking. Percentage of urban households that use electricity is the highest in the capital city, Addis Ababa, with about 68% users. In recent years, most urban households are increasingly using electricity for cooking as prices of other fuels such as kerosene, LPG, and charcoal are continuously rising while that of electricity has remained constant for the last eight years. Though electricity use for cooking increased from 2.4% in 2004 to 6.2% in 2011, recent electricity use has shown exponential growth.[364]

Like rural households, cookstove and cooking fuel usage in urban households is very much dependent on availability and price of both fuel and stove.Unlike the rural household, charcoal is the most widely used cooking fuel by the urban households. On average, over 90% of the urban households in all regions of the country use charcoal mainly for cooking purposes rather than for baking as shown by the survey. Fuelwood is the second important fuel and is used by about 70% of the urban households. In some regions, such as Addis Ababa, fuelwood is used only by 27% of the households while in other regions such as Gambella and Somali over 90% of the urban households use it for cooking. Electricity, being used by about a third of the urban households, is the third most important cooking/baking fuel. The percentage of urban households that use electricity is the highest in Addis Ababa (68%) while none of the urban households in Gambella region use it for cooking.[365]

Cooking stoves that are used by the urban households are open fire, traditional enclosed stoves, Upesi, Tikikil and charcoal stoves. Some stoves such as open fire, traditional enclosed stoves, and the improved Gonzie stove can be used for both cooking and baking. Open fire and traditional enclosed stoves are traditional cookstoves while Tikikil and perhaps Upesi are improved for energy efficiency. There are three major types of charcoal stoves that are in use by urban households. The metal charcoal stove and clay charcoal stoves are traditional while Lakech charcoal stove is an improved one.[366]

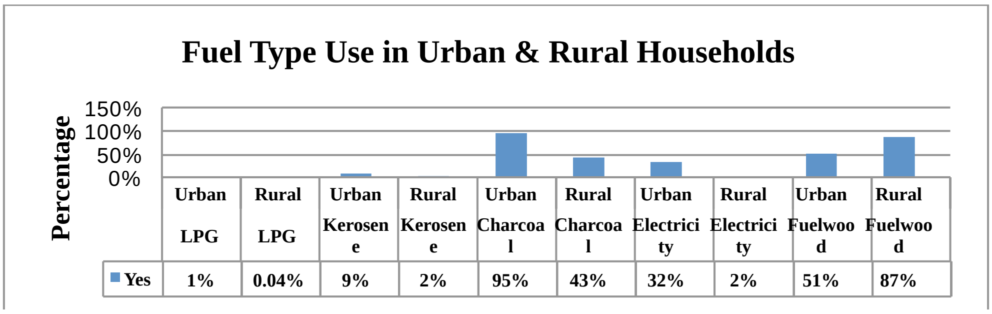
Charcoal stoves are observed to be the most prominent stoves used by over 90% of the urban households of the country. Of the three types of charcoal stoves, Lakech charcoal stove has the highest penetration rate of 41% in urban households. Next to Lakech, traditional metal charcoal stoves and all clay charcoal stoves penetrated into about 33% and 21% of the urban households respectively. Except in Tigray, Afar, Amhara and Southern Nations, Nationalities and People (SNNP) regions, where the traditional metal charcoal stove is most common, the

[363] Ibid.
[364] Ibid.
[365] Ibid.
[366] Ibid.

Lakech charcoal stove is generally the most widely used charcoal stove in the other regions.In Gambella, however, the traditional clay charcoal stoves are almost entirely used by all urban households.[367]

Next to charcoal stoves, open fire stoves are the second most widely used cooking stoves used by 27% of the urban households. In most of the regions, 30% to 40% of urban households use open fire for cooking. However, ownership and usage of the open fire stove as a cooking stove is the least in Tigray (2%) and Addis Ababa (9%). Ownership and use of traditional enclosed stoves (4%), Upesi (2%) and Tikikil (0.5%) for cooking is limited only to a small percentage of the urban households. Ownership of Upesi stove in the urban households ranges from 7% in Southern Nations Nationalities to 3% in Oromia and Somali regions.[368]

Stoves used for baking purposes in urban households include open fire, traditional enclosed stoves, Gonzie and electric mitad. Open fire is the most prominent baking stove used by 41% of urban households. Use of open fire stove for baking ranges between 40% and 70% in different regions of the country. Only about 15% of households in Addis Ababa and none in Tigray region use open fire for baking. Traditional enclosed firewood stoves are used by about 22% of the urban households. Electric stoves are used for baking by about 50% of households in Addis Ababa. Ownership of the improved Mirt stove for baking ranges from 6% to about 13% in different regions of the country. But in Somali and Addis Ababa regions, only less than 3% of the households are reported to own Mirt.[369]



Source: Holistic Ethanol Feasibility Study (2014)

Relative costs of cooking on a useful energy basis				
Fuel Type	Firewood		Kerosene	Bio-ethanol
Cooking Device	3-stone	Rocket	Wick	CCS
Fuel Unit	kg	kg	Liter	Liter
Price of fuel US$/unit	0.15	0.15	0.91	0.60
Price of stove, US$	0	25	20	50
Efficiency of stove,%	10	25	42	60
Useful energy MJ/unit	1.5	3.8	14.8	14.4
Fuel cost, US$/year	256	102	157	107
Expenditure, US$/year	256	110	162	115
Expenditure, US$/month	21	9	14	10

[367] Ibid.
[368] Ibid.
[369] Ibid.

Source: Ethiopian Country Strategic Plan for Safe Access to Fuel and Energy (2014)

Current Clean Cooking Initiatives in the Country

There are government and development partner initiatives running for decades promoting improved firewood stoves and improved charcoal stove but the stoves penetration in rural households remain low. The 2014 national survey conducted show about 12% of the rural households use the improved metal charcoal stove Lakech. Also, the ownership and use of improved firewood stoves (Upesi and Tikikil) and electric stoves for cooking in rural areas is very small. They are owned by only 5% and 1% households respectively. About 72% of the rural households use open fire stoves for baking. Urban households use the improved firewood Upesi and Tikikil stoves as well as charcoal stoves. Traditional metal charcoal stoves and all clay charcoal stoves penetration is about 33% and 21% of the urban households respectively. Next to charcoal stoves, open fire stoves are the second most widely used cooking stove used by 27% of urban households. Electric stoves are also widely used in 25% households of the urban areas. Open Fire is the most widely baking stove in urban areas though efforts are made to promote the improved firewood baking stove Gonzie. The improved firewood Mirt and Gonzie stoves are used only by 5% and 1% of the urban households respectively.[370]

Government and development partner initiatives are promoting the following improved stove dissemination.

Mirt: Designed by MoWE for the baking of injera, a local bread, which accounts for a large percentage of biomass energy use in Ethiopia.
Gonziye: Developed by the MoWE; utilizes locally procured clay instead of concrete; some versions can be reconfigured for use with a cooking pot.
Laketch: A round ceramic stove designed to be used with lump charcoal has been in use for 20 years in Ethiopia; the product is now self-sustaining and producers no longer receive extensive training or support.
Merchaye: An adaptation of the Laketch stove; designed to use a pressed charcoal briquette.
Tikikil: An example of the common “rocket elbow” design; jointly developed by the MoWE and GIZ; sold over 30,000 stoves to date; standard design.
CLEANCOOK: Currently receiving a lot of attention from the government; Gaia Association (NGO) is piloting the distribution of imported ethanol stoves mostly in refugee settings; MOWE is in the process of designing and training producers.

Government Initiatives

The Government of Ethiopia has placed energy as its main development agenda for the last two decades. Recognizing the urgent need to address household energy demands and reducing the debilitating health, social, and environmental impacts from traditional energy sources and technologies on poor rural women and children, the government has issued policies and strategies for developing alternative sources of energy, including the development of liquid biofuel and the promotion of fuel saving cook stoves.

The first Ethiopian National Energy Policy was formulated in 1994. Considering the limitations of the policy to address the current energy situation, the Government of Ethiopia drafted an updated Energy Policy in February 2013. One of the rationales for the need to update the energy

[370] Ibid.

policy was to give emphasis to the development and utilization of renewable energy sources that support the Climate Resilient Green Economy (CRGE) strategy of the country. The CRGE strategy is part of Ethiopia's first Growth and Transformation Plan (GTP) 2011-2015 that has the goal of maintaining the double-digit growth rate the country registered to elevate the country to middle income country status by 2025.[371] The GTP is a five year plan that will be followed by successive GTPs. The CRGE strategy outlines the vision, strategy, financing, and institutional arrangements Ethiopia need to be pursued to attain the triple goals of economic growth, net-zero emission, and building climate-resilience. The green economy strategy identifies reducing demand for fuelwood through fuelwood-efficient stoves as the most important measure to reduce emissions and for positive social impact while other advanced cooking and baking technologies (electric, biogas, and liquid petroleum gas - LPG stoves) offer an additional combined potential of 15 Mt CO_2e.[372]

To achieve this, the strategies devised are wide scale dissemination of fuel-efficient cookstoves and shift to other alternative cooking energy sources with less carbon intense fuels. The CRGE has put deployment of 9 million clean and efficient cookstoves as its short-term target for 2016. The long term target of the CRGE is 2030 and envisages a deployment of 31 million clean and efficient cookstoves. Among clean cookstoves, electric, biogas, ethanol and Liquefied Petroleum Gas (LPG) are identified as alternative energy sources.[373]

Along with the other strategies, the current five-year strategic plan of the Ministry of Water, Irrigation, and Energy sets the direction and targets for energy for the period 2011-2015. The main actions and targets for the power sector include increasing generation capability for grid by four times from 2 GW to 8 GW, doubling the length of the distribution network, and doubling the number of customers on the grid. The other major plans are to provide access to electricity to three million households and institutions through PV systems, disseminating nine million improved cook stoves, and increasing production and use of liquid biofuels.[374]

Relevant Organizations

Ministry of Water, Irrigation and Energy (MoWIE): MoWIE is the mandated government organization for energy production and use. The ministry has Alternative Energy Technology Development and Promotion Directorate, Biofuels Development Coordination Directorate, Regional Bureaus of Energy, and a research wing that work for development and promotion of improved cookstoves in the country. The Ministry has played a leading role in the national cookstove programs leading the development and dissemination of several types of efficient cookstoves throughout the country. The Ministry Directorates provide technical assistance and capacity building support to private entrepreneurs, such as micro and small enterprises that are involved in production and dissemination of improved cookstoves. MoWIE is in charge of the National Improved Cookstove Plan for dissemination of nine million cookstoves all over the country. The Ministry works with other government organizations, bilateral organizations, NGOs, and the private sector to achieve dissemination of the nine million cookstoves.[375]

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371 Ibid.
372 *Ethiopia's Climate-Resilient Green Economy Strategy* (Federal Democratic Republic of Ethiopia, 2011).
373 Ibid.
374 Ministry of Water and Energy, *Strategic Plan For The Year 2011-2015* (Addis Ababa: Federal Democratic Republic of Ethiopia, 2010).
375 Gaia Association, *The Holistic Feasibility Study*.

Development Bank of Ethiopia (DBE): was established primarily to finance investments that are in line with the Government's priority development areas. It provides short, medium and long-term investment loans and technical assistance to viable projects. DBE has set up a fund to promote private sector investment in clean energy technologies including cookstoves. It also provides credit lines to lend to end-users and energy micro-entrepreneurs.[376]

German Technical Cooperation – Energy Coordination Office (GIZ-ECO): has been operational since 1998 in Ethiopia and is one of the major players in the dissemination of improved firewood stoves for households, businesses and institutions. It provides technical support in the design, development, promotion of cookstoves, and private sector development.[377]

Gaia Association: is a local non-governmental organization established in 2005 mainly to promote clean cooking through use of bioethanol. Gaia Association works in partnership with government organization and the private sector for the promotion and dissemination of ethanol stoves. Today, Gaia has disseminated ethanol stoves to more than 10,000 households mostly in the refugee camps.[378]

Horn of Africa Regional Environment Center-Network (HoAREC): is part of the Addis Ababa University and mainly engaged in practical applications of energy and environmental technologies for practical solutions. It is a network and cooperation of five countries in the horn of Africa. Among other activities, improved cookstoves is one of the major areas of work for HoAREC.[379]

Policy Review

The production and utilization of ethanol fuel to replace imported petroleum and solid biomass requires conducive government regulations and policies. This section reviews relevant policies, strategies and programmes on ethanol production and utilization in Ethiopia. The draft Ethiopian National Energy Policy (2013), Biofuels Development and Utilization Strategy (2007), the Government's Growth and Transformation Plan (2010-2015), and Fuelwood-Efficient Stoves Investment Plan (2012-2016) are revised.[380]

Ethiopian National Energy Policy 2013

The draft Ethiopian National Energy Policy was developed to ensure the availability, accessibility, affordability, safety, and reliability of energy services to support accelerated and sustainable social and economic development and transformation of the country. The draft policy aims to address the existing energy poverty; high dependence and unsustainable use of biomass resources; wasteful and inefficient energy production, transportation and utilization; low institutional, human, and technological capacity; low private sector participation; high dependence on imported petroleum fuels' climate change impacts on

[376] Ibid.
[377] German Technical Cooperation, 'Energising Development (Endev) Ethiopia', accessed September 25, 2015, https://www.giz.de/en/worldwide/18899.html.
[378] Project Gaia, 'Ethiopia', last modified 2014, accessed September 25, 2015, https://projectgaia.com/projects/ethiopia/.
[379] Horn of Africa Regional Environment Centre and Network, 'Welcome To Hoa-REC&N', accessed September 25, 2015, http://www.hoarec.org/index.php/en/#.
[380] Gaia Association, *The Holistic Feasibility Study*.

national development and energy sector; weak enforcement of standards and regulations; and inadequate transfer of technology and localization.[381]

The policy seeks to improve the security and reliability of energy supply and turn Ethiopia into a regional hub for renewable energy; increase access to affordable modern energy; promote efficient, cleaner, and appropriate energy technologies and conservation measures; strengthen energy sector governance and build strong energy institution and ensure environmental and social safety and sustainability of energy supply and utilization.[382]

Under the policy objective to enhance diverse and efficient bioenergy production, the involvement of stakeholders, the introduction of attractive biodiesel pricing, and the development of biodiesel market infrastructure for investors are given due attention. In order to ensure bioenergy supply security, promoting the use of bioenergy by establishing processing, distribution, transportation, and marketing infrastructure and the promotion of bio-oil, biodiesel and other alternative fuels for household energy use are mentioned as policy instruments. The policy highlighted household, transport, industry, agriculture and service sectors as the major energy consuming sectors.[383]

The introduction of diverse household energy alternative fuels and technologies such as improved and efficient lighting technologies, domestic biogas, electricity, biofuels, solar cookers, and kerosene end-use devices for the household and service sector and increasing the blending ratio from the current E5 for ethanol and biodiesel to the maximum feasible extent in the transport sector are taken as main instrument to attain the policy objectives.

Even though the updated energy policy addresses most of the current energy issues, it failed to create awareness about benefits of ethanol use as household cooking fuel at micro and macro levels. The policy failed to endorse a national strategy for ethanol fuel and clean cookstove usage, place clear enforceable regulations allowing/facilitates the local manufacture of the clean cookstove and/or import of parts, provide supportive political environment for ethanol businesses (pricing and tax incentive) and establish product standard for both the clean cookstove as well as the ethanol fuel. Inconsistent treatment of renewable energy technologies is also widely observed. Energy conversion technologies and end-use devices for solar and wind resources benefit from favorable import taxes while technologies for conversion and utilization of biomass and biofuels are not.

The Biofuels Development and Utilization Strategy of Ethiopia

Ethiopia started the implementation of the biofuels since 2007 to facilitate adequate production of biofuel from indigenous resources so as to substitute imported petroleum and export excess products. The building block of the strategy is that the development of biofuels should not have unintended consequences on food security, land access, the environment, cultural values, and the economy. The strategy has also clearly outlined the need for participation of local communities in development of biofuels so that they can be beneficiaries of the development. The biofuels strategy provides an implementation guideline in order to ensure the achievements of the national energy policy objectives while avoiding unintended consequences.[384]

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[381] Ibid.
[382] Ibid.
[383] Ibid.
[384] Ministry of Mines and Energy, *The Biofuel Development And Utilization Strategy Of Ethiopia* (Addis Ababa: Federal Democratic Republic of Ethiopia, 2007).

The strategy identified sugarcane, jatropha, castor, and palm trees as potential feedstocks for ethanol and plant oil production for energy use. Other appropriate feedstock can also be considered as long as they fulfill the sustainability criteria emphasized under this strategy and the general environmental policy of Ethiopia. The strategy invites participation of the private sector in feedstock production as well as bio-ethanol processing. The strategy indicates that the private sector should be encouraged to produce bio-ethanol from sugarcane and other plant sources and create domestic and foreign market channels, as well as substitutes for kerosene and household fossil fuel use. However it provides greater emphasis for utilization of biofuels, particularly ethanol, mainly in the transport sector while the household sector is deemed more economically feasible and a technically viable option. The strategy needs to see the best possible options of using biofuels and accordingly provide the necessary support for their wide spread use. When strategies are not aligned to the policy objectives, unintended results could happen. Ethanol fuel, as an indigenous and renewable energy resource, is intended to substitute petroleum. However, policy instruments such as pricing disfavor ethanol. In the price structure of fuels, kerosene is exempted from value added tax while ethanol is not. This will affect the household market development effort for ethanol. Hence, price setting for ethanol for cooking fuel use should be consistent and in support of the policy.[385]

The First Growth and Transformation Plan

Degradation of forest resources due to unsustainable harvest of biomass for cooking is one of the major problems identified in the Climate-Resilient Green Economy (CRGE). The household energy sector, particularly cooking energy, has been identified as an opportunity to make significant environmental and social impacts by reducing the demand for fuelwood, which would reduce emissions and the unsustainable harvest of biomass resources. Biofuels development and utilization is given due emphasis in the government's five year (2010-2015) Growth and Transformation Plan (GTP). Regarding development of ethanol, the GTP seeks to increase production to nearly 200 million liters at the end of the planning year.[386]

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The strategy plan envisages development of large-scale sugar industries by the government and the private sector. This would also produce the targeted amount of ethanol from the waste molasses by-product. As an implementation strategy the GTP also promotes distributed production of bio-fuels at farm scale in rural areas.

Ethanol is primarily treated as a transport fuel, but it is mentioned that it can be one of the alternative sources of cooking energy.

Fuelwood-Efficient Stoves Investment Plan (2012-2015) - Final Version

The government of Ethiopia identified fuelwood-efficient and fuel-shift stoves as one of the immediate priorities to the development of CRGE, this Investment Plan has been formulated by the Ministry of Water, Irrigation, and Energy. The aspiration and focus of this initiative has two horizons (i) in the long term (2030) deploying 31 million fuelwood-efficient stoves in rural and urban areas, and (ii) in the short term (2015), 9 million stoves in rural areas.[387]

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385 Ibid.

386 Ministry of Finance and Economic Development, *Growth And Transformation Plan*.

387 Ministry of Water and Energy, *National Programme For Improved Household Biomass Cook Stoves Development & Promotion In Ethiopia* (Addis Ababa: Federal Democratic Republic of Ethiopia, 2013).

This Investment Plan (IP) describes how to achieve the Government of Ethiopia's 9 million stoves target by improving activities across the entire value chain of stove production and bundles these activities in improvement programs. In this context the IP addressed most of the potential barriers that hinders large-scale dissemination of ICS especially in the rural areas.[388]

Though this investment plan is stated to be technology neutral, it exclusively focuses on the efficient fuelwood stoves. The IP seems to have no room to entertain ethanol fuel and stoves.

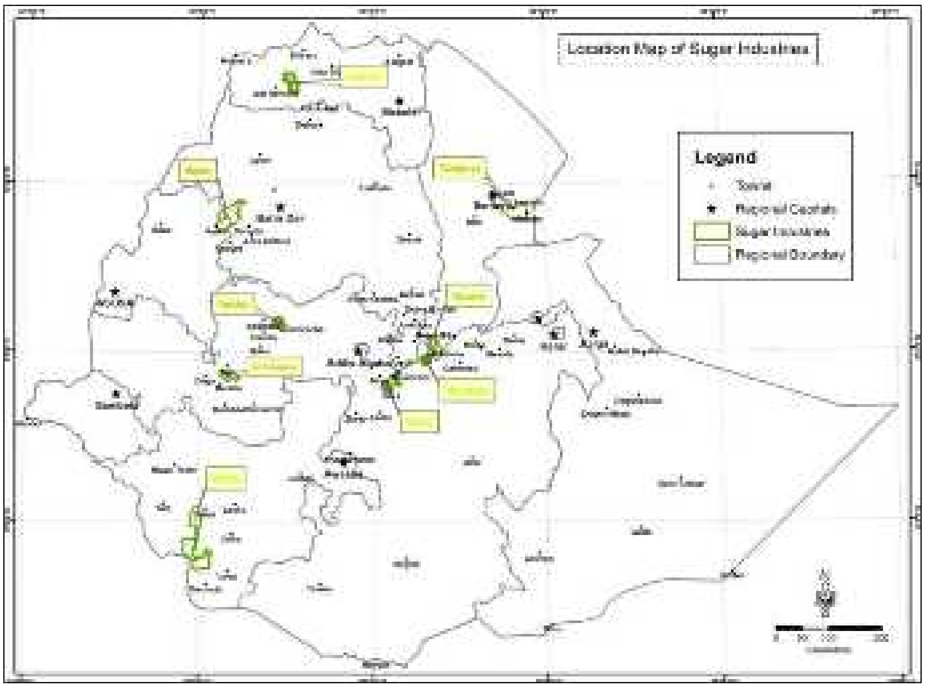
Overview of Current and Projected Ethanol Production

Feedstocks for Ethanol Production

Ethiopia grows four different groups of feedstocks for bioethanol production; sugarcane and sweet sorghum, grain crops (such as maize and wheat), roots and tubers (such as potato, sweet potato, taro, cassava, etc.), and fruits (such as mango, banana, cactus, melons, etc). However, most of these crops are staple crops and are not promoted for bioethanol production in the country and this will continue, at least for the near future. As a result, Ethiopian ethanol production uses non-staple crops and sugar production by-product molasses. There are no plans to produce ethanol directly from cane juice or from other alternative sources by the government or private enterprises at this time. [389]

Ethiopia has a total of 500,000 Ha of land suitable for sugarcane cultivation and out of this 342,000 Ha is already committed for production.[50] The three operational state owned sugar factories of Fincha, Metahara, and Wonji produce molasses. Fincha and Metahara produce ethanol from all the molasses they produce. Wonji does not produce ethanol at present, and molasses from this factory is sold to the factory for other uses. At present, molasses production at Wonji is at a capacity of 70% producing 421,704.9 quintals per year.[51] This is approximately sufficient to produce 10,542,622 liters of bioethanol per year assuming a conversion rate of one to four. The amount of molasses supply will increase with Wonji's planned capacity increase. The figure and table below show the location of Ethiopian sugar industries and production capacities of existing and new factories under construction.[390]

[388] Ministry of Water and Energy, *National Programme For Improved Household Biomass Cook Stoves Development & Promotion In Ethiopia.*
[389] Ethiopia Sugar Corporation, 'Ethiopian Sugar Industry Profile', last modified 2015, accessed September 25, 2015, http://www.etsugar.gov.et/index.php/en/about.
[390] Ibid.



Existing and planned sugar and ethanol production facilities in Ethiopia (Source: Ethiopian Sugar Corporation, 2012)

Estimated Current and Five Years Projected Crushing Capacity, Annual Sugar Production and Cultivated Land of Ethiopian Sugar Factories and Projects

	Factory	Status	Crushing Capacity (TCD*)		Annual Sugar Production (Tons)		Cultivated Land (Hectare)	
			Current (2015)	Future (2020)	Current (2015)	Future (2020)	Current (2015)	Future (2020)
1	Wonji Shewa	Operational	6,250	10,000	150,000	250,000	12,985	16,585
2	Metehara	Operational	5,372	5,372	130,000	130,000	10,230	10,230
3	Finchaa	Operational	12,000	12,000	270,000	270,000	20,985	20,570
4	Tendaho	Under Commissioning	13,000	26,000	275,000	550,000	21,255	40,255
5	Kesen	Under Commissioning	6,000	10,000	150,000	250,000	8,503	16,663
6	Arjo Didesa	Under Commissioning	8,000	10,000	200,000	250,000	13,182	14,216
7	Omo-Kuraz-1	Under Project	-	12,000	-	270,000	10,114	21,114
8	Omo-Kuraz-2	Under Project	-	12,000	-	270,000	0	20,000
9	Omo-Kuraz-3	Under Project	-	12,000	-	270,000	0	21,000
10	Omo-	Under	-	24,000	-	540,000	0	40,000

	Kuraz-4	Project						
11	Omo-Kuraz-5	Under Project	-	24,000	-	540,000	0	40,000
12	Beles-1	Under Project	-	12,000	-	270,000	12,039	21,039
13	Beles-2	Under Project	-	12,000	-	270,000	0	21,000
14	Beles-3	Under Project	-	12,000	-	270,000	0	18,000
15	Welkayt	Under Project	-	24,000	-	540,000	2,500	38,000
16	Other	Planned	-	12,000	-	270,000	0	10,000
17	Other	Planned	-	12,000	-	270,000	0	15,000
		Total	50,622	241,372	1,175,000	5,480,000	111,793	383,672

* TCD= Refers to crushing capacity of the factory in tons of cane per day

<u>Bioethanol Production and Projections</u>

Finchaa Sugar Factory is the first Ethiopian factory that started bioethanol production with a volume of 209,444 liters in 2001 and reached 8 million liters in 2010. Following Finchaa, Metahara Sugar Factory started producing 12.5 million liters per annum in 2010. This increased the annual total national production of ethanol to 20.5 million liters. The Ethiopian government is expanding sugar and ethanol production with new factories that will commence production in the near future at Tendaho, Kuraz, Wolkait, Beles and Kesem to increase production to 200 million liters as shown in the table below. Later on, production is expected to reach 317 million liters when full capacity is attained.[391]

Table Projected sugar in tonnes and bioethanol in M^3 of seven sugarcane estates and factories (Ethiopian Sugar Corporation, 2014).

Factory/Estate	Capacity per annum	
	Sugar in tones	Bioethanol
Metehara	136,692	12,500 m^3
Finchaa	270,000	20,000 m^3
Wonji-Shoa	222,700	12,800 m^3
Tendaho	619,000	55,400 m^3
Kesem	153,000	12,500 m^3
Kuraz	1,946,000	183,134 m^3
Beles	242,000	20,827 m^3

Stakeholders for Ethanol Stove and Fuel Business

<u>Ministry of Water, Irrigation and Energy (MoWIE):</u> The Ministry is responsible for planning and allocating all of the ethanol produced by state owned sugar factories. MoWIE under its strategic plan for 2011 to 2015 devised a National Improved Cookstove Program, which sets a target for dissemination of nine million cookstoves all over the country. The

[391] Ibid.

Ministry has developed an investment plan to reach its target by the end of the planning period. The investment plan shows that the Ministry has several development partners to work with including government organizations, bilateral organizations, NGOs, and the private sector.[392]

The Ministry's Biofuels Development Coordination Directorate plays a coordination role in biofuels development and use for various end uses, including the use of biofuels for transport and cooking fuel. It plays a major role in price setting and allocation of ethanol for household cooking by lobbying and providing useful information to relevant government organizations including the Ministry of Trade, Ministry of Industry, and the Ethiopian Sugar Corporation.[393]

Ministry of Trade: Major roles of the Ministry of Trade in relation to fuel supply are provision of fuel supply license, price regulation, and quality control. The Ministry of Trade regulates petroleum fuel prices and controls quality as well. It closely works with the Ethiopian Petroleum Enterprise, Ethiopian Sugar Corporation, and petroleum companies. The Ministry of Trade sets the price of ethanol. The Biofuels Development Coordination Directorate of the MoWIE provides the necessary information and advises, which help the Ministry of Trade to determine ethanol fuel price.[394]

Ministry of Industry: The primary role of the Ministry of Industry is to provide support to medium and large industries. The ministry provides technical support to the sugar industries when required. However, all public sugar industries under the Ethiopian Sugar Corporation are under the direct supervision of the Prime Minister's Office.[395]

Ministry of Women, Youth and Children, and Regional Bureaus of Women's Affairs: The Gender Affairs Directorate is in charge of mainstreaming gender issues in the planning and implementation of projects and programs in government organizations. Ethiopian Women Development and Change Package is a section under the Gender Affairs Director, which is responsible for dealing with the problems of rural women. Cooking energy supply and use is recognized by the Ministry as one of the major problems that affect rural women and children. The Ministry closely works with the Woreda level Women Development Army to promote and disseminate clean and energy efficient cooking technologies in rural areas. The Regional Women's Affairs Bureaus closely work together with Regional Energy Bureaus in the manufacturing and dissemination of improved cookstoves.[396]

Ethiopian Standards and Conformity Agency (ESCAE): ESCAE inspects and certifies imported or locally manufactured products for conformity to standards set by the Ethiopian Standard Agency. Discussions are underway with MoWIE and the ESCAE to establish standards for improved cookstoves.

Ethiopian Sugar Corporation: The Ethiopian Sugar Corporation, in its five-year strategic plan, emphasized the production and supply of energy from the bi-products of sugar, bagasse, and molasses. Enhanced production and supply of ethanol is one of the priorities of the

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[392] Ministry of Water and Energy, *National Programme For Improved Household Biomass Cook Stoves Development & Promotion In Ethiopia.*
[393] Ibid.
[394] Gaia Association, *The Holistic Feasibility Study.*
[395] Ibid.
[396] Ibid.

Corporation. It targets to produce 44,340 cubic meter of ethanol by the end of the 2015 from the expansion projects of the existing sugar factories and the new ones that will be constructed.[397]

Conclusions and Recommendations

Improving energy efficiency, the sustainable management of existing sources of energy, and introducing new renewable fuels are necessary to meet the energy demand for cooking sustainably. The initiatives in Ethiopia thus far have focused on improving energy efficiency and management of resources for biomass fuels with much less focus on providing new sustainable fuels for cooking. However, several studies have shown that most of the initiatives in the country are not able to deliver the multi-aims of the initiatives sustainably. In recent effort to provide a new sustainable fuel, ethanol has been identified as the most viable clean domestic fuel due the growing local production and competitive price. Annual domestic ethanol production from sugarcane molasses alone may rise to 350 million liters in the next five years. In addition to molasses, Ethiopia has other potential feedstock for ethanol production including sugar crops, sweet sorghum, and crop waste (fruits, vegetables, sugar crops), which may increase potential output to 500 million liters or more annually.

Ethiopia's vision for 2025 is to become a middle-income country on a climate- resilient and green economy path. Introduction of ethanol as a domestic, renewable cooking fuel meets the aim of reducing forest degradation (replacing biomass fuels) and at the same time reduces the financial risks to the economy of dependence on imports (replacing petroleum fuels). The country has already developed a policy that identifies ethanol as a desirable domestic fuel that will improve the security and reliability of energy supply both as a transport and cooking fuel. At current market prices, ethanol is a cheaper cooking fuel compared to kerosene and LPG; it is slightly more expensive than biomass; and much more expensive than electricity. However, social valuation of ethanol and its alternatives makes ethanol a cheaper cooking fuel compared to both petroleum and biomass fuels. The health and environmental benefits of ethanol compared to petroleum and biomass fuels further improves its competitiveness against petroleum and biomass cooking fuels.

The market for ethanol as a cooking fuel has not grown, although ethanol production in the country started ten years ago. Availability constraints, rising price for ethanol, inadequate public awareness and marketing, and limited distribution infrastructure and services are identified as the main reasons for limited ethanol use as cooking fuel. The current commercial market for ethanol as cooking fuel is very small and limited to Addis Ababa. The market is not growing and probably shrinking because of uncertainties of supply and rising prices. On the other hand, potential availability of ethanol is high from state owned sugar factories (from public and private investment in ethanol distilleries from molasses waste). There is also potential to promote private investment in ethanol distilleries from a variety of feedstocks, including sugarcane, sweet sorghum, other sugar crops, and crop waste. There is clear advantage in using ethanol for cooking rather than for other uses including transportation. Cooking can be the largest market for ethanol produced in Ethiopia; cooking with ethanol has multiple economic and environmental benefits. Ethiopia can benefit using ethanol for cooking by reducing household energy expenditures, substituting cooking with fossil fuels, avoiding energy-related deforestation, creating jobs, and reducing GHG emissions.

[397] Ethiopia Sugar Corporation, 'Ethiopian Sugar Industry Profile'.

However, sustainable market development is required to ensure large-scale adoption of ethanol for cooking. For this, suitable policies and regulations, investment in ethanol production and distribution, promotion and marketing should be in place. This will ensure increases in ethanol production and long-term availability, competitive ethanol pricing, public awareness and education, and distribution capability.

IV. 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.[398]

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.[399] 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 then starch. Cellulose is also surrounded by lignin, which is resistant to enzyme or acidic pretreatment.[400]

This report does not include 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 and spoil 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, labor, and energy costs.[401]

Feedstocks Selected for the Study

This report defines tropical second generation bioethanol as a biofuel derived from plant materials of two 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 defined as biofuel produced from crops that may often also be used as food crops. However, these crops often are produced in abundance, yet may not make it to market in the EAC region because of the lack of transportation or refrigeration.

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

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[398] *Fuel From Farms: A Guide To Small-Scale Ethanol Production* (Golden: Solar Energy Resource Institute, 1982), pp. 18.
[399] Ibid, pp. 26.
[400] Ibid, pp. 28.
[401] Ibid, pp.29.

- 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*)
- Prickly pears cactus (*Opuntia ficus-indica* or *Opuntia polycanta*)

- 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 the 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 underutilized 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 7.5 – 8.5 tons per hectare produced in the United States, production yields in the EAC are only about 1.8 tones per hectare.[402] 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:

[402] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production', last modified 2015, accessed September 25, 2015, http://faostat3.fao.org/download/Q/*/E.

- The amount of ethanol per ton of grain is approximately 400 liters, which is high compared to other raw materials.[403]
- 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 liters[404] per hectare because it is suitable to grow between the rows of cassava and sugarcane when these crops are still small or directly after the harvest.[405]

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.[406] 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.

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.[407] Seeds are also not commercially produced.[408]

This study is not meant to be exhaustive of 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.

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[403] Calculated by international tropical agriculture specialist, John Loke.
[404] F.O. Olasantan, H.C. Ezumah and E.O. Lucas, 'Effects Of Intercropping With Maize On The Micro-Environment, Growth And Yield Of Cassava', *Agriculture, Ecosystems & Environment* 57, no. 2-3 (1996): 149-158, accessed September 28, 2015, http://www.sciencedirect.com/science/article/pii/0167880996010195.
[405] Imran Haider Shamsi et al., 'Effect Of Maize Population (As Intercrop) On The Growth Of Ratoon Sugarcane And Maize Yield', *Asian J. of Plant Sciences* 2, no. 7 (2003): 532-534.
[406] J.N. Tissieres, 'Alcohol Fuels From Sisal Waste: New Solutions To Old Problems', in *International Symposium On Alcohol Fuels*, 1st ed. (Paris: Éditions Technip, 1986), 612-613.
[407] Carlos Razo et al., *Producción De Biomasa Para Biocombustibles Líquidos: El Potencial De América Latina Y El Caribe* (Santiago: Unidad de Desarrollo Agrícola, 2007), accessed September 28, 2015, http://www.olade.org/sites/default/files/CIDA/Biocomustibles/CEPAL/produccion%20de%20biomasa.pdf.
[408] Primary research by international tropical agriculture specialist, John Loke, e.g. Syngenta does not produce actually seed of sugar beet productive in the tropics.

Molasses

Production: The average production in 2010 to 2013 of molasses from sugarcane in the EAC is as follows:[409]

Kenya: 140 kt
Ethiopia: 85 kt
Uganda: 71 kt
Tanzania: 62 kt
Burundi: 5 kt
Rwanda: 2 kt

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

Sugarcane. Photo: Mette Nielsen via Wikimedia Commons.

Photo: John Loke.

Description: Bulk quantities of molasses can be purchased from sugar producers. For fermentation, molasses must be mixed with water.[410] Ethanol yield is approximately 200 liters per MT molasses.[411] Molasses can be stored for years and is easier to store than other

[409] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production', last modified 2015, accessed September 25, 2015, http://faostat3.fao.org/download/Q/*/E.
[410] Conni Thorsson, 'Process For The Production Of Ethanol Through Molasses Fermentation' (United States, 1989).
[411] Mercado Mata and Carlos Fransisco, 'Rendimiento De Etanol Y Producción De Vinaza Con Cuatro Sustratos Para La Fermentación De Melaza Con Saccharomyces Cerevisiae', *Zamorano: Escuela Agrícola Panamericana* (2006), accessed September 29, 2015, http://bdigital.zamorano.edu/handle/11036/753.

waste materials, such as fruits, roots, tubers, and stems of crops.[412] The energy and capital requirements to produce bioethanol from molasses are at least 25% lower than the requirements for sugarcane and sweet sorghum because no milling is required.[413] Compared to chips of cassava and sweet potato, the ethanol yield from molasses is low.[414] Mixing molasses with cassava or sweet potato chips will increase distillation efficiency of both energy and purchase/maintenance of equipment by approximately 50%.[415] 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 microdistillery.[416]

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 year round, 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 120-140 USD per MT.[417] 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.[418, 419, 420, 421, 422] Biogas digestion of vinasses typically has low yields[423, 424]. No dry cakes or animal feed can be obtained from the vinasses.

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[412] Eat By Date, 'How Long Does Molasses Last? Shelf Life, Storage, Expiration', accessed September 29, 2015, http://www.eatbydate.com/other/baking/how-long-does-molasses-last-shelf-life/.
[413] Reynaldo Palacios-Bereche et al., 'Extraction Process In The Ethanol Production From Sugarcane – A Comparison Of Milling And Diffusion', *Chemical Engineering Transactions* 39 (2014).
[414] Li Zhen-chong, Li Jun and Wei Chang Lian, *Increasing Cassava Yield Per Unit Is The Way Of Cassava Fuel-Alcohol About Raw Material Problem* (Kezaisheng Nengyuan/Renewable Energy Resources, 2008).
[415] Primary Research by International Tropical Agricultural Specialist, John Loke.
[416] Ibid.
[417] F.O.Lichts, 'World Molasses & Feed Ingredients Report', last modified 2015, accessed September 29, 2015, https://www.agra-net.net/agra/world-molasses-and-feed-ingredients-report/.
[418] Katie Hidalgo, 'Vinasse In Feed: Good For Animal And Environment', *All About Feed*, last modified 2009, accessed September 29, 2015, http://www.allaboutfeed.net/Nutrition/Raw-Materials/2009/11/Vinasse-in-feed-Good-for-animal-and-environment-AAF011591W/.
[419] Evandro Galvão Tavares Menezes et al., 'Physico-Chemical And Sensorial Evaluation Of Sugarcane Spirits Produced Using Distillation Residue', *Brazilian Archives of Biology and Technology* 56, no. 1 (2013): 121-126, accessed September 29, 2015, http://www.scielo.br/pdf/babt/v56n1/16.pdf.
[420] Ahmed O., Abdel Moneim E. Sulieman and Sirelkhatim B. Elhardallou, 'Physicochemical, Chemical And Microbiological Characteristics Of Vinasse, A By-Product From Ethanol Industry', *American Journal of Biochemistry* 3, no. 3 (2013): 80-83, accessed September 29, 2015, http://article.sapub.org/10.5923.j.ajb.20130303.03.html#Aff1.
[421] Malgorzata Krzywonos et al., 'Utilization And Biodegradation Of Starch Stillage (Distillery Wastewater)', *Electron. J. Biotechnol.* 12, no. 1 (2009), accessed September 29, 2015, http://www.ejbiotechnology.info/index.php/ejbiotechnology/article/view/v12n1-5/685#64.
[422] Renato de Mello Prado, Gustavo Caione and Cid Naudi Silva Campos, 'Filter Cake And Vinasse As Fertilizers Contributing To Conservation Agriculture', *Applied and Environmental Soil Science* 2013 (2013): 1-8, accessed September 29, 2015, http://www.hindawi.com/journals/aess/2013/581984/abs/.
[423] 'The Biogas Production From Mesophilic Anaerobic Digestion Of Vinasse', *IOSR Journal Of Environmental Science, Toxicology And Food Technology* 5, no. 6 (2013): 72-77.
[424] Carmen Baez-Smith, *Anaerobic Digestion Of Vinasse For The Production Of Methane In The Sugar Cane Distillery* (Loxahatchee: Smith Baez Consulting, Inc., 2006), accessed September 29, 2015, http://www.baez-chem-i-consulting.com/Download%20page%20files/MethaneProductionfromVinasse.pdf.

Recommendations: Molasses is an idealfeedstock for large distilleries located close to the sugar factories providing molasses. Molasses is also a recommended feedstock to start production at microdistilleries because a milling system is not required, reducing start up costs. It is possible to achieve an 8% concentration of ethanol from molasses at microdistilleries. To ensure that the production costs of the molasses ethanol are as low as possible, it is beneficially to concentrate diluted molasses with other feedstocks like grinded dry chips of sweet potato and cassava, or waste of different fruits.[425]

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

Roots and Fruits at Markets Unfit for Human Consumption

Production. Sugar and starch feedstocks. The average production in 2010 to 2013 of vegetables, melons, and pineapples in the EAC is as follows:[426]

Vegetables and melons:

Tanzania: 2,385 kt
Kenya: 2,246 kt
Ethiopia: 1,852 kt
Uganda: 1,080 kt
Rwanda: 658 kt
Burundi: 442 kt

Pineapples:

Tanzania: 338 kt
Kenya: 164 kt
Ethiopia: 6 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. [427, 428, 429] Wastes from the following crops are suitable: cassava, (sweet) potato, banana, plantain, pineapple peels, rotten melons, carrot and papaya.

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[426] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.
[427] Jenny Gustavsson et al., *Global Food Losses And Food Waste* (Rome: Food and Agriculture Organization, 2011), accessed September 29, 2015, http://www.fao.org/docrep/014/mb060e/mb060e.pdf.
[428] Anton Nahman and Willem de Lange, 'Costs Of Food Waste Along The Value Chain: Evidence From South Africa', *Waste Management* 33, no. 11 (2013): 2493-2500, accessed September 29, 2015, http://www.sciencedirect.com/science/article/pii/S0956053X13003401.
[429] Gudila A. Kereth et al., 'Assessment Of Post-Harvest Handling Practices: Knowledge And Losses Of Fruits In Bagamoyo District Of Tanzania', *Food Science and Quality Management* 11 (2013): 8-15, accessed September 29, 2015, http://pakacademicsearch.com/pdf-files/agr/525/8-15%20Vol%2011,%20Issue%201%20(2013).pdf.

Description. To assure that production of bioethanol from waste collected at vegetable markets will be economically feasible, at least 5 Metric Tons (MT) 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. [430, 431, 432]

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 odor, blocking drainage channels, visual unattractiveness, 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. It should also be available at relative large volumes to produce at least 1,000 L bioethanol per day at each distillery and therefore it is expected that production will only be feasible in cities larger 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.

Microdistilleries using waste can operate throughout the whole 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 distilleries operate nearby vegetable markets, the transport of the ethanol to the families using ethanol cookstoves is easy. Another important aspect is that the socializing of the distillery initiative will also be much easier if located close to the market. To fuel the boilers biomass is needed. In (or nearby) large cities waste from carpenters should also be available at a low cost. The amount of vinasse (spent mash) will be high with 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 microdistillery. 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 nearby the distilleries). Small amounts of dry cake will be obtained. Economically it will be an advantage to agree with truck companies to transport

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[430] R. Arumugam and M. Manikandan, 'Fermentation Of Pretreated Hydrolyzates Of Banana And Mango Fruit Wastes For Ethanol Production', *Asian J. Exp. Biol. Sci.* 2 (2011): 246-256, accessed September 29, 2015, http://www.ajebs.com/vol6/13.pdf.

[431] Janani K. Ketzi et al., 'Comparative Studies Of Ethanol Production From Different Fruit Wastes Using Saccharomyces Cerevisiae', *International Journal of Innovative Research in Science, Journal Engineering and Technology* 2, no. 12 (2013), accessed September 17, 2015, http://www.ijirset.com/upload/2013/december/15_Comparative.pdf.

[432] In Seong Choi et al., 'A Low-Energy, Cost-Effective Approach To Fruit And Citrus Peel Waste Processing For Bioethanol Production', *Applied Energy* 140 (2015): 65-74, accessed September 29, 2015, http://www.sciencedirect.com/science/article/pii/S0306261914012392.

vinasses to the farms, which produce vegetable for the markets. Truckloads of dry chips of sweet potato and cassava can also be transported easily.

Recommendations: 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.[433]

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

Mango Fruits

Production: The average production of mango fruit from 2010 to 2013 in the EAC:[434]

Kenya: 528 kt
Tanzania: 398 kt
Ethiopia: 69 kt
Rwanda: 18 kt
Burundi and Uganda: N/A

Credit: John Loke

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 5 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 approx. 80 L per MT of waste.[435] Storage time of waste after recollection cannot be more than four days. Both biogas production using the waste of the

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434 Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.
435 R. Arumugam and M. Manikandan, 'Fermentation Of Pretreated Hydrolyzates Of Banana And Mango Fruit Wastes For Ethanol Production'.

distilleries and biofertilizer 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 due to the high starch concentration in seeds, and thus pulp and seeds should be processed as a mixture.[436] Investment is inexpensive because the milling system does not require huge motors. There are no costs related to assisting farmers to start production.

Benefits and challenges: Mango is commonly cultivated in most countries of the EAC as a means to provide shade near roads, fields, and houses.[437] Frequently 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 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.[438] 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 to fertilize other mango plants or in rice production.[439] To fuel the boilers, shrubs with growing conditions similar to mango trees, like pencil plant and devils backbone, can be grown nearby and act as natural fences.[440]

Recommendations. Microdistilleries using mango waste cannot operate throughout the whole 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.[441, 442, 443]

[436] Yoram Fuchs, Edna Pesis and Giora Zauberman, 'Changes In Amylase Activity, Starch And Sugars Contents In Mango Fruit Pulp', *Scientia Horticulturae* 13, no. 2 (1980): 155-160.
[437] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.
[438] Primary Research by International Tropical Agricultural Specialist, John Loke.
[439] Sukhsatej Dhingra and Amin C. Kapoor, 'Nutritive Value Of Mango Seed Kernel', *Journal of the Science of Food and Agriculture* 36, no. 8 (1985): 752-756.
[440] John Loke, Luz Adriana Mesa and Ywe Jan Franken, *Euphorbia Tirucalli Bioenergy Manual* (FACT Foundation, 2011), accessed September 29, 2015, http://www.jatropha.pro/PDF%20bestanden/Euphorbia%20tirucalli%20Bioenergy%20Manual%20FACT.pdf.
[441] Primary Research by International Tropical Agricultural Specialist, John Loke.
[442] Selvyn González, *Evaluación De La Fermentación De Mezclas De Suero Láctico Y Melaza Para La Obtención De Etanol* (Universidad de San Carlos de Guatemalacentro Universitario Del Surescuintla, Informe Finalseminario, 2009), accessed September 29, 2015, http://www.scribd.com/doc/35362349/EVALUACION-DE-LA-FERMENTACION-DE-MEZCLAS-DE-SUERO-LACTICO-Y-MELAZA-PARA-LA-OBTENCION-DE-ETANOL#scribd.
[443] Luiz Carlos Basso, Thiago Olitta Basso and Saul Nitsche Rocha, 'Ethanol Production In Brazil: The Industrial Process And Its Impact On Yeast Fermentation', in *Biofuel Production - Recent Development And Prospects*, Marco Aurélio dos Santos Bernardesed. , 1st ed., 2011, accessed September 29, 2015, http://cdn.intechopen.com/pdfs-wm/20058.pdf.

Prickly Pear Cactus

Production: In Ethiopia, approximately 379,338 Ha are covered by prickly pear cactus.[444] Assuming an average fresh fruit yield of 12 MT/Ha per year, estimated prickly pear cactus production in Ethiopia is 4,552,056 MT per year. For Kenya, Uganda, Tanzania, Burundi and Rwanda there is no data available because prickly pear is rarely cultivated as a crop.

Type of Feedstock: Bioethanol from prickly pear is a second-generation biofuel because cactus is not considered an important fruit for human consumption. The fruit is the portion of the plant that is suitable for ethanol production; the leaves are not.[445]

Credit: Mussie Tesfay

Credit: John Loke

Description. To produce bioethanol from prickly pear fruit, there are two options: collect fruits from abandoned fields or living fences or start new fields. Several varieties can be grown to reduce the risk of losses from diseases or pests. Fruit yields of 20,000 kg/Ha have been commonly reported.[446, 447,448, 449] At dry weight percentages of 8%, this results in annual dry matter production of about 1600 kg/Ha only from the fruits.[450] Prickly pear it must be

[444] Gebremeskel Gebretsadik, Getachew Animut and Firew Tegegne, 'Assessment Of The Potential Of Cactus Pear (Opuntia Ficus Indica) As Livestock Feed In Northern Ethiopia', *Livestock Research for Rural Development* 25 (2013), accessed September 29, 2015, http://www.lrrd.org/lrrd25/2/moen25026.htm.
[445] Norma Retamal, José M. Durán and Jesús Fernández, 'Ethanol Production By Fermentation Of Fruits And Cladodes Of Prickly Pear Cactus [Opuntia Ficus-Indica (L.) Miller]', *Journal of the Science of Food and Agriculture* 40, no. 3 (1987): 213-218, accessed September 29, 2015, http://onlinelibrary.wiley.com/doi/10.1002/jsfa.2740400304/abstract.
[446] A Monjauze and Henry N LeHouérou, *Le Role Des Opuntia Dans L'économie Agricole Nord Affricaine*, 1965.
[447] P. Inglese, G. Barbera and T. La Mantia, 'Research Strategies For The Improvement Of Cactuspear (Opuntia Ficus-Indica) Fruit Quality And Production', *Journal of Arid Environments* 29, no. 4 (1995): 455-468.
[448] P. Inglese et al., 'Crop Production, Growth, And Ultimate Size Of Cactus Pear Fruit Following Fruit Thinning', *HortScience* 30, no. 2 (1995): 227-230, accessed September 29, 2015, http://hortsci.ashspublications.org/content/30/2/227.abstract.
[449] John Parish and Peter Felker, 'Fruit Quality And Production Of Cactus Pear (Opuntiaspp.) Fruit Clones Selected For Increased Frost Hardiness', *Journal of Arid Environments* 37, no. 1 (1997): 123-143, accessed September 29, 2015, http://www.sciencedirect.com/science/article/pii/S0140196397902615.
[450] Fernando Angel Galizzi et al., 'Correlations Between Soil And Cladode Nutrient Concentrations And Fruit Yield And Quality In Cactus Pears, Opuntia Ficus Indica In A Traditional Farm Setting In Argentina', *Journal*

mixed with a small amount of water during the fermentation process to assure pumping is possible. The ethanol yield is approximately 70 L per MT of fruit.[451, 452]

The prickly pear fruit has a very short shelf life; it cannot be stored more than one day after harvest. The fruit is seasonal and can only be harvested four months per year.[453] However, the fruit can be concentrated into juice and molasses. This molasses can be stored for approximately eight months.

Both biogas production using the waste from the fermentation process and the quality of the biofertilizer from the biogas digester are extremely high compared to other feedstocks such as sugarcane, molasses and root and tuber crops. However, the energy requirement to produce bioethanol from prickly pear cactus is high because the concentration of sugars in the fruits are low compared to other feedstocks, about 10-18% Brix of pulp and peel.[454, 455, 456] Up front investment is low because the milling system does not require huge motors. Establishment of the production fields will cost approximately between 240 and 1,000 USD per Ha, if plant material is available.[457]

Benefits and Challenges: Prickly pears are commonly cultivated in Ethiopia. In other EAC countries, production is unknown. Cactus grown for bioethanol should be a high priority feedstock, because it does not need large amounts of water and it is not commonly used for food. In regions where the cactus is grown during two rainy seasons a year, ethanol yields may be significantly higher from a second annual harvest. Cactus is highly drought-tolerant and can survive months without significant rainfall. Compared to crops like cassava, sweet potato, and sugarcane, the cost to grow cactus is low because cactus only needs planted once every eight years.

Although a good feedstock for the region, prickly pear presents several challenges. Investors must be attracted and committed to a long-term program. It will be necessary to introduce sufficient plant material to EAC regions where cactus is not currently grown, to train farmers, and to identify of the most productive varieties. Harvesting can be laborious and complicated

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of Arid Environments 59, no. 1 (2004): 115-132, accessed September 29, 2015, http://www.sciencedirect.com/science/article/pii/S0140196304000254.

[451] Oscar E. Bustos, 'Alcoholic Beverage From Chilean Opuntia Ficus Indica', *American Journal of Enology and Viticulture* 32, no. 3 (1981): 228-229, accessed September 29, 2015, http://www.ajevonline.org/content/32/3/228.abstract.

[452] Sam-Pin Lee, Suk-Kyung Lee and Young-Duck Ha, 'Alcohol Fermentation Of Opuntia Ficus Fruit Juice', *Preventative Nutrition and Food Science* 5, no. 1 (2015): 32-36, accessed September 29, 2015, http://www.koreascience.or.kr/article/ArticleFullRecord.jsp?cn=E1FSA3_2000_v5n1_32.

[453] Personal communication between two cactus producers in the Department of Huila in Colombia, and John Loke, 2008.

[454] Personal communication between Mussie Tesfay, Gaia Association, and John Loke, 2014.

[455] R. A. Chavez-Santoscoy, J. A. Gutierrez-Uribe and S. O. Serna-Saldívar, 'Phenolic Composition, Antioxidant Capacity And In Vitro Cancer Cell Cytotoxicity Of Nine Prickly Pear (Opuntia Spp.) Juices', *Plant Foods for Human Nutrition* 64, no. 2 (2009): 146-152, accessed September 29, 2015, http://www.ncbi.nlm.nih.gov/pubmed/19468836.

[456] Giuseppe Barbera et al., 'Physical, Morphological And Chemical Changes During Fruit Development And Ripening In Three Cultivars Of Prickly Pear Opuntia Ficus-Indica (L.) Miller', *Journal of Horticultural Science and Biotechnology* 67, no. 3 (1992): 307-312, accessed September 29, 2015, http://www.researchgate.net/publication/235751234_Physical_morphological_and_chemical_changes_during_fruit_development_and_ripening_in_three_cultivars_of_prickly_pear_Opuntia_ficus-indica_(L.)_Miller.

[457] J.C Guevara, O.R Estevez and C.R Stasi, 'Cost-Benefit Analysis Of Cactus Fodder Crops For Goat Production In Mendoza, Argentina', *Small Ruminant Research* 34, no. 1 (1999): 41-48, accessed September 29, 2015, http://www.sciencedirect.com/science/article/pii/S0921448899000425.

because of the cactus spines. The energy requirements to obtain ethanol or molasses from cactus fruits, based on analysis of fermentation and distillation trials by the International Tropical Agriculture Specialist, are 50% higher than processing cassava or sweet potato.

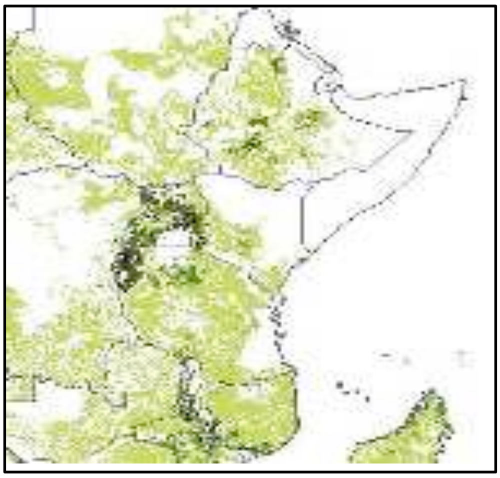
Recommendations. The potential to grow cactus on abandoned, infertile fields is very attractive. Employment will be generated during the production and processing of cactus into ethanol. The amount of vinasses is low, but the concentration of nutrients is high compared to other feedstocks.[458] Therefore the digestion of vinasses is characterized by relative high yields of biogas. The dry cake obtained after distillation can be commercialized as a biofertilizer for cash crops.

[458] Jean Magloire Feugang, 'Nutritional And Medicinal Use Of Cactus Pear (Opuntia Spp.) Cladodes And Fruits', *Frontiers in Bioscience* 11, no. 1 (2006), accessed September 29, 2015, http://www.researchgate.net/publication/7062959_Nutritional_and_medicinal_use_of_Cactus_pear_(Opuntia_spp.)_cladodes_and_fruits. pp. 2574-2589.

Sweet Potato

Production: The average production in 2010 to 2013 in kilotons (1 kt = 1,000 MT) of tubers of sweet potato in the EAC:[459]

Tanzania: 3,121 kt
Uganda: 2,656 kt
Rwanda: 943 kt
Ethiopia: 917 kt
Kenya: 898 kt
Burundi: 855 kt



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 farmers fields and at vegetable markets.

Dark green indicates regions with high production of sweet potato.[460]

Source: Drew Avery via Wikimedia Commons

[459] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.
[460] Harvest Choice International Food Policy Research Institute (IFPRI), 2011.

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[461]), which is the reason that farming knowledge and plant material of many varieties is commonly available in the EAC.[462] 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 during the whole year. This is case of 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 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% lower than crushing stems of sugarcane and sweet sorghum because of differences in milling systems and sugar/starch content.[463]

Benefits and challenges: Less land is needed to grow sweet potatoes than other crops due to their high crop yields.[464] Water footprintis also much less than sugarcane and other traditional ethanol crops.[465,]

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[461] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.
[462] Richard Gibson, 'How Sweet Potato Varieties Are Distributed In Uganda: Actors, Constraints And Opportunities', *Food Security* 5, no. 6 (2013): 781-791, accessed September 29, 2015, http://link.springer.com/article/10.1007%2Fs12571-013-0302-8.
[463] Gaia Association, *The Holistic Feasibility Study* (Addis Ababa: Project Gaia, 2015), accessed September 25, 2015, https://projectgaia.com/our-approach/resources/.
[464] Vincent Lebot, *Tropical Root And Tuber Crops* (Wallingford, UK: CABI, 2009).
[465] C.O, Cusumano and Néstor Zamudio, *Manual Técnico Para El Cultivo De Batata (Camote, Boniato) En La Provincia De Tucumán, Argentina* (Ediciones INTA, 2013).

[466] 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 will result in the production of tubers at a lower cost than tubers for food consumption. 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 relative 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 (3 MT a day at minimum) collected at farmer’s fields and vegetable markets are always highly beneficial for the production of bioethanol for stoves. 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 microdistilleries. Average yields (MT/ha; 2013) vary between 4 (Tanzania), 5 (Uganda), 9 (Burundi), 10 (Rwanda), 18 (Kenya) and 38 (Ethiopia).[467]

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[466] Winnie Gerbens-Leenes and Arjen Y. Hoekstra, 'The Water Footprint Of Sweeteners And Bio-Ethanol', *Environment International* 40 (2012): 202-211.
[467] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.

Cassava

Production: The average annual production in 2010 to 2013 of fresh cassava roots in the EAC.[468]

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

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 the farmers' fields and at vegetable markets.

Credit: International Institute of Tropical Agriculture (IITA)

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

Description: Cassava is a crop grown by millions of farmers in East Africa. Farmers are very experienced in cultivating this root crop, and seeds for several varieties are commonly available. The crop cycle is long, commonly taking about one year. However, distilleries processing cassava can produce bioethanol year round because dry chips can be made from fresh roots by cutting roots into slices and drying the slices in the sun. These dried chips can be stored for six months.[469]

Cassava is mildly drought-tolerant. It can survive up to four months without any significant rainfall or irrigation.[470] Sugarcane compared both to 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, compared to sweet potato, yields are lower. The energy and capital requirements to process cassava chips at a distillery are at least 50% lower than crushing stems of

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[468] Ibid.
[469] Solomon Abera and Sudip Kumar Rakshit, 'Effect Of Dry Cassava Chip Storage On Yield And Functional Properties Of Extracted Starch', *Starch - Stärke* 56, no. 6 (2004): 232-240.
[470] Patricia Moreno and Sharon Gourdji, 'Cassava Starch Content And Its Relationship With Rainfall', *Research Program On Climate Change, Agriculture, And Food Security*, last modified 2015, accessed September 29, 2015, https://ccafs.cgiar.org/publications/cassava-starch-content-and-its-relationship-rainfall#.VgrOK49Viko.

sugarcane and sweet sorghum. This is due to differences in milling systems and sugar/starch content. At a microdistillery the efficiency of starch extraction by milling roots and tubers using a hammer mill (1.5 MT/hour; 15 HP)[471] is minimum 95%, extraction of juice from the stems of sugarcane is approx. 60% (0.9 MT/hour; 8 HP).[472]

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 relative high yields of biogas. The dry cake obtained after distillation can be commercialized as a biofertilizer 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 (3 MT a day at least) 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 microdistilleries.

[471] Penagos, 'Triturador Picador PENAGOS TP-32C', last modified 2015, accessed September 10, 2015, http://www.etagro.com/index.php?page=shop.product_details&category_id=5&flypage=flypage.tpl&product_id=142&option=com_virtuemart&Itemid=1.
[472] Penagos, 'Trapiche Horizontal TH – 8', last modified 2015, accessed September 29, 2015, http://www.penagos.com/producto/trapiche-horizontal-th-8/.

Elephant Ear Leaf-Shaped Crops

<u>Production</u>. The average production in 2010 to 2013 of rhizomes from taro and cocoyam in the EAC:[473]

Rwanda: 149 kt
Burundi: 87 kt

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

Source: Amcaja via Wikimedia Commons.

Source: Luz Adriana Mesa.

[473] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.

Source: ChildofMidnight via Wikimedia Commons.

Type of feedstock. Starch feedstock. Bioethanol from elephant ear leaf-shaped 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.[474, 475, 476, 477] 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.[478] Because of easy multiplication, vegetative plant material of one or more species from Xanthosoma and Colocasia is commonly available.[479, 480] The crop cycles are long, in general one year, but microdistilleries processing taro can produce bioethanol throughout the year, using dry chips from fresh rhizomes, which are cut into slices and sun dried.[481] These chips also are able to be stored for up to six months. These crops are not productive in drier agro ecological zones; they require some water; however, it can be grown in water channels of rice,

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[474] United Nations Food and Agriculture Organization, 'Definition And Classification Of Commoditites', last modified 1994, accessed September 29, 2015, http://www.fao.org/es/faodef/fdef02e.htm#2.05.
[475] I S.V. Irwin et al., 'Molecular Characterization Of Taro (Colocasia Esculenta) Using RAPD Markers', *Euphytica* 99, no. 3 (1998): 183-189, accessed September 29, 2015, http://link.springer.com/article/10.1023%2FA%3A1018309417762.
[476] O. Mwenye et al., 'Ethno-Botanical And Morphological Characterisation Of Cocoyams (Colocasia Esculenta L. Schott And Xanthosoma Sagittifolum L. Schott) Germplasm In Malawi | RUFORUM Institutional Repository', *Repository.Ruforum.Org*, last modified 2015, accessed September 29, 2015, http://repository.ruforum.org/documents/ethno-botanical-and-morphological-characterisation-cocoyams-colocasia-esculenta-l-schott.
[477] Julian Osuji and Prince Nwala, 'Epidermal And Cytological Studies On Cultivars Of Xanthosoma (L.) Schott. And Colocasia (L.) Schott. (Araceae)', *IJPSS* 4, no. 2 (2015): 149-155.
[478] B.K. Ndabikunze et al., 'Proximate And Mineral Composition Of Cocoyam (Colocasia Esculenta L. And Xanthosoma Sagittifolium L.) Grown Along The Lake Victoria Basin In Tanzania And Uganda', *African Journal of Food Science* 5, no. 4 (2011): 248-254, accessed September 29, 2015, http://docs.mak.ac.ug/sites/default/files/Ndabikunze%20et%20al.pdf.
[479] Nwoko, S. U. "Development of Gocken Multiplication Technology for Cocoyam." Online at http://mpra. ub. uni-muenchen. de/17441/MPRA Paper17441/15 (2009): 17.
[480] H. Chand, M. N. Pearson and P. H. Lovell, 'Rapid Vegetative Multiplication In Colocasia Esculenta (L) Schott (Taro)', *Plant Cell, Tissue and Organ Culture* 55, no. 3 (1998): 223-226, accessed September 29, 2015, http://link.springer.com/article/10.1023%2FA%3A1017156112466.
[481] Humphrey Chukonoyere Ezumah, 'The Growth And Development Of Taro, Colocasia Esculenta (L) Schott, In Relation To Selected Cultural Management Practices.' (Ph. D., University of Hawaii at Manoa, 1972).

among oil palm, and in banana plantations.[482, 483] Compared to other crops, the cost to produce elephant ears 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.[484, 485, 486] Energy and capital requirements to process chips (sundried fragments of rhizomes) at the distillery are at least 50% lower than crushing stems of sugarcane and sweet sorghum. Leaves can be used to feed fish cultivated in ponds.[487, 488]

Benefits and challenges: Although rhizomes of elephant ear 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.[489, 490, 491] 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.[492] 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 largest challenge is the testing of different Xanthosoma varieties concerning their ethanol yield, which is highly dependent on oxalates in the rhizomes that affect yeast performance during fermentation.[493]

Recommendations. The fact that elephant ears grow in wetlands is attractive.[494] 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

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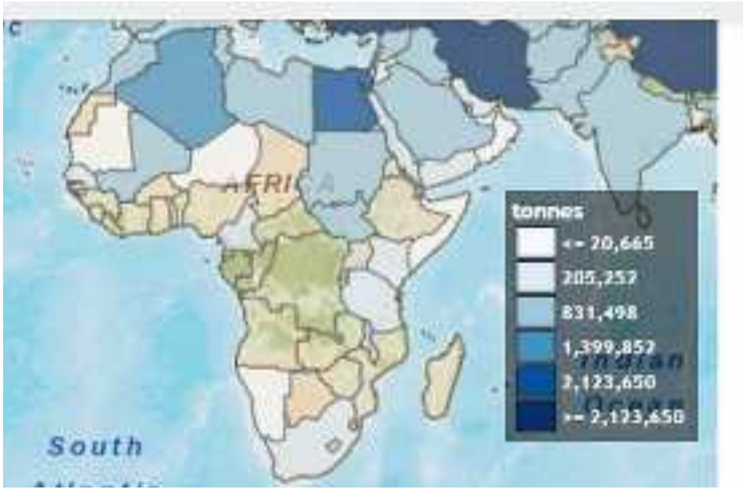
[482] S. Sunitha et al., 'Aroids And Water Relations: An Overview', *Journal of Root Crops* 39, no. 1 (2013): 10-21, accessed September 29, 2015, http://www.isrc.in/ojs/index.php/jrc/article/view/174/65.
[483] H. B. Naithani and K. Koch, 'Colocasia Esculenta', in *Edible Medicinal And Non Medicinal Plants: Volume 9, Modified Stems, Roots, Bulbs*, T. K. Limed. , 1st ed. (Springer, 2014), 454.
[484] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production', last modified 2015, accessed September 25, 2015, http://faostat3.fao.org/download/Q/*/E.
[485] E.L. Omenyo et al., 'Farmer Participatory Evaluation Of Eight Elite Clones Of Cocoyam (Xanthosoma Sagittifolium L. Schott)', *Ghana Journal of Agricultural Science* 48, no. 1 (2014): 21-27, accessed September 29, 2015, http://www.ajol.info/index.php/gjas/article/view/116240.
[486] S. Noor et al., 'Development Of Fertilizer Recommendation For Aquatic Taro (Colocasia Esculenta) In Grey Terrace Soil.', *Pertanika Journal of Tropical Agricultural Science* 38, no. 1 (2015): 83-92.
[487] Peter Omolo Otieno, 'Nutritional Evaluation Of Plant Leaves Fed To Fish By Farmers In Western Kenya' (Kenyatta University, 2012).
[488] I. Adejumo, 'Colocasia Esculenta (L.) Schott As An Alternative Energy Source In Animal Nutrition', *British Journal of Applied Science & Technology* 3, no. 4 (2013): 1276-1285.
[489] Primary Research by International Tropical Agricultural Specialist, John Loke.
[490] B. Adelekan, 'An Evaluation Of The Global Potential Of Cocoyam (Colocasia And Xanthosoma Species) As An Energy Crop', *British Journal of Applied Science & Technology* 2, no. 1 (2012): 1-15.
[491] Shubo Zhang et al., 'A Prospective Approach For Exploring Potential Biofuel Plants', *Journal of Life Sciences* 7, no. 1 (2013): 69-75.
[492] S. Sunitha et al., 'Aroids And Water Relations: An Overview', *Journal of Root Crops* 39, no. 1 (2013): 10-21, accessed September 29, 2015, http://www.isrc.in/ojs/index.php/jrc/article/view/174/65.
[493] Primary Research by International Tropical Agricultural Specialist, John Loke.
[494] A. M Puste et al., 'Importance Of Aqua-Terrestrial Ecosystem And Development Of An IFS Module In Water Monitoring, Productivity And Sustainability', *ARPN Journal of Science and Technology* 2, no. (2012): 31-47, accessed September 29, 2015, http://www.ejournalofscience.org/archive/vol2s/vol2s_3.pdf.

sugarcane and other feedstocks.[495, 496] The digestion of vinasses is characterized by relative high yields of biogas. The dry cake obtained after distillation can be commercialized as a biofertilizer for cash crops. It is recommended to grow biomass like pencil plant and devils backbone to assure sufficient fuel for the boilers of the distilleries.[497]

[495] Richelle M Alcantara, 'The Nutritional Value And Phytochemical Components Of Taro [Colocasia Esculenta (L.) Schott] Powder And Its Selected Processed Foods', *J Nutr Food Sci* 03, no. 03 (2013).
[496] B.K. Ndabikunze et al., 'Proximate And Mineral Composition Of Cocoyam (Colocasia Esculenta L. And Xanthosoma Sagittifolium L.) Grown Along The Lake Victoria Basin In Tanzania And Uganda', *African Journal of Food Science* 5, no. 4 (2011): 248-254, accessed September 29, 2015, http://docs.mak.ac.ug/sites/default/files/Ndabikunze%20et%20al.pdf.
[497] Primary Research by International Tropical Agricultural Specialist, John Locke.

Melons

Production: The average production in 2010 to 2013 of fruits from watermelon in the EAC:[498]



Kenya: 79.9 kt.
Tanzania: 26.3 kt.

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

Source: Ji-Elle via Wikipedia.

[498] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.

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) land must be available at a low cost, 2) melon varieties must be sweet (Brix higher than 14%) 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.[499] The pure plant oil can be used to fuel diesel generators for electricity generation of the microdistilleries or can be commercialized to fuel diesel engines outside the microdistilleries. Several varieties can be grown, and it 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.[500] The ethanol yield is approximately 70 liters per MT of fruit.[501, 502] The fruit cannot be stored more than one day after collection. Because harvest time will not be longer than four months per year, it is worthwhile to concentrate the fruit juice and peels of melon into a molasses. The molasses can be stored for a longer amount 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 biofertilizer are

[499] A Aktaş, Y Sekmen and P Sekmen, 'Biodiesel Production From Waste Melon Seeds And Using It As Alternative Fuel In Direct Injection Diesel Engine', *Journal of the Energy Institute* 83, no. 2 (2010): 69-74.
[500] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.
[501] Luis Fernando Hernández Gómez, Juan Úbeda and Ana Briones, 'Characterisation Of Wines And Distilled Spirits From Melon (Cucumis Melo L.)', *International Journal of Food Science & Technology* 43, no. 4 (2008): 644-650.
[502] Luis F. Hernández-Gómez et al., 'Comparative Production Of Different Melon Distillates: Chemical And Sensory Analyses', *Food Chemistry* 90, no. 1-2 (2005): 115-125.

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 the concentration of sugars in fruits (14% Brix) is low compared to cactus and mango. [503, 504] 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 500-1,000 USD per Ha supposing that plant material is available.[505]

Benefits and challenges: The integration of melon in crop rotation cycles with crops that out-yield melon is beneficial because the management of soil fertility, pests and diseases will be optimized.[506, 507] Due to the fact that the time between sowing and harvest is short (three to four months[508]) 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.[509] 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 no 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 microdistilleries; additional other fuels (biomass) are needed.

Recommendations: Because 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.

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[503] Rebecca Brown, *No3 2013 Melon Variety Trial* (Rhode Island Agricultural Experiment Station Bulletin, 2014), accessed September 30, 2015, http://digitalcommons.uri.edu/cgi/viewcontent.cgi?article=1009&context=riaes_bulletin.
[504] Laurence Cathrine Collin, Albertus Cornelius and Maria van de Ende, 'Hybrid Melon Variety 34-757 RZ' (United States, 2015).
[505] Cadenas del Sector Hortofruticola de Cordoba, 'Guia Técnica Para El Cultivo De Melon', accessed September 30, 2015, http://www.cadenahortofruticola.org.
[506] J.O. Olaoye, 'Challenges Of Weeding Operation In Intercropping And Mixed Cropping Systems In Nigeria', *Agrociencia* 16, no. 3 (2012): 144-151.
[507] Pauline Chivenge et al., 'The Potential Role Of Neglected And Underutilised Crop Species As Future Crops Under Water Scarce Conditions In Sub-Saharan Africa', *International Journal of Environmental Research and Public Health* 12, no. 6 (2015): 5685-5711.
[508] Bonnie Plants, 'Growing Cantaloupe And Honeydew Melons', last modified 2013, accessed September 30, 2015, http://bonnieplants.com/growing/growing-cantaloupe-and-honeydew-melons.
[509] D.M. Bardiviesso et al., 'Nitrogen Fertilization On Yield And Quality Of Yellow Melon In The Cassilândia - MS', *Revista Agrarian* 6, no. 20 (2013): 140-147.

Sugarcane and Sweet Sorghum

Production: The average production in 2010 to 2013 of stems from sugarcane in the EAC.[510]

Kenya: 5,693 kt
Uganda: 3,363 kt
Tanzania: 2,933 kt
Ethiopia: 2,588 kt
Burundi: 192 kt
Rwanda: 115 kt

There is no production data available of sweet sorghum.

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.

Sugarcane:

Credit: Luz Adriana Mesa

Credit: Creative Commons Corporation

[510] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.

Sweet Sorghum:

Credit: Swathi Sridharan via Creative Commons

Credit: Kansas State University

Description: Considering area cultivated, sugarcane is the second most important food crop in Africa outranking maize and yams.[511] 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 during only one season although irrigation may change this.[512] Sugarcane needs large amounts of water to achieve high yields, but sweet sorghum needs less.[513] 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 in a soil of a low fertility. Sweet sorghum is much less demanding.[514] Energy and capital requirements to process canes at a distillery are at least 50% higher than milling roots or tubers.[515]

Sweet sorghum is still not grown commonly in Africa.[516] However, sweet sorghum is an ideal crop because it can survive some months without significant rainfall.[517]

[511] Ibid.
[512] Federico Ganduglia et al., *Manual De Biocombustibles*, ebook, 1st ed., 2009, accessed September 25, 2015, https://arpel.org/library/publication/142/.
[513] B V S Reddy, A Ashok Kumar and S Ramesh, 'Sweet Sorghum: A Water Saving Bio-Energy Crop', in *International Conference On Linkages Between Energy And Water Management For Agriculture In Developing Countries* (Patancheru, India: ICRISAT, 2007), 1-12, accessed September 25, 2015, http://oar.icrisat.org/4799/1/SweetSorghumWatersavingJan2007.pdf.
[514] R.P. Wiedenfeld, 'Nutrient Requirements And Use Efficiency By Sweet Sorghum', *Energy in Agriculture* 3 (1984): 49-59.
[515] Ibid.
[516] Food and Agriculture Organization of the United Nations Statistics Division, 'Metadata / Production'.

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% of the juice out of the stems. Frequently, only 60% of the juice is obtained.[518] 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.[519, 520] The amount of vinasses both of processing sugarcane[521] and sweet sorghum[522] is large, but the concentration of nutrients is low, and therefore, the digestion of vinasses is characterized by relatively low yields of biogas. 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.[523]

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[517] Marcello Mastrorilli, Nader Katerji and Gianfranco Rana, 'Productivity And Water Use Efficiency Of Sweet Sorghum As Affected By Soil Water Deficit Occurring At Different Vegetative Growth Stages', *European Journal of Agronomy* 11, no. 3-4 (1999): 207-215.

[518] Kehinde A. Adewole, Michael T. Adamolekun and Robinson Akinnusi, 'Development Of A Sugarcane Juice Extractor For Small Scale Industries', *Journal of Multidisciplinary Engineering Science and Technology (JMEST)* 2, no. 5 (2015), accessed September 25, 2015, http://www.jmest.org/wp-content/uploads/JMESTN42350769.pdf.

[519] Ashok Pandey et al., 'Biotechnological Potential Of Agro-Industrial Residues. I: Sugarcane Bagasse', *Bioresource Technology* 74, no. 1 (2000): 69-80.

[520] C. Chuck-Hernández et al., 'Sorgo Como Un Cultivo Multifacético Para La Producción De Bioetanol En México: Tecnologías, Avances Y Áreas De Oportunidad', *Revista mexicana de ingeniería química* 10, no. 3 (2011): 529-549.

[521] Cintya Aparecida Christofoletti et al., 'Sugarcane Vinasse: Environmental Implications Of Its Use', *Waste Management* 33, no. 12 (2013): 2752-2761.

[522] E. Espana-Gamboa et al., 'Vinasses: Characterization And Treatments', *Waste Management & Research* 29, no. 12 (2011): 1235-1250.

[523] Federico Ganduglia et al., *Manual De Biocombustibles*, ebook, 1st ed., 2009, accessed September 25, 2015, https://arpel.org/library/publication/142/.

V. Recommendations for Establishing a Microdistillery

There are important issues to consider in planning for a microdistillery. One must decide what feedstocks to use and what the supply of feedstock will be throughout the year. One must be able to obtain site control for building the distillery. This site must have a water supply. Roadway access is also important. 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 co-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 microdistillery and cookstove business can fail. These might include:

- The microdistillery lacks proper management to oversee day-to-day operations, marketing of fuel and by-products, and procurement of inputs.
- The project does not work closely with farmers or famers' cooperatives to build community ownership and reliable feedstock supply.
- There is not enough capital for purchasing suitable equipment, management and labor, 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 microdistillery entrepreneur does not receive the 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. Not enough boiler fuel is available or cheap enough to fire the boiler to produce steam.
- The entrepreneur lacks access to the 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 for ethanol production and sale for 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 microdistillery. This section of the report outlines the various aspects involved in planning and building a microdistillery and provides recommendations for organizations and entrepreneurs who hope 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 microplant 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. We generally define microdistilleries as producing less than 5,000 liters of ethanol per day. For the purposes of this discussion, we will adopt the distinction of microplants vs. small plants used in David Blume's book, *Alcohol Can Be a Gas!*. This is a distinction made to distinguish fermentation process and equipment used. Blume notes that there are two basic approaches that can be used to size very, very small plants. These are for a microplant ranging up to 15,000 gallons per year (approximately 150 liters per day) and a small plant ranging up to 250,000 gallons per year (approximately 2,500 liters per day. [524] We define all of these plants as microdistilleries, but we adopt Blume's distinction here to discuss very small microdistilleries.

In considering very small microdistilleries, Blume notes that there are two approaches that can be taken. One is a very simple microplant. The microplant 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.[525] In some cases, this could be just one person or one family of several persons providing fuel for themselves and their neighbors. 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 microplant 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.[526] In Blume's discussion, both the microplants 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.

Microdistilleries can be modular and initial plans could leave room for eventual expansion and even for transition from batch to continuous distillation. One argument for scaling up from very, very small plants to somewhat larger microdistilleries is the experience and capacity building that comes with operating a very, 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, 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 – 5,000 liters per day. This is less of an artisanal approach and more of a business approach. While smaller projects may be

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[524] David Blume, R. Buckminster Fuller and Michael Winks, *David Blume's Alcohol Can Be A Gas!* (Santa Cruz, Calif.: International Institute for Ecological Agriculture, 2007), pp. 231.

[525] Ibid., pp. 231.

[526] Ibid., pp. 234.

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 liters 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.[527] It also allows for a more efficient boiler that can burn low grade biomass efficiently and cleanly. If starting smaller than 1,500 liters 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.[528]

Microplants 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 labor 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 book Produção de Álcool na Fazenda, 2011.[529] The alcohol produced in the artisanal distilleries would be of lower strength, perhaps 80%, thus requiring less energy to produce. It would be upgraded to 95% 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 microplant from mango drops and in another microplant 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 central plant and two or three go down, the central plant is still being supplied by the remaining microplants. This concept was also explored by Marcello Guimarães Mello in Biomassa: Energia dos Trópicos em Minas Gerais, 2001.[530] Guimarães is identified by some as the "father" of modern microscale farm-based distillation.[531] This approach to the production of fuel ethanol remains unproven, although there are many examples of successfully operating microplants of various descriptions.

Selecting Feedstocks

When selecting the feedstocks a facility will use 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 microdistillery 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 stores for long periods. Other feedstocks may be

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527 Personal communication between Gaston Kremer, Green Social Bioethanol, and Hilary Landfried, September 2015.
528 David Blume, R. Buckminster Fuller and Michael Winks, *David Blume's Alcohol Can Be A Gas*!, pp. 234.
529 Juarez de Souza e Silva, *Produção De Álcool Na Fazenda* (Viçosa: Aprenda Fácil Editora, 2011).
530 Marcello Guimarães Mello, *Biomassa: Energia Dos Trópicos Em Minas Gerais* (Belo Horizonte, 2001).
531 Juarez de Souza e Silva.

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 year around 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% without using more equipment and without increasing fuel for the boiler, assuming that the ethanol concentration in the mash can be kept high, e.g. 12%, rather than a more normal concentration of 8%.[532] If this approach is taken, it will be necessary to experiment with feedstocks and run tests to make sure 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 outgrowers, this may be desirable. Feedstocks should also be sourced from different localities and ecosystems to reduce the risk of climatic factors that could wipe out one area's entire crop. Thus wild crops or forest crops could supplement field crops.

<u>Storage</u>:
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 for 3 months to a year or more. Other feedstocks must be processed immediately.

Ethanol will store 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).

<u>Water Management</u>:
In many cases, we do not recommend producing feedstocks that require irrigation, 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, 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

[532] Gaia Association, *The Holistic Feasibility Study*.

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[533], [534], [535], [536]. Fruits like melons can be used to add water to the fermentation process and may also add simple sugars as well.[537]

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 microdistillery.[538] 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 L of ethanol per MT. After molasses, high yielding feedstocks include fresh roots, tubers, and rhizomes, which yield 140 L of ethanol per MT; fresh fruits and seeds such as fallen mangoes and other fruits unfit for human consumption, which yield 100 L of ethanol per MT; and prickly pear, melons, and fresh stems of sugarcane and sweet sorghum, which all yield 80 L of ethanol per MT.[539] 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 increases 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 1. Yields of the production of bioethanol from the feedstocks described in this study.[540]

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[533] S. Shanavas et al., 'Process Optimization For Bioethanol Production From Cassava Starch Using Novel Eco-Friendly Enzymes', *Biomass and Bioenergy* 35, no. 2 (2010): 901-906.
[534] R. Arumugam and M. Manikandan, 'Fermentation Of Pretreated Hydrolyzates Of Banana And Mango Fruit Wastes For Ethanol Production'.
[535] Liang Zhang et al., 'Application Of Simultaneous Saccharification And Fermentation (SSF) From Viscosity Reducing Of Raw Sweet Potato For Bioethanol Production At Laboratory, Pilot And Industrial Scales', *Bioresource Technology* 102, no. 6 (2011): 4573-4579.
[536] Conni Thorsson, 'Process For The Production Of Ethanol Through Molasses Fermentation' (United States, 1989).
[537] Jan Suszkiw, 'Watermelons Tapped For Ethanol', *United State Department Of Agriculture*, last modified 2009, accessed October 5, 2015, http://www.ars.usda.gov/is/pr/2009/090520.htm.
[538] Journey to Forever, 'Mother Earth Alcohol Fuel: Chapter 3 - Basic Steps', last modified 1980, accessed October 1, 2015, http://journeytoforever.org/biofuel_library/ethanol_motherearth/meCh3.html#alcoholyield.
[539] Ibid.
[540] The figures in this chart were provided by international feedstock expert, John Loke and are reflective of his 10+ years experience in the field.

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 below mango trees								
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

Other Considerations

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

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 Microdistillery:

The site for a new microdistillery 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 microdistillery, 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 microdistillery should ideally be not more than one hour because the transport of feedstocks, vinasses (the affluent of the biodigesters), 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.

Equipment at the Microdistilleries:[541]

Project Gaia recommends a fuel quality of 90-95% ethanol for use in the CLEANCOOK stove. To achieve this quality, an efficient distillation column is needed. The following are the major pieces of equipment included in a microdistillery:

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 fusel 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

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

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 liters 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 microdistillery providers. Based upon direct experience, we recommend the following companies; however, there are many manufacturers of microdistilleries:

1. Green Social Bioethanol[542]
2. Blume Distillation[543]
3. Spectrum Technology[544]

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 a high acidity, a 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 biofertilizer 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 microdistillery will require an organized team and good management. There are many variables involved in running a successful and profitable microdistillery. 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 microdistillery. 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. If farmers own or share in the distillery, they obtain value from the products of the distillery and therefore from the supply of their crops to the plant.

[542] http://green-social.com/
[543] http://www.blumedistillation.com/
[544] http://www.spectrumbio.net/index.html

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