Biomass Gasification

The East African Study

Working Paper

June 2012

Prepared for PISCES by Practical Action Consulting

Although this research is funded by DFID, the views expressed in this report are entirely those of the authors and do not necessarily represent DFID's own policies or views. Any discussion of their content should therefore be addressed to the authors and not to DFID.

Author: Kennedy Muzee
Contributors: Tameezan wa Gathui, Hannah Wanjiru
Editors: Dr Collin Pritchard, Mattia Vianelo
Main image: Acacia logs that are used to make charcoal inefficiently in Kikopey, Nakuru County.
Inset image: A simple gasifier assembly that can be used to produce both mechanical and electrical power in stationary installations that comes in either 10kw or 20kw output.
All images: Practical Action (unless otherwise stated)

Acknowledgements

This report drew primarily on desk research and contributions of statistical data, project case studies and human testimonies. I would like to thank Dr James Onchieku (KEFRI), Arudo Oraka (Moi University), K.V. Bhatt and Damaris Akoth (Tower Power (K) Limited), Carol Koech (GE Energy) and John Tumuhimbise (Ministry of Energy and Minerals, Uganda), for their valuable contribution and insights into this study.

Contents

List of Tables

List of Figures

Executive Summary

Biomass gasification, which is the conversion of solid fuels like wood and agricultural residues into a combustible gas mixture, is a fairly new technology in East Africa with most of the projects either at planning or demonstration stages. The technology has been applied in electricity generation especially in rural areas allowing households to access their energy needs. The technology has also been applied in enterprise development in the peri-urban and rural areas where it has been used for running sawmills, power supply and milling of cereals.

Unfortunately, East African policy documents do not explicitly mention this specific technology while they generally highlight the potential of renewable energy to meet the region's energy needs. The regional governments are still developing their gasification programme. For instance, Uganda sought the assistance of The Energy Resource Institute (TERI), an Indian research organisation, in developing its biomass gasification programme. In the case of Burundi, it abandoned its gasification programme due to poor feedstock assessment. Kenya and Tanzania have had several projects on the ground with mixed results.

The biomass gasification energy sub-sector is largely driven by the private sector and research institutions. Key representatives of research institutions include the Kenya Forestry Research Institute (KEFRI) and the Kenya Industrial Research and Development Institute (KIRDI). Others include MultiMedia University, Moi University, Kenyatta University and Jomo Kenyatta University of Agriculture and Technology (JKUAT). There are also national and international non-governmental organisations such as Envirofit engaged in the sub-sector. The main drivers are the private sector with Tower Power Limited planning to generate a total of 23MW of electricity in Marigat and Mariakani.

The Indian sub-continent has been at the forefront in biomass gasification technology development with numerous success stories. Many research institutions are engaged in fabrication and installation of gasifiers. Some of the notable successes include the decentralised energy systems India (DESI), a power gasifier which generates 80kW of electricity that is supplied to the surrounding colleges. Another notable case is in Malawi where ethanol is produced for blending of diesel and petrol fuels up to 20% thereby reducing the country's fuel imports. Saran renewable energy (SRE) gasification plant in India supplies about 220MWh per year, saving approximately 0.35 litres of diesel per kWh. This project has reduced an estimated 206 tonnes/year of CO_2 and increased local incomes through sale of biomass feedstock.

Best practice as evidenced by the case studies includes the need for well-designed business/project models. The models have to be carefully designed with special attention on feedstock supply, conversion technology and energy allocation. The business/project models should also provide suitable incentives to both the farmers and the entrepreneurs in order to ensure a mutually benefiting sustainable system. The DESI case study highlights the significance of involving the local population. The gasification plant was constructed by local and international partners and later transferred to the local partner. In addition to this, the gasification technology to be adopted should be available locally. This includes appropriate feedstocks, manpower requirement and spare parts. Other best practices include social, economic and employment benefits.

There are numerous barriers to the uptake and upscale of biomass gasification in East Africa; technical, non-technical, insecurity of specific feedstock supply, research and development, level of awareness/information and institutional barriers. Despite these barriers, there exist opportunities for this technology. It offers an opportunity for CO_2 capture which results in negative CO_2 emissions; it can attain very high efficiency as it takes advantage of the heterogeneous nature of biomass by producing a wide variety of low and high value end-products from the same feedstock. Furthermore, regionally, there is guaranteed feedstock as almost all types of carbon-rich material can be gasified.

The study recommends that financial incentives for the gasification technology should be made available. These can be in the form of feed-in tariffs, green certificates, tender schemes, blending requirements, and differential taxation. There is also need for continued research and development. This will go a long way to resolve the problems and will help in addressing issues related to adaptation of the technology to local conditions. Gaps also exist in entrepreneurial development. Thus, joint ventures between international financing organisations, governments and private companies should be encouraged. There is a need to increase capacity through training. There should also be a plan for knowledge transfer rather than hardware transfer for the technology packages in the long run.

Background

Energy is central to achieving the goals of sustainable development in East African economies yet the magnitude of energy needs facing the region today are high. Present government strategies seek to increase woodfuel supply through promotion of fast growing trees and to optimise efficiency in domestic, institutional and industrial consumption of woodfuel through promotion of improved stoves. Despite these efforts, the region has continued to experience imbalance in biomass energy supply/demand and sustainability is far to be attained. This imbalance exerts considerable pressure on forest and vegetation stocks, thereby accelerating the processes of land degradation.

Policy Innovation Systems for Clean Energy Security (PISCES) is a DFID funded energy action research project whose purpose is to increase available knowledge and understanding of the policy trade-offs between energy, food and water security in the context of Bioenergy. Biomass gasification is viewed today as an alternative to conventional fuel. In the gasification process, wood, charcoal and other biomass materials are gasified to produce so called ´producer gas´ for heat or electricity generation. Because of increased fuel prices and environmental concerns, there is renewed interest in the technology and PISCES is commissioning a desk study to identify the current status of the technology in East Africa.

Objectives of the Study

The objective of this study was to review the status of biomass gasification technology in East Africa. The report focuses on technologies, feedstock options, stakeholders in the sector, and illustrates some case studies and the best practices. Challenges and opportunities to improve energy access in East Africa have also been highlighted.

1 East African Biomass Gasification Technology

1.1 Introduction

Biomass gasification is the conversion of solid fuels like wood and agricultural residues into a combustible gas mixture. The gasification system basically consists of a gasifier unit, a purification system and energy converters - burner or engine. In order to generate electricity, the generated gas is used as a fuel in an electric generator set with a combustion motor. The gasifier is essentially a chemical reactor that uses wood chips, charcoal, coal or similar carbonaceous materials as fuel and burns them in a process of incomplete combustion owing to controlled air supply. Products of the gasification process include: solid ashes, partially oxidised materials like soot (which require to be removed periodically from the gasifier) and generator gas. The main flammable components of the resulting generator gas are carbon monoxide (CO), hydrogen (H2), and methane (CH4).

Conversion of biomass to liquid fuels can be carried out in three ways; direct biomass liquefaction, fast pyrolysis, and gasification to syngas followed by catalytic conversion to liquid fuels (or indirect liquefaction).

In direct biomass liquefaction, the feedstock is put in contact with a catalyst at high temperatures in the presence of added hydrogen. The product is a synthetic oil, or bio-oil.

Pyrolysis and gasification are thermo-chemical conversion technologies that decompose biomass and its residues into valuable intermediate products. In a bio-refinery, these products can be further processed to high-quality commodities such as solid, liquid and gaseous fuels and refined chemicals.

Biomass resources include agricultural residues; animal manure; wood wastes from forestry and industry; residues from food and paper industries; municipal green wastes; sewage sludge; dedicated energy crops such as the grasses, sugar crops (sugarcane, sorghum), starch crops (maize, wheat) and oil crops (sunflower, jatropha, palm oil).

Organic wastes and residues have been the major biomass sources so far, but controversially, energy crops are gaining importance and market share. With re-planting, biomass combustion is a carbon-neutral process as the carbon dioxide (CO2) emitted has previously been absorbed by the plants from the atmosphere. Residues, wastes and bagasse are primarily used for heat and power generation amongst the sugar industries in the region. Most biomass fuels have a heating value in the range of 10-16 MJ/kg (table 1).

Table 1: Sample Substance Heating Values

Type of fuel	Fuel	Calorific value	
		kJ/g	kwh/k
Solid	Charcoal	33	10.7
	Coal	25.33	8.1
	Wood	17	5.5
	Dung cake	6 – 8	2 – 2.6
Liquid	Kerosene	48	15.5
	Petrol	50	
	Diesel	45	15.5
	Ethanol	30	9.7
	Biogas	35 – 40	11.3 – 20.9
	Butane	50	
	Methane	55	17.8
	Hydrogen	150	48.5

Source: Parasnis, 2010

The figure below shows the common biomass conversion paths.

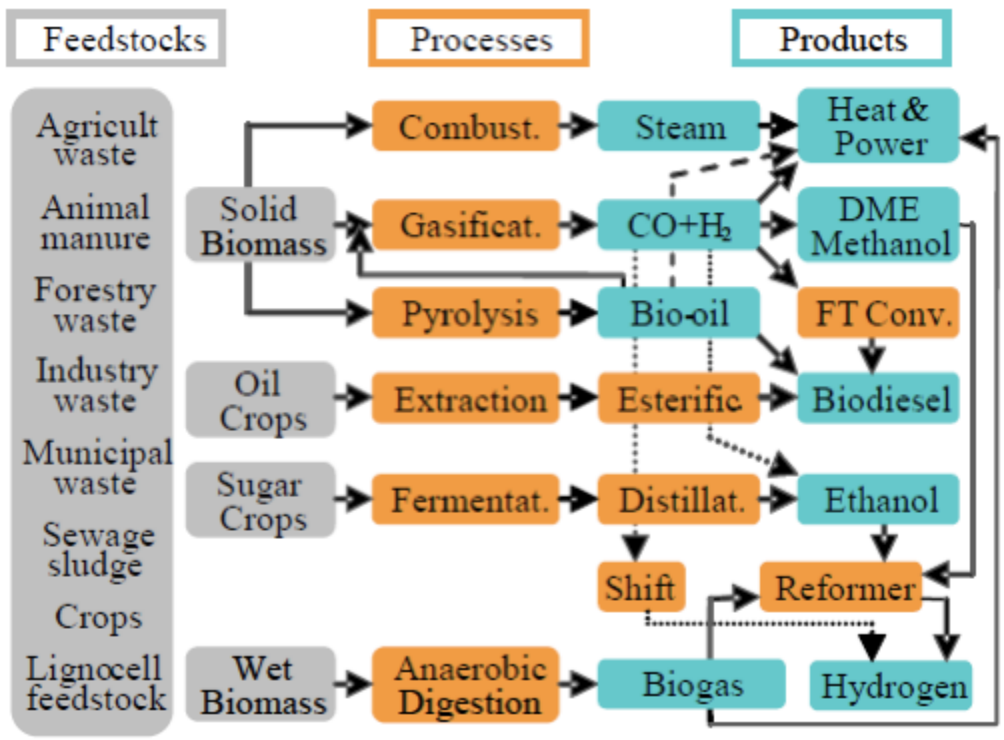

Figure 1: Biomass Conversion Paths

Source: OECD/IEA, 2007

Current technical research, development and demonstration (RD&D) efforts to advance biomass gasification are concentrated in three general areas: progress in scale-up; exploration of new and advanced applications; and improving operational reliability (Babu 2005).

Owing to the variety of feedstocks and processes, costs of bio-power vary widely. Co-firing in coal power plants requires limited incremental investment of between US$50 - US$250/kW and the electricity cost may be competitive (US$ 20/MWh) if local feedstock is available at low cost (no transportation). In the case of biomass, typical costs range from US$3 - US$3.5/GJ and the electricity cost may exceed US$30 - US$50/MWh. Due to their small size, dedicated biomass power plants are more expensive ranging between US$1,500 and US$3,000/kW than coal plants. Electricity cost in cogeneration mode range from US$40 - US$90/MWh. Electricity cost from new gasification plants is around US$100 - US$130/MWh, but with significant reduction potential in the future (OECD/IEA, 2007). To date, gasifier is the best available technology tapping the highest amount of energy content in the biomass (Bhatt, 2011).

1.2 Biomass Gasifier Technologies

Different gasification reactor technologies exist in the market. The major ones include; down-draft fixed bed (also known as co-current fixed bed); up-draft fixed bed (also known as counter-current fixed bed); fluidised bed; entrained flow; slurry bed; supercritical water. Other minor technologies include Lurgi dry ash; BGL slagging; blue tower; vertical vortex; screwing two-stage; and the plasma gasifier. The main technologies are discussed in the following sub-section.

1.2.1 Down-Draft Fixed Bed Gasifier (DDFB)

This type of gasifier consists of a fixed bed of carbon-rich fuel which the oxidising medium flows through downwards. The gas produced is at a high temperature and the thermal efficiency is also relatively high. A significant advantage is that the formed tar levels are low (Biomass Engineering, 2008).

1.2.2 Up-Draft Fixed Bed Gasifier (UDFB)

This gasifier is similar to the down-draft type except that air, oxygen or steam flow through the bed upwards. The throughput of this method is relatively low, but the thermal efficiency is similar to the down-draft type. The volume percentage of methane in the producer gas is significant, which facilitates methanation for Synthetic Natural Gas (SNG) production. Tar production is also high at normal operation temperatures implying additional costs in cleaning (Biomass Engineering, 2008).

1.2.3 Fluidised Bed Gasifier (FB)

A fluidised bed can be bubbling (BFB) or circulating (CFB). Fluidised beds are very common for combustion of coal, biomass and waste in medium to large heat and power plants (>5 MW). In the fluidised bed, the fuel is fluidised by the oxidising agent. The operational temperature is lower, meaning that the fuel needs to be reactive. Fluidised beds generally require careful feedstock preparation, considering moisture content and size of the solid fuel particles (Biomass Engineering 2008).

1.2.4 Entrained Flow Gasifier (EF)

In this technology, the solid or liquid fuel fed to the entrained flow gasifier is gasified with oxygen. Reaction occurs in a dense cloud of aerosol at high temperatures and usually high pressures. A high throughput can be achieved, but the thermal efficiency is reduced as the high-temperature syngas must be cooled significantly before cleaning (Biomass Engineering 2008). Low methane and tar production but high oxygen requirements are other features of the EF-gasifier, which make it most suitable for H2 -rich gas production (Olofsson et. al. 2005). EF-gasifiers are the only attractive option for extremely large (> 1,000 MW thermal) bio-refinery systems.

1.2.5 Indirect Gasifier

With indirect gasification, heat is supplied from an external source which can be any heat source of the right temperature. The goal is to transfer the heat generated in the external heater to the gasification reactor. This can be done by circulating and heating the fluidising fluid bed reactors (e.g. in a twin-bed or dual-bed gasifier) and by heating the reactor walls in fixed-bed reactors (Karlsson and Malm 2005).

The indirect gasification has the following major advantages: it offers flexibility of the heating source which facilitates process heat and by-product recovery; low nitrogen dilution risk; and high methane content in the syngas if methanation (catalytic process of converting syngas to SNG) is the primary purpose (ibid).

2 Applications Of Biomass Gasification

As highlighted in the previous section, there are many different kinds of gasifiers dependant on their design and types of fuels they use. Portable gasifiers have been applied in running motor vehicles while stationary gasifiers integrated with engines are being used to generate electricity (10- 100 kWe), sericulture, textile dyeing, drying cardamom and rubber, tobacco curing, brick making and in large scale cooking. These technologies are widely in use in rural areas of developing countries (Onchieku et al, 2011; TERI, 2010).

Gasifiers, when integrated with engines, provide mechanical power which can be used for running automobiles and other stationary machinery. The use of downdraft gasifiers fuelled with wood or charcoal to power cars, lorries, buses, trains, boats and ships have already proved their worth in the past. Before and during 2nd World War, gasifiers were largely used to power vehicles. Most of the gasoline and diesel driven vehicles during this period were converted to run on producer gas (Onchieku et al, 2011).

Past studies indicate charcoal gasifiers present less operational problems and are therefore recommended for village level applications. This is in contrast with gasifiers fuelled with wood or agricultural residues. Thus, they are suited for village applications. For example, micro scale gasification systems (1-10kw) can be used by small and medium scale farmers to provide power to run their irrigation system. The equipment is small, cheap, simple and transportable (ibid).

If firewood is available in sufficient quantities, biomass gasification technology can serve as an option for energy supply in rural communities. Owing to great concern for conservation of forests and availability of fossil fuels, gasification is not seen as universally applicable technology, but acts as a component within range of available regenerative energies (table 2). It can be a valuable supplement to renewable sources of energy such as wind, solar and hydropower.

Table 2: Technical Summary of Biomass Gasification

Variable	Electricity	Cooking gas	Heat
Scale/application	Small-medium scale		
Energy provided	Electricity, rotation	Heat	Heat
Electrical capacity	5-500kW	10-1200 Nm3/hr	40-5000MJ/hr
Equipment	Gasifier, gas clean-up, diesel engine	Gasifier, gas clean-up, gas distribution, stove	Gasifier and furnace
Feedstock	Wood chips, maize cobs, rice husks, cotton stocks, coconut shells, palm nut shells, soy husks, saw dust, biomass briquettes		
Availability	Very readily available		
Feedstock input	1.0 - 1.4kg biomass + 0.1L diesel / kWh	0.1 - 0.15kg biomass / MJ	
Key costs	Capital, diesel fuel, labour	Capital, labour	
Environmental concerns	Wastewater clean-up otherwise it is a clean combustion process		
Employment	Small, increases with labour intensity of biomass collection		
Capacity requirements	Low to medium skill level for operator		

Source: Kartha et al., 2005

The following section provides the detailed application of biomass gasification adoptable to the region.

2.1 Electricity generation

Most of the rural areas in the East Africa region are characterised by wide dispersal of the population and inadequate infrastructure. To improve living standards and productivity of these rural communities, a sustainable source of energy is required. Electricity is necessary to provide households basic needs such as lighting and to run small scale implements and appliances such as TV, radio and other ICT devices. Energy is also required in agriculture for operating irrigation pumps, threshers, planters, etc. Gasifier-engine system combined with a generator can provide electrical energy for lighting and other household needs. Small scale gasifier systems ranging between 10 - 30kw can be adopted by communities to improve the quality of their lives. Figure 2 shows a simplified gasifier engine that can be used to generate electricity for rural communities.

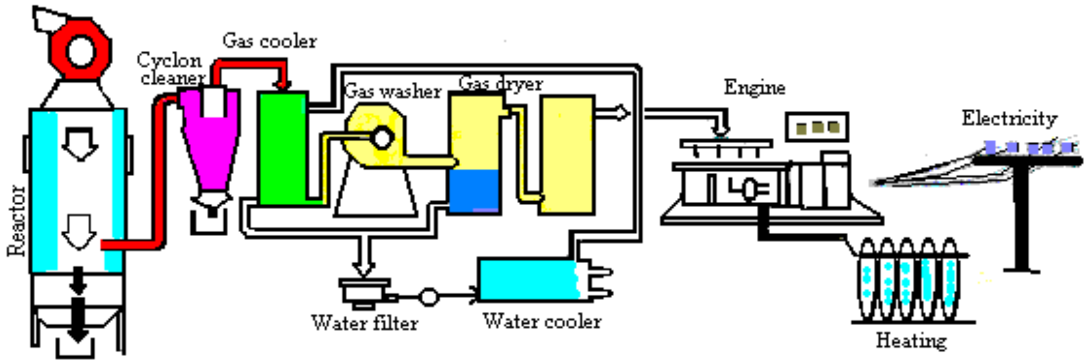

Figure 2: Gasifier engine system combined with generator

Source: Onchieku et al, 2011

According to the biomass energy resource assessment by the Asian and Pacific Centre for Transfer of Technology (APCTT) handbook, the typical capital cost of gasifier based power generation systems consisting of a gasifier, producer gas cleaning and cooling system, engine and generator is provided in table 3.

Table 3: Typical Capital Cost of Power Gasifiers (1)

Generation capacity	Capital cost (US$/kW)	Source
10-25 kWe systems with 100% producer gas engines	1,490 – 1,703	MNRE, 2008
50-500 kWe systems with 100% producer gas engines	937	CII, 2005
50-500 kWe in dual fuel mode	639	CII, 2005

Source: Maithel, 2009

From the table above, the capital cost depends on the size of the power plant. The unit cost decreases with increase in size of the power gasifier plant. The unit cost is significantly higher for smaller sized systems (<25 kWe). Another factor to note is that 100% producer gas engines are costlier compared to dual fuel engines. Furthermore, the cost of the biomass gasifier reactor, cleaning and cooling train, depends significantly upon the choice of material (e.g. stainless steel or mild steel, its thickness) and the quality of fabrication.

Other sources of cost analysis indicate a different story as highlighted in the table below.

Table 4: Typical Capital Cost of Power Gasifiers in India (2)

Generation capacity	Capital cost (US$/kW)
>500kW	> 1000
30-500kW	300 - 800
7-30kW	150

Source: Onchieku et al, 2011

2.2 Household energy

Gasifier stoves can be adopted by households for cooking purposes. A gasifier stove is a metallic biomass fuelled cooking stove designed in such a way that the fuel is first converted into combustible gases through intense heating which then burns with a clean flame. The stove can be fuelled with dry firewood, sawdust, agricultural wastes, wood shavings, chunks or twigs (DEEP, 2010).

The stoves are very compatible to the cooking habits of the rural majority in East Africa that currently rely on firewood as fuel, and could be used as substitute for other conventional stoves such as charcoal cookstoves or the three stone fire place. The gasifier stove is currently being applied in preparation of food and heating water. Moreover, the stoves can be locally produced by the informal sector (jua kali). The stove requires basic raw materials such as sheet metal, tin cans, screws and pop rivets, and can be made with simple hand-tools such as tin snips, pliers, hammers and screwdrivers.

The components of the stove can readily be found locally and include the outer chamber, inner chamber, the pot rest and the stand. The outer chamber can be made from iron sheet gauge 28. An 8kg sheet can produce approximately 3 stoves. The inner chamber is made from iron sheet gauge 26 and similarly, a sheet of 8kg can produce lining for 5 stoves. Approximately 2kg of scrap metal can be used to make the stove stand (legs) and pot holder. A 2kg scrap metal is good enough to make an additional 2 stoves. Depending on the amount and type of fuel used, the stove can burn within the range of 30 minutes to 1 hour.

The gasifier stove is attractive to restaurants, peri-urban households who use charcoal and firewood and rural households still using firewood for cooking purposes. Some of the notable benefits of the stove include; significant fuel savings compared to the traditional three-stone stove; clean burning i.e. less air pollution than many types of biomass stoves, including charcoal cookstoves that releases a lot of carbon monoxide; cooks faster; uses readily available biomass materials such as agro-residues (ibid).

2.3 Enterprise development

According to Onchieku et al (2011), in Kenya, large scale enterprises with an energy requirement above 500 kW use specialised fluidised bed or fixed bed installations. The equipment is custom built and fully automated. The cost of such equipment is in the range of US$ 1,000 per installed kW and above.

For medium scale applications with an energy requirement between 30 -500 kW, fixed bed equipment fuelled by wood, charcoal and some types of agricultural wastes is ideal. The cost of the equipment is in the range US$300 - 800/kW (gasifier only) depending on type and capacity, level of automation and auxiliary equipment. It can be used in small to medium size industries (secondary wood industries, sawmills, coconut desiccating factories, etc.) as well as in power supply to remote communities (Onchieku et al, 2011).

There is also small scale equipment that is ideal for village application. The energy requirement for these types of equipment range between 7 - 30kW and can be applied in maize or cereals milling, small scale sugarcane crushing, looms etc. One advantage with the equipment is that it is very cheap i.e. costs less than US$150/kW and it is extremely reliable and requires any specialised skill in operation and maintenance (ibid).

The last set of equipment can be applied in micro scale industries with an energy requirement between 1 - 7kW. This equipment can also be used by small and medium scale farmers in East Africa to power irrigation systems. Due to the size of the equipment, it can be moved from one place to another in addition to being simple and cheap (ibid).

Biomass gasification is also applied in shaft power systems where agricultural appliances such as tractors and harvesters are attached. Another useful application of producer gas units is in irrigation systems. The case study on Saran Renewable Energy (SRE) provided in this report, highlights some of the benefits of mechanical power generated by the gasifier. This power has been used to support small businesses, including grain and oil mills, sawmill, a welder, a battery charging station, a cinema and ‘generators’ supplying village lighting. In addition to this, the electricity from the Saran renewable energy (SRE) plant is used to operate ten irrigation pumps by farmers living close to the transmission lines. A total of 30 hectares are irrigated, at about one third of the cost of diesel pumps that were once being used.

2.4 Transport fuels

Methanol, hydrogen and Fischer-Tropsch Liquids (FTL) can be produced from biomass through gasification. Besides MeOH, hydrogen and FT-liquids, DiMethylEther (DME) and synthetic natural gas can be produced from syngas. The syngas undergoes a series of chemical reactions. The downstream equipment of the gasifier for conversion to H2, methanol or FT diesel is the same as that used to make these products from natural gas. FTL resembles a semi-refined crude oil. The mixture can be shifted to synthetic diesel or gasoline or further refined to jet fuel, naphtha and other fractions (Onchieku et al, 2011; Schwietzke et al., 2008).

Currently, commercial biofuels production via gasification is non-existent in East Africa but interest is on the rise and development efforts have been made over the past decades. The main development challenge is gas cleaning; scale up of processes and process integration.

3 East African Policy Scenario Analysis

Most East African policy documents do not explicitly mention biomass gasification technology but generally highlight the potential of renewable energy to alleviate the regions energy needs.

Biomass gasification being a relatively new technology, Kenyan policy documents do not explicitly mention it. For instance, Sessional Paper No. 4 of 2004 indicates that the government through waiver of import duty and taxes on equipment for electricity generation from renewable energy sources will promote electricity generation. This, it foresees, will endear potential investors to venture into electricity generation. With capital costs of the gasifiers in the range of 7 – 500kW costing US$ 150 – 800, this policy will go a long way in ensuring the technology is accessible to communities willing to engage in joint projects. Small and medium scale enterprises also have an opportunity to venture into the business of electricity generation. Unfortunately implementation of this policy has been difficult for the sector. Solar photovoltaics (PVs) which have been around for some time, were dogged by this policy. Previously, importation of fully assembled PV systems attracted no duty while importation of its spare parts attracted duty. This meant that once the system broke down, there were no spare parts to replace them due to affordability concerns.

Furthermore, Sessional Paper No. 4 of 2004 goes further to state that the government will undertake pre-feasibility and feasibility studies on the potential for renewable energy sources and for the packaging and dissemination of information. The last time a comprehensive biomass assessment was performed was in 2000 and for this technology to be widely accepted, more up-to-date data is necessary. Moreover, a central information clearing house on technologies is non-existent. Instead, the information is in the reserve of various institutions and ministries.

The Kenyan Energy Act, 2006 Section 43 (3a and 4) empowers the Energy Regulatory Commission to ensure that the rates or tariffs established for contracts to supply electrical energy are just and reasonable. Unfortunately, the feed-in tariffs keep being reviewed annually and key players in the sector complain that this is not enough incentive to grow the sector. Another stumbling block is the long negotiation process before a mutually benefiting tariff structure is agreed upon.

In the case of Tanzania, the Rural Energy Act, 2005 and the Energy Policy, 2003 highlights the government's commitment to facilitate rural energy provision in the form of financial support for the capital costs of investment, technical assistance for project preparation, training and other forms of capacity building; and promotion of efficient biomass conversion and end use technologies in order to save resources and minimise threats on climate change respectively. Biomass gasification is a relatively new technology in Tanzania and technical expertise to run and operate the gasifiers is lacking. More effort in the form of training and awareness is required if the country is to take advantage of the technology. Technology dissemination will be made easier once the relevant institutions acquire the relevant skills.

Uganda National Energy Policy, 2002 seeks to diversify power generation sources to ensure security of supply and establish the availability, potential and demand of the various energy resources in the country. To this end, the Ministry of Energy contracted the energy resource institute (TERI) to develop its biomass gasification programme. Unfortunately, this was abandoned midway and no headway has been reported, although it is suggested that a local company was given that mandate (Tumuhimbise, pers.comm).

The energy sector in Rwanda is undergoing vigorous changes and its impacts are yet to be studied in greater detail especially in regard to the laid down policy. The National Energy Policy, 2004 advocates for the introduction of appropriate rural energy development, financial, legal and administrative institutions. In addition, the policy seeks to establish norms, codes of practice, guidelines and standards for renewable energy technologies, to facilitate the creation of an enabling environment for sustainable development of renewable energy sources. Recently, the Energy, Water and Sanitation Authority (EWSA) advertised for experts on renewable energy and energy efficiency so as to develop and harmonise its national policy for renewable energy and energy efficiency. Before biomass gasification becomes a household name in Rwanda, devoted effort is required in training, research and development.

The Burundian structural adjustment programme for the power sector was initiated in 1989, which included privatisation, but civil and political unrest slowed the process. Although the Sectoral Policy on Energy, Water and Mines, 2006 allows for duty free importation of renewable energy hardware to promote widespread usage, not much has been achieved in the biomass gasification sub-sector.

The table below provides a summary of the various energy policy documents in the region.

Country	Policy document	Policy statement
Kenya	Sessional Paper No.4 of 2004	Government is committed in promoting electricity generation from renewable energy sources through waiver of import duty and taxes on equipment for power generation from renewable energy sources as one of the incentives to investors. Section 6.4.1 (i-iv) … government to undertake pre-feasibility and feasibility studies on the potential for renewable energy sources and for the packaging and dissemination of information. Section 6.6.3 part 2 (c & d) provides for review of the fiscal regime applicable to the energy sector with a view to granting tax holidays on: power plants using renewable energy including biomass (10 years) and dividend incomes from investments made on domestic energy sources (7 years).

Country	Policy document	Policy statement
	Energy Act, 2006	Part V, Section 103 empowers the Minister to promote development and use of renewable energy technologies. Section 27, Part 1 allows for generation of electricity and transmission up to 3 MW without a license. Section 43 (3a and 4) empowers the Energy Regulatory Commission to ensure that the rates or tariffs established for contracts to supply electrical energy are just and reasonable. MoE encourages potential Independent Power Producers (IPPs) to carry out feasibility studies on renewable energy generation on the basis of which power purchase agreements with the Kenya Power and Lighting Company (KPLC) are negotiated.
	National Climate Change Response Strategy paper	Recommends zero rating of taxes on renewable energy technologies. This is foreseen to reduce the high upfront cost of such technologies. Emphasises the promotion of use of alternative renewable energy such as solar, biomass, wind, biofuels and agricultural wastes. Identifies the role the biomass has to play in mitigating against climate change. Advocates for concerted effort in promotion of efficient biomass, solar and liquefied petroleum gas (LPG) cookers with the government taking centre stage on issues of cost through provision of subsidies and/or tax waivers to vulnerable groups in the society.
	National Energy Policy, 2004	Provide sustainable energy services for development. Utilise energy as tool to accelerate economic empowerment for urban and rural development. Improve access to affordable energy services. Provide an enabling environment for the provision of energy services. Promote development of indigenous energy resources. Promote energy efficiency and conservation as well as prudent environmental, health and safety practices

Country	Policy document	Policy statement
Tanzania	National Communications to the UNFCC for Tanzania	Improve efficiency in existing plants through maintenance, improved steam production and management, improvements to motor drive systems, cogeneration and power factor correction. To develop indigenous sources of energy to substitute for imported petroleum products. To ensure that the existing and expanded supply of energy is environmentally sustainable.
	Rural Energy Act, 2005	Supplying modern energy to rural areas promotes growth in economic production and productivity as well as social services. Promoting, facilitating and supporting modern energy services in rural areas will enable sustainable development to be achieved. The role of government in rural energy service provision is that of a facilitator of activities and investments by private and community entities. Facilitation of rural energy provision shall be in the form of financial support for the capital costs of investment, technical assistance for project preparation, training and other forms of capacity building.
	National Energy Policy, 2003	Generation of electric power shall be fully open to private and public investors as independent power producers. Investment shall be based on economic and financial criteria considering open access to regional network, balanced domestic supply and environmentally impacts. Promote efficient biomass conversion and end-use technologies in order to save resources….and minimising threats on climate change.
	National Forest Policy, 1998	Enhance contribution of the forest sector to sustainable development of Tanzania. The policy advocates for joint management of resources between the government and communities. Private individuals will be allowed to manage natural forests and get incentives to establish private forests.

Country	Policy document	Policy statement
Rwanda	National Energy Policy, 2004	Encourage efficient end-use technologies and good household practices. Encourage wider application of alternative sources of energy for cooking, heating, cooling, lighting and other applications. Ensure sufficient, reliable and cost effective energy supply to the industry and commerce sector in order to meet its increasing demand. Encourage efficient use of alternative energy sources. Introduce appropriate rural energy development, financial, legal and administrative institutions. Establish norms, codes of practice, guidelines and standards for renewable energy technologies, to facilitate the creation of an enabling environment for sustainable development of renewable energy sources. Promote efficient biomass conversion and end-use technologies in order to save resources; reduce rate of deforestation and land degradation, and minimising threats on climate change. Ensure inclusion of environmental considerations in all renewable energy planning and implementation, and enhance co-operation with other relevant stakeholders. Support research and development in renewable energy technologies.
	Vision 2020	Support research and development of rural energy. Promote application of alternative energy sources other than wood and charcoal, in order to reduce deforestation, indoor health hazards and time spent by rural women and children in search of firewood. Promote entrepreneurship and private initiative in the production and marketing of products and services for rural and renewable energy. Ensure continued electrification of rural economic centres and make electricity accessible and affordable to low income customers. Facilitate increased availability of energy services, including grid and non-grid electrification to rural areas. Establish norms, codes of practice, standards and guidelines for cost effective rural energy supplies.

Country	Policy document	Policy statement
Uganda	National Energy Policy, 2002	Diversify power generation sources to ensure security of supply. To establish the availability, potential and demand of the various energy resources in the country. To increase access to modern, affordable and reliable energy services as a contribution to poverty eradication. To improve energy governance and administration. To stimulate economic development. To manage energy – related environmental impacts.
	Priority Policy Action no. 2 (strategic intervention)	Develop selected renewable energy projects e.g. Kakira sugar cogeneration…
	National Communication	To meet some of the objectives, the government shall employ the following strategies: Promote the use of alternative sources of energy and technologies, which are environmentally friendly. Promote efficient utilisation of energy resources. Promotion of private sector participation in the development of both conventional and renewable energy resources.
Burundi	Poverty Strategy Paper, 2006	Measures the government will take to expand national power capacity by disseminating information on alternative energy sources affordable to low-income households. UNDP Energy Thematic Trust Fund (TTF) project, which closed in 2003, had the objective of strengthening national policy framework to support energy for poverty reduction and sustainable development. Consideration will be given to supporting either community or private sector managed national grid interconnected rural electrification projects through a one-off financial subsidy. Government to fund rural electrification activities on a cost-sharing basis with communities.

Country	Policy document	Policy statement
	Sectoral Policy on Energy, Water and Mines, 2006	Promote private sector participation in biomass energy production, distribution and marketing.
		Promotion of fast maturing trees for energy production; promote establishment of commercial woodlots including peri-urban plantations.
		Regulate charcoal market to encourage sustainability.
		Increase the rate of adoption of efficient fuel wood (firewood) stoves from 8% currently to 26% by 2020.
		Promote inter-fuel substitution especially peat, kerosene, biogas and LPG.
		Raise awareness among the affected population through networks of different sectors (education, health, etc.) to inform on the impact of solid fuel use on health and preventive measures.
		Promote research in and development and demonstration of the manufacture of cost effective RETs.
		Promote development of appropriate local capacity for manufacture, installation, maintenance and operation of basic RETs.
		Promote development for RETs which are yet to reach commercialisation.
		Allow duty free importation of renewable energy hardware to promote widespread usage.
		Provide tax incentives to producers of renewable energy technologies and related accessories to promote their widespread use.
		Provide fiscal incentives to financial institutions to provide credit facilities.
		Support community based water lifting and pumping, using renewable energy technologies through cost sharing arrangements and fiscal incentives.
		Promote feasibility studies on the utilisation of municipal waste as a source of energy.
		Promote feasibility studies on the utilisation of agricultural waste as a source of energy.

Sources: MoI, 2004; MoE, 2004; GoK, 2010, MoEM, 2003; MEMD, 2002; MoEM, 2005; MoWEM, 2006; PRSP, 2003, RoR, 2006

4 Status And Potential Of Biomass Resources

Economies in all of the countries' of East Africa are agro-based. Over 75% of the total agricultural outputs in the region are produced by smallholder farmers with farm sizes of about 2.5ha on average, producing mainly for home-consumption, and using traditional technologies. The main crops grown include cereals, root crops, banana, tea, pyrethrum, sisal, cut flowers, coffee, cotton and tobacco (Salami, et al, 2010). These constitute an extensive quantity of biomass which can be used as feedstock for biomass gasification. The following section discusses the various feedstocks for gasification.

4.1 Wood and forest resources

Wood waste is a renewable resource that can be used to generate electric power, steam or liquid biofuels such as ethanol. Wood waste refers to low-grade timber material with no other identifiable market or environmental value. This includes material that is left in the forest after the higher-value timber resources have been harvested, and the sawdust, shavings, off-cuts and other wastes associated with timber processing. The table below provides the East African wood charcoal production figures.

Table 6: East Africa Wood Charcoal Production, 2010

Country	Tonnes
Rwanda	264,503
Burundi	303,048
Kenya	902,486
Uganda	906,579
Tanzania	1,558,324
Total	**3,934,940**

Source: FAOSTAT, 2011

4.2 Agricultural residues/wastes

As indicated in the previous sub-section, the lion's share of East Africa's economies is agro-based. In the case of Tanzania, agriculture remains the main contributor to the GDP, contributing 43%. In Uganda and Kenya, however, the rapid development of the service sector with a growth rate of about 9.5% has outpaced agriculture, contributing 45% and 60% of the GDP, respectively, far above agriculture's contribution of 30% and 34%. Nevertheless, agriculture still accounts for about 75% of the labour force in all these countries, underscoring the importance of the sector in job creation and poverty reduction across countries. The main crops grown in the region include maize, beans, sorghum and millet. The following tables provide East African agricultural production figures. Wastes or residues generated from these crops are captured in Appendix 1.

Table 7: East Africa Agriculture Production (tonnes), 2009

Country	Commodity					
	Beans	Cassava	Coconut	Coffee	Groundnuts	Oil palm
Burundi	202,934	235,369	0	25,130	7,967	15,500
Kenya	465,363	819,967	60,134	57,000	27,296	0
Tanzania	948,974	5,916,000	577,099	68,577	385,480	65,000
Uganda	452,000	5,179,000	0	195,871	185,000	0
Rwanda	326,532	980,000	0	28,000	10,414	0

Source: FAOSTAT, 2011

Table 8: East Africa Agriculture Production (tonnes), 2009

Country	Commodity						
	Rice paddy	Sisal	Sorghum	Sugarcane	Tea	Wheat	Maize
Burundi	78,432	0	81,176	132,769	6,729	8,583	120,379
Kenya	37,198	16,155	99,000	5,610,700	314,100	129,200	2,439,000
Tanzania	1,334,000	23,800	709,000	2,370,000	32,000	92,400	3,324,200
Uganda	181,000	0	497,000	2,350,000	48,663	20,000	1,272,000
Rwanda	111,076	0	174,499	63,000	20,000	72,430	285,505

Source: FAOSTAT, 2011

4.3 Coal

Coal reserves in Tanzania are estimated at about 1,200 million tonnes of which 304 million tonnes are proven (Kassenga, 1997). Coal sites include Kiwira, northwest of Lake Nyasa and Mchuchuma/Katewaka on the south east of the lake. Generally, the available coal is bituminous, with an average ash content of about 25% and calorific value of between 22 and 28MJ/kgm (DEA, 2008). Some coal from Kiwira is presently being used to generate electricity (6MW) and also for other thermal requirements in some industries including cement and textiles mostly in the neighbouring regions of Mbeya, Iringa and Morogoro (MoEM, 2003). The coal has been analysed to contain high content of sulphur, which calls for the application of cleaner technologies (Mkilaha and John, 2001). Efforts are being made under the Mtwara Development Corridor project to utilise coal at Mchuchuma-Katewaka for the generation of up to 400MW of electricity (Kusekwa, 2011). While increasing the electrification level, such developments will also improve the existing generation mix by relieving its strong bias to hydropower.

Kenya has coal reserves that are due for exploitation in the Eastern province where production is expected in the next three years. The coal is for local use and it is estimated at 400 million tonnes and is earmarked to save in foreign exchange through substitution of coal and oil imports. The lion's share of the coal will go into cement and steel industries which import coal worth KShs. 3.6 billion a year (Reuters, 2011).

Uganda, Rwanda and Burundi do not have coal resources for exploitation.

5 Status Of Biomass Gasification Technology In East Africa

Biomass gasification application in East Africa is still at a very nascent stage. Despite this fact, there have been some biomass gasification projects that are in various stages of implementation. The following section discusses some of these projects.

5.1 Mafia Island Project, Tanzania

This project was initiated by H.J. Stanley and Sons Limited as an independent power producer (IPP). The company was to generate electricity through a biomass gasifier and then sell it to the national utility, Tanzania Electricity Supply Company (TANESCO). The project cost about US$ 8 million and was envisaged to use coconut wastes to generate 2MW of electricity from a gasification power plant which will then be transmitted through a 60km 11KV line. The technology adopted was the 200KV Ankur biomass gasifier WBG 500 imported from India. The coconut plantation stands on 3,000 hectares of land.

Financing of this project was secured in four phases. Phase I cost US$ 508,000 and Phase II depended on the success of Phase I. Subsidy on Phase I was secured through a 50:50 sharing by UNEP/AFREPREN. According to the project developers, the Rural Electrification Authority/Rural Electrification Fund was to come on board and bring in extra funding. Consequently, the electricity generated would attract a tariff of US$ 0.15/kWh. This tariff was to increase to US$ 0.20/kWh in case the government did not provide a subsidy.

This project was meant to provide multiple benefits; increase Tanzania's energy mix, deliver electricity access to 2 – 4 additional villages, new value to the coconut biomass that was previously considered as a 'waste' (old coconut palms, leaves and shells).

Source: Batalia, 2006

5.2 Tanganyika Planting Corporation (TPC) and Mtibwa Sugar, Tanzania

These projects were initiated by Tanganyika Planting Corporation (TPC) and Mtibwa Sugar. The main objective of the two projects was to expand cogeneration capabilities for the factories. The electricity generated was to be used by the factories' own power needs and the surplus to be sold to the national utility, the Tanzania Electric Supply Company limited (TANESCO).

The bagasse, the waste from sugarcane processing, was to be used as the feedstock in the gasification power plant that could generate more than 15MW of electricity. TPC was to source its fuel from the expanded production capacity from 500 – 144,000 tonnes. In the case of Mtibwa, it was to use its existing 5,000 hectares with additional raw material sourced from out growers. As a result of this, an additional production capacity of approximately 300% was to be actualised.

The bagasse gasification project was to cost US$ 8 million although at the time Mtibwa was undecided on whether to go ahead with the project. Subsidy was to be arranged between the individual companies and REA/REF. The electricity generated was to be sold to the main grid at US$ 0.15/kWh. This project was to increase Tanzania's electricity generation capacity and consequently get more rural population connected on the national grid.

Source: Batalia, 2006

5.3 Biomass Gasification in Coffee and Manufacturing Industries, Uganda

In 2011, Taylor Biomass Energy, a United States of America based company, signed a collaboration agreement with Uganda's Sesam Energetics Limited to construct a US$160 million biomass gasification plant in Kampala.

The plant will use gasification technology to generate at least 40 MW of power, and recycle at least 1,030 metric tons of municipal solid waste from Kampala per day, generating energy for over 35,000 households. The project will be executed by Taylor Biomass Energy Uganda.

Project proponents indicate that the project will provide over 400 direct jobs, with an additional 1,100 indirect jobs and will save about 3 million tons of greenhouse gas emissions annually. Taylor Biomass Energy is finalising a power purchase agreement with the state-run Uganda Electricity Transmission Company on a waste management contract, and securing the necessary finances to begin constructing the recycling plant.

The electricity generated will be used predominantly by the coffee and manufacturing industries.

Source: Waste Management World, 2011

5.4 Mukono Gasification Plant, Uganda

The gasifier installed on a 100 acre farm in Mukono, Uganda, was manufactured by Ankur Scientific India and powers a Fieldmarshall modified diesel engine producing 3-phase electricity that runs on a dual fuel-mode rated at 25 % diesel and 75% gas. This is the first time this technology has been implemented in Uganda. The maximum electrical output is rated at 10 kW. The grid consists of 30 electricity poles and a total of 700m wire to transmit power to the farm house, pig stay and security lights. The following are the highlights:

- The gasifier has been operational since August 2006 on a daily basis, for 6 hours in the evenings and producing 3kW.
- The gasifier uses eucalyptus as a feedstock.
- The system is operated by a qualified technician and the daily workload is approximately 1.5h per day including fuel preparation.
- The 500 litres of cooling water are replaced every 2 to 3 months.
- Under the current use of 18kWh daily, the gasification system uses 0.84kg of air dried wood and 0.17 litres diesel per kWh produced. This totals 15kg of wood and 3 litres of diesel per day. The system produces electricity at 0.67US$/kWh.
- Economic analysis (Buchholz et al, 2007) of this project indicated the need for well-designed business models to manage the feedstock supply, conversion technology, and energy allocation. Such business models have to provide incentives for farmers and entrepreneurs to provide biomass and electricity all year around.

Source: Buchholz et al, 2007.

5.5 Biomass Gasification in Burundi

By 1984, a 36kWh dual-fuel diesel generator set equipped with a downdraft gasifier was installed at the Tora Tea Factory in Burundi. The installation was designed and built in Belgium and financed by the EC/LOME II Programme and provided at no cost to the factory through the Government of Burundi. Although the unit was tested only with woodfuel, it was sold as suitable for peat gasification. The World Bank's Biomass Gasification Monitoring Programme (BGMP) established, however, that the plant could not be operated for any sustained period on Burundi's peat, the only fuel available. This marked the end of biomass gasification effort at the Tora Factory.

Source: Stassen, 1995

5.6 Biomass Power Generation, Kenya

There are plans by a local company, Tower Power Limited to put up two biomass power plants in Mariakani and Baringo in Kenya. The planned total generation capacity is estimated to be 23MW and will use Prosopis juliflora (commonly known as Mathenge) as feedstock. The clean electricity generated will be used to power an industrial park around the areas and also the surrounding community will benefit from these projects.

Use of P. juliflora as feedstock is based on extensive research pioneered by Tower Power Limited's sister companies in India. P. juliflora contains a lot of energy and if well processed can be used to generate power. According to Tower Power Limited, the feedstock will be grown by the local communities and additional supplies sourced from the neighbouring Taveta District.

In the case of the Baringo district, the use of P. juliflora as a feedstock will help in controlling the plant owing to its invasive nature and has been in the local media owing to its destructive growth habits. These two projects will provide employment, both directly and indirectly to over 1000 beneficiaries (Source: Tower Power Limited, 2012).

Other biomass gasification plants can be found in Mogotio and Rea Vipingo where sisal waste is used as feedstock. The electricity generated is used internally by the factories. Rea Vipingo generates approximately 1.5MW. Another company, E-Z Energy is scheduled to start generating 30MW of electricity in Turkana and will use P. juliflora as feedstock (pers. comm).

6 Biomass Gasification Stakeholders In Kenya

The Kenyan biomass gasification programme has attracted government affiliated institutions such as the Kenya Forestry Research Institute (KEFRI), Kenya Industrial Research and Development Institute (KIRDI); public institutions – MultiMedia University, Jomo Kenyatta University of Agriculture and Technology (JKUAT) and the private sector. The following sub-sections discuss these stakeholders in more detail.

6.1 Kenya Forestry Research Institute (KEFRI)

KEFRI was established in 1986 under the Science and Technology Act (Chapter 250) to carry out research in forestry and allied natural resources. The institute has a role to play in influencing policies on forest resource management.

Currently, KEFRI is implementing two projects on biomass gasification technology in collaboration with the Ministry of Energy and MultiMedia College of Kenya. The first gasification project is on electricity generation and will act as a demonstration/pilot project. This project is supported by the Finnish and Austrian governments through the Energy and Environment Programme (EEP – Southern and Eastern Africa). The project is earmarked to generate about 55kW on completion.

The second biomass gasification project is for application at household level using micro-gasifiers. These are specially designed cookstoves that use small quantities of biomass resources of different sizes. It is expected that KEFRI will develop a sustainable fuel supply model which will be the basis for sustainability of the programme while engaging entrepreneurs. Artisans have already been trained on fabrication skills adopting the Top Lit DownDraft (TLUD) technology. This project is funded by United Nations Development Programme (UNDP) and the Ministry of Energy.

KEFRI is also involved in research on biofuels using Jatropha, croton and castor as the first generation feedstock. There are many experimental trials of Jatropha on provenances and varieties to develop best practices along the value chain.

6.2 Kenya Industrial Research and Development Institute (KIRDI)

KIRDI is a national research institute established in 1979 under the Ministry of Trade and Industry and mandated to undertake multidisciplinary research and development in industrial and allied technologies. The institute's core objectives are handled by the R&D and Technology Transfer departments. The major R&D departments are; Engineering, Energy and Environment amongst others.

The Energy Division is charged with the responsibility of researching, designing and developing energy efficient technologies as well as championing the growth of bio-fuels and renewable energies as alternative sources of energy.

6.3 Jomo Kenyatta University of Agriculture and Technology (JKUAT)

The Institute of Energy and Environmental Technology (IEET) was established in 1990 to carry out research and training in energy and environmental technologies within JKUAT. The establishment of the Institute arose from the need for rational management of energy, natural resources and the environment at large.

The institute is currently putting a lot of emphasis on innovations and development of energy, environmental and occupational health and safety technologies. These include development of cleaner production technologies for adoption in industries, innovations in renewable energy and non-renewable energy technologies to help alleviate climate change impacts.

6.4 Ministry of Energy (MoE)

The MoE is charged with policy formulation in the energy sector. The national energy policy has a number of broad objectives, including ensuring adequate, quality, cost effective and affordable supply of energy to meet development needs, while protecting and conserving the environment.

The Energy Act 2006 advances the government's quest to promote renewable energy through provision of an enabling framework for efficient and sustainable production, distribution and marketing of biomass and other renewable energy sources. The Act does not explicitly mention household energy types and its development in Kenya.

6.5 Envirofit

Envirofit International was established to develop well-engineered technology solutions to improve the human condition on a global scale, with a primary emphasis on applications in the developing world. It utilises donations and institutional support to fund product development and early stage product commercialisation, and then uses operating income to develop and expand its businesses.

Envirofit is the world leader in design, manufacture and distribution of clean efficient cookstoves worldwide. Envirofit has a wealth of experience in product design, an established supply base for high quality low cost product and a dedicated supply chain team that can deliver product anywhere in the world.

Since its inception, over 250,000 clean technology cookstoves have been sold, allowing over a million people to breathe easier, reduced CO2 emissions by over 360,000 tonnes and saving almost 200,000 trees.

6.6 Sustainable Agriculture Community Development Programmes (SACDEP)

SACDEP was launched in October 1992 and works within the framework of sustainable agriculture principles. The mission of the organisation is to facilitate sustainable development for communities in Kenya and the East African Region who have low access to resources, to enable livelihood improvement through sustainable agriculture principles and practices.

SACDEP designs, implements and evaluates projects guided by the four principles of sustainable agriculture - economic feasibility to farming enterprises especially for small-holders; environmental soundness to all agricultural undertakings; social justice to all especially small-holders and cultural acceptability to all initiatives introduced.

In addition to other projects, SACDEP train rural households on benefits of renewable energy. Renewable energy is applied in food processing, cooking, lighting, transportation etc.

6.7 Tower Power Limited, Kenya

Tower Power Limited is a private company founded by Dr Manu Chandaria whose Comcraft Group has pioneered Industrialisation in Kenya. Tower Power Limited operates throughout the entire range of energy sector activities. The firm boasts of highly experienced research scientists, technicians, service providers, a highly accomplished engineering team and a rapidly growing presence in clean energy industries in the country.

The company is positioned to address the rural community's energy requirement by use of the available biomass, right from initial investigations through to plant operation and maintenance, engineering, projects, and distribution. Tower Power Limited is currently active in projects to deliver small scale biomass power generation plants, windmill energy generating projects in Kenya.

The company is in advanced stages of negotiating a power purchase agreement (PPA) with the Kenyan government. Tower Power Limited's plan involves four strategies, namely; multiple renewable energy sources to reduce hydro dependence and acquire fuel diversity, multiple locations to mitigate harsh climatic conditions and replace costly emergency independent power production, multiple small scale power generation plants to gain advantage of distributed network and multiple power consuming customers unifying their need to secure power supply.

They are currently working on two small scale biomass power plants that will generate a total of 23MW. The power plants will be located at Marigat location, Baringo District and Mwavumbo location, Kwale District. The feedstock for the power plants will be P. juliflora, an otherwise notorious weed. Each of the power plants will generate 11.5MW which will be distributed to the national grid (in Marigat) and sold to the local industries in Mwavumbo. Tower Power Limited estimates that the standing biomass in Baringo alone can run the project for 30 years sufficiently without depletion.

7 Case Studies: Successful Biomass Gasification Projects And Best Practice

Philippines, Indonesia, Brazil and India were amongst the first countries to implement biomass gasification programmes based on locally developed technologies. Several biomass gasification systems were installed through donor financed projects and local entrepreneurs in a large number of developing countries. This section highlights some of the successful cases.

7.1 Biomass Gasification Projects in Developing countries

With the continued global campaign to combat climate change, many developed and developing countries are now looking for alternative sources of energy to minimise greenhouse gas (GHG) emissions. In addition to being carbon neutral, the use of biomass for energy reduces dependency on the consumption of fossil fuel; hence, contributing to energy security and climate change mitigation. As earlier observed, biomass gasification technology in the region is still at pilot stage with some projects being abandoned all together.

The Indian subcontinent has been very active in biomass gasification technology with many successful case studies being reported. The Energy Resource Institute (TERI), for instance, has developed about 10 biomass gasifier based packages and has ownership of 6 patents since its inception; it has installed more than 300 systems all over India with a cumulative capacity of more than 13MW. The gasification systems have been exported to Sri Lanka, Nepal, Bhutan and Thailand. Moreover, TERI is involved in developing the Ugandan biomass gasification programme.

The following section highlights some successful biomass gasification projects in developing countries that can be replicated in the region.

7.1.1 Case Study 1: Decentralised Energy Systems India (DESI) Power Gasifier, India

This was a demonstration gasifier installed in Orchha, Madhya Pradesh in India, by a non-governmental organisation (NGO) engaged in promotion of renewable energy. The organisation installed an 80kW electricity generator which supplies power to a local college and for its own consumption (mainly for research and manufacture of paper).

The plant consumes approximately 1 tonne/day of a biomass material which is harvested and locally processed before being used in the gasifier. Experiments with vertical integration (in which gasifier managers produced the weed) demonstrated a market-oriented approach of purchasing Ipomea from local suppliers resulted in improved performance. Through cogeneration, heat is produced via the engine exhaust which is also used for production of paper thus improving the general economic performance of the company.

The gasifier plant has been operational since 1996 and runs for 10-12 hours per day. It has a modest cost of less than 0.10 US$/kWh. This project has been profitable owing to load factor and the cost of the feedstock. In the former case, a load factor of 50-60% is necessary for electricity to be produced below the grid price. In the latter case, the long-term nature of the project has revealed that biomass per hectare significantly decreases after the first harvest, requiring an increasing feedstock producing area over time. This has prompted exploration of other alternative feedstocks as source of fuel.

This case study highlights how communities in East Africa can benefit from adopting and scaling up of biomass gasifier for electricity generation purposes. This can see the emergence of small and medium scale enterprises engaging in electricity generation thus improving the local economy through direct job creation (both skilled and unskilled labour), creation of new income streams through sale of otherwise 'useless' biomass. The electricity generated can be used to run clinics, schools, village polytechnics and market centres.

Source: Adapted from Kartha et al., 2005

7.1.2 Case Study 2: Ethanol Production, Malawi

Ethanol has been produced in Malawi since 1982 when the first ethanol plant went into production next to the Dwangwa Sugar Mill. The ethanol has been used in blending of diesel and petrol fuels up to 20% thereby reducing the country's fuel imports, manufacturing of rectified alcohols for pharmaceutical and other industrial use and finally used in production of base potable alcohols for use in drinking spirits.

Currently, there are two ethanol producing companies in Malawi with a combined production capacity of 18 million litres a year. Cumulatively, Ethanol Company (ETHCO) has produced more than 20 million litres/year since 1982 for blending of 15-22%. Ethanol is produced through fermentation process of molasses by using an Azeotropic system of distillation. From the sugar mill effluent (molasses), there are normally three steps of production before ethanol is made.

Fermentation of molasses: Liquid residue from sugar production (molasses) containing approximately up to 50% sugar is mixed with yeast and fermented to obtain between 6% and 7% ethanol. The solid residue after fermentation contains mostly yeast and minerals and is used as fertilizer. Yeast is sometimes separated and used by the food industry.

Distillation: The fermented mash, now called "beer," contains between 8% -9% alcohol, as well as all the non-fermentable solids from the wheat and the yeast cells. This "beer" is then sent through a three-column distillation system where the alcohol is removed from the solids and the water. The alcohol leaves the final distillation column almost 100% alcohol. The residue, called stillage, is transferred from the bottom of the column for further processing.

Denaturing: Ethanol used for fuel is denatured with a small amount (0-5%) of some product, usually poisonous, such as petrol, to make it unpleasant for human consumption.

Following the opening up of the sugar market to competition from imports within countries in the Common Market for Eastern and Southern Africa (COMESA) region in 2010 and the extremely high and uncompetitive production costs especially in Kenya, sugar companies in East Africa need to review their production strategies and to diversify their activities. Ethanol production provides an avenue where they can still remain competitive. Ethanol produced can be used to generate electricity and /or used by rural households for cooking purposes. As is the case with Malawi, ethanol can be used in the production of transportation fuels.

Source: Adapted from Liwimbi, 2007.

7.1.3 Case Study 3: Saran Renewable Energy (SRE), India

This is a private company established in 2006 to supply electricity to Bihar, one of the poorest states in India. SRE provides reliable electricity to small businesses from a biomass gasifier, and reliable income to farmers who produce and supply the biomass. The gasification plant cost about US$170,000 to construct which was financed by investment from the directors, a bank loan and an anticipated government subsidy. Saran Renewable Energy had a turnover of US$66,000 and 12 staff in 2009.

SRE uses a down-draught open-top gasifier, manufactured by Netpro under licence from the Indian Institute of Science (IISc) in Bangalore. The dual-fuel Kirloskar engine was made in Pune.

The plant is maintained by technicians trained in Bangalore, with heavy maintenance undertaken by an engineering company based in Haryana. Both the gasifier and the engine used by SRE have been reliable, and the electricity generated has a stable voltage and frequency. The plant operates for about 85% of the time during scheduled hours of supply, but down time can usually be arranged for quiet periods so the availability for most users is higher. During the first two years of operation, the plant had to be shut down for only two days for emergency maintenance. With proper maintenance the plant life should be 15 years. Customers were already familiar with using electricity, so did not require much training to convert to SRE supply. An adequate stock-pile of fuel is stored on site to prevent shortages but fuel is always available locally at very short notice since the plant is in a rural area.

The biomass used is locally known as ‘dhaincha’, - a woody plant which grows on uncultivated waterlogged land, or can be added in the existing crop rotation during the monsoon. The gasification plant uses a dual-fuel generator, to supply 128kW of electricity at 240V. Customers are linked by two 3kV transmission line. The gasification plant runs irrigation pumps connected to the transmission lines and a pipe to supply to farms close to the plant. As a result, the gasification plant has replaced diesel pumps that were used to run grain mills, cold stores, sawmill, a welding business and a clinic. The project has seen emergence of some customers as ‘generators’ of electricity which is applied in lighting or charge batteries for other customers. A charge of US$ 0.15/kWh is levied to customers, which is US$ 0.13/kWh less compared to diesel generated electricity.

The gasification plant runs for 11 hours a day and supplies about 220MWh per year, saving approximately 0.35 litres of diesel per kWh, or about 77,000 litres of diesel per year. An estimated 206 tonnes/year of $CO2$ are reduced. The project in addition has increased local incomes through the sale of biomass. The capital costs are expected to be recovered in about six years through electricity sales.

Source: Ashden Awards, 2009

7.1.4 Case Study 4: Gosaba Rural Electrification Project, India

One of the first successful applications of biomass gasifier for rural electrification in an off-grid mode is 500kWe gasifier plant setup at Gosaba island of Sundarban in India. The plant was set-up in 1997 and consists of 5 x 100kWe units. The gasifiers are closed-top downdraft systems based on woody biomass. The plant has dual-fuel engines. The transmission and distribution line is spread over a length of 6.25 km of high-tension line and 13.67km of low-tension line. The plant serves around 900 consumers. The plant is managed by a local co-operative and the state government.

Source: Ghosh, Sagar and Kishore, 2003

7.2 Biomass Gasification Best Practice

Based on experiences from the region and other successful projects in developing countries provided in this report, the following are some best practices recommended for upscaling biomass gasification technology in East Africa (Parasnis, 2010; UNDP-UNEP, 2009; UNEP, 2009; Brew-Hammond and Kemausuor, 2008; OECD/IEA, 2007).

7.2.1 Need for a well-designed business/project models

The case of small scale gasification in Uganda provided in section 5.4 highlights the success that gasifier systems can have in ensuring electricity supply in rural areas. The models have to be carefully designed keeping in mind feedstock supply, conversion technology and energy allocation. The models should also provide suitable incentives to both the farmers and the entrepreneurs in order to ensure a mutually benefiting sustainable system.

The farmers supplying biomass could be motivated by reduction of their electricity bills and the entrepreneur could be compensated by ensuring adequate returns on the investment through fair tariffs. Without reliable business/project models, investors will not take the risk of investing. Capacity building is essential to develop and promote business opportunities.

7.2.2 Involvement of local population

The DESI case study highlights the significance of involving the local population. The gasification plant was collaboration between local and international partners and later transferred to the local partner under mutually agreed terms. The local partner may be an NGO or a co-operative body or an industry, actively involved in these projects right from the beginning. The 'EmPower' Partnership Programmes run by DESI Power helped in setting up micro enterprises owned and managed by local village organisations. A number of power plants and the linked micro enterprises in neighbouring villages formed clusters having an intrinsic relationship between them, providing mutual support and markets for survival as well as growth.

7.2.3 Local availability of the technology

To be adopted, a gasification technology should be locally available. This includes appropriate feedstocks, manpower requirement and spare parts. This is exemplified by Burundi experience where biomass gasification could not be operated for sustained period on peat which resulted in abandonment of the biomass gasification project all together.

7.2.4 Social benefits

To further enhance acceptance by the locals, the project needs to be structured in such a way that majority of the rural population can realise its impact at different levels, especially for those who cannot afford to derive direct benefits. The case of Saran Renewable Energy (SRE) best exemplifies this. One of the main SRE customers is a nursing station which uses electricity to run its services of collecting and analysing blood and other samples during the day time. To support education, SRE set up a study centre with free electricity, where children can study in the evenings. It also provided subsidised electricity to a computer training centre.

7.2.5 Economic and employment benefits

One of the most chronic challenges in developing countries, especially in the rural areas, is poverty and high unemployment rates. A project focused towards alleviating these challenges will have a significant impact and uptake especially around establishment of private and communal enterprises. Electricity generated by SRE supported small businesses, including grain and oil mills, sawmill, a welder, a battery charging station, a cinema and 'generators' supplying village lighting. Expensive generation of electricity via diesel generators was eliminated in the process.

Electricity from the SRE plant is used to operate ten irrigation pumps by farmers living close to the transmission lines. SRE also runs an irrigation pump close to the plant and sells water to local famers. 30 hectares in total are irrigated, at about one third of the cost of diesel pumps. A farmer with a hectare of marshy land can produce about 5 tonnes/year of dhaincha and earn an extra US$150 - 200/year, a significant amount in a typical rural setting.

8.0 Barriers To Biomass Gasification Technology Uptake/Upscale

There are numerous barriers to uptake and upscale of biomass gasification in East Africa. These can be categorised into technical, non-technical, insecurity of feedstock supply, research and development, level of awareness/information barriers and institutional barriers (Babu, 2005; Dasappa, 2007; OECD/IEA, 2007; UNDP-UNEP, 2009; TERI, 2010). The barriers are highlighted in the following section.

8.1 Technical and non-technical barriers

- There is limited technical and institutional capacity in the public and private sectors, to manufacture, implement and manage biomass based gasifier systems. Local manufacturing capacity and/or assembly of renewable energy technology components are currently lacking, although the knowledge, skills and expertise to operate renewable energy systems is available in the region.
- Inadequate technical and operational data to create awareness in target user groups. Moreover, there is no comprehensive data on the requirement of the electricity demand country wise at village level. Data on biomass assessment is out-dated as exemplified by Kenya.
- Real-time monitoring and timely control of critical gasifier operational parameters

are essential in obtaining the right products.
- Hot gas particles, tar, alkali, chlorides and ammonia removal are costly operations and affect the economy of the system significantly.
- Heat recovery is critical in obtaining high overall efficiencies. Low value heat (low-moderate temperatures) should primarily be recovered within the system, for example for drying the biomass or heating the reactor. An alternative is to connect the gasification system with outside endothermic processes.
- The manufacturers of gasifiers, gas turbines and other equipment connected to the gasifier are unable to provide performance guarantees, mainly because there is not enough experience from commercial operation of biomass gasification systems.

8.2 Insecurity of feedstock supply

There are a number of conflicts of interests embedded in feedstock supply as observed by Larson (2008), including:

- Bio-energy crops and food crops may compete for the same land area thus exacerbating food security concerns in countries such as Kenya and Uganda.
- Competition for resources such as land, water and feedstock: in developing countries, although current bio-energy use is largely not sustainable, it is of a very low cost and a vast majority of the population are dependent on it. Harnessing bio-energy potential on an industrial scale, if not implemented appropriately, may deprive them of their only energy source. Moreover, energy crops and food production compete for finite water resources.

8.3 Research and development (R&D)

- Inadequate attention is given to research and development and technological transfer/licence partnership among public and private sectors in biomass gasifier technology.
- There is continuous need for local technology development and increasing market size of the technology.

8.4 Level of awareness / Information barriers

Given the low connectivity and literacy levels, prevalent poverty and sparsely populated rural areas, lack of information is an important barrier to renewable energy utilisation and development in sub-Sahara Africa. Some key information barriers are as follows:

- There is no sufficient statistical data available on the renewable energy resources in terms of locations, sizes, and other characteristics to better define project opportunities for investors as evidenced by this study.
- A central information-clearing house on technologies does not exist. Instead, the information is scattered among various institutions and ministries.
- There is lack of information on comprehensive evaluation of biomass gasification already installed in the region. Many potential investors and equipment suppliers are not fully informed about the relevant government policies and programmes.
- Awareness level among public as well as decision-makers about the potential of biomass gasification for providing electricity and energy services is low.
- The modern biomass energy technologies have not been adequately publicised/promoted to interest private users. There is limited and/or low awareness of the availability, benefits and opportunities of biomass gasifier technology within the different stakeholders and in the public domain.

- Inadequate government policies and incentives, i.e. market push, are contributing to the lack of interest from users.
- There is an absence of market pull due to competition from fossil fuels.

8.5 Institutional barriers

- There is a need to develop linkage between academic institutions, private sector, industries and government to prepare and link technology development with local needs.

8.6 Policy and legal barriers

The introduction and success of any renewable energy technology, including biomass gasification, is to a large extent dependent on the existing policy framework. Government policies are important because of their ability to create an enabling environment for mobilising resources and encouraging private sector investment. Most of the early policy initiatives on renewables in the region were driven by the oil crises of the 1970s. In response, governments established either an autonomous Ministry of Energy or a department dedicated to the promotion of sound energy policies, including the development of renewables.

All five of the east African countries do not have a clear-cut policy on biomass gasification technology. This has led to ad hoc implementation of the technology with the private sector leading the way. This approach leaves very little recourse to national energy plans which are rarely available or out of date and inadequate.

9 Opportunities For Biomass Gasification

Biomass gasification technology has been in existence for a long time, albeit with limited success. Commercial coal gasifiers have been adopted in the metal industry and the sector is looking up in regard to clean coal technology. Biomass gasification is receiving increasing attention especially in developing countries where rural electrification is still scarce and energy demand outstrips supply.

In rural areas of East Africa, where there is inadequate grid supply, small-scale biomass gasification systems can be competitive compared with other electrification options such as diesel engines. The gasification system for this purpose usually consists of a small down-draft gasifier and the electricity is generated in a gas engine. These gasification systems have been developed and manufactured in India and they can be found in many countries, including India, Cambodia, Uganda and Mozambique.

There are numerous benefits accruing from use of biomass as feedstock in gasification. These include:

- Typically, biomass produced in a sustainable way is CO2 neutral feedstock. Thus, biomass gasification offers the opportunity of CO2 capture which will result in negative CO2 emissions.
- To avert food-biofuel competition, bio-energy crops should be grown on land not suitable for food production and marginal land.
- Gasification can attain very high efficiency as it takes advantage of the heterogeneous nature of biomass by producing a wide variety of low and high

value end-products from the same feedstock.

- There is guaranteed feedstock as almost all types of carbon-rich material can be gasified.
- Local authorities such as city councils and municipal councils stand to benefit from biomass gasification as they can sell the 'wastes' to private firms engaged in gasification at a fee. In addition, the councils could benefit directly through generation of electricity which can be sold to the national grid or sold privately to households within the municipality as is the case with Kampala City Council. This will go a long way in reducing urban waste management menace as is the case in Dandora dumpsite in Nairobi.
- It offers flexibility in the end-product i.e. the production route and the equipment can be adapted to the feedstock available locally and to the end-products demanded by the market.
- Gasification in bio-refineries can provide the market with multiple energy services, such as electrical power and transportation fuels.
- Synergy effects: in countries with natural gas such as Tanzania synthetic natural gas (SNG) can be pumped in the same pipelines, substituting fossil natural gas. Syngas and SNG can replace fossil fuels in industrial burners with minor modifications.

Final Recommendations

1. Financial incentives are essentially concerned with either increasing the price of competing energy sources or reducing the cost of bio-energy supply. They include feed-in tariffs, green certificates, tender schemes, blending requirements, and differential taxation.
2. Research, development and demonstration (RD&D): The road from an innovative idea to a ready-to-sell product or service can be very long and difficult. R&D to resolve the problems and demonstration of a new technology are very costly but nevertheless necessary steps towards commercialisation. R&D facilities should be established for addressing issues related to adaptation of the technology to local conditions.
3. Entrepreneurial development is complementary to direct financial incentives. Joint ventures between international financing organisations, governments and private companies are becoming increasingly important.
4. Power purchase liberalisation: nowadays, the global energy market is dominated by a small number of large-scale energy services companies. The production of power and fuels are centralised and these companies are reluctant to allow in non-traditional suppliers. By legislatively requiring these companies to purchase bio-energy from small-scale producers (e.g. syngas-based electrical power to the national grid or blending of bio-diesel in fossil diesel), a higher demand for new bio-energy development will be created.
5. Capacity building is an important component in the overall success of any implementation plan. There is need for training at various levels, technicians to planners on aspects related to distributed power generation using biomass gasification systems. There should also be a plan for knowledge transfer rather than hardware transfer for the technology packages in the long run. Training of youth at schools and colleges as a part of curriculum will also go a long way in instilling entrepreneurial skills in them.
6. The East African region urgently needs to develop several distributed biomass applications as direct firing only for heat is not enough. The national governments need to set targets i.e. per square kilometre 1mWth, should be the target. There is a need for national government bodies to adjudicate and ensure avoidance of investment duplication.

References

Ashden Awards, 2009. Case study summary Saran Renewable Energy, India. London. www.ashdenawards.org/files/pdfs/saran_full.pdf

Babu, S. P., 2005. Observations on the Current Status of Biomass Gasification. IEA Bio-energy Task 33: Thermal gasification of biomass. Paris: IEA.

Batalia, C.J., 2006. MIRREIA work in Tanzania. ESD-E7/UNEP Rural Electrification Nairobi Workshop: 1st – 3rd Mar, 2006.

Bhatt, 2011. East Africa Biomass Prospects. Pers. comm. Tower Power Limited.

Biomass Engineering, 2008. The Clean and Renewable Energy Resource. Website (accessed 6 Aug 2009): http://www.biomass.uk.com

Buchholz, T., Timothy Volk, Timm Tennigkeit, Izael Da Silva, 2007. Economics of a Gasification Based Mini-grid – A Case Study from a 10 Kw Unit in Uganda.

Brew-Hammond, A. and Kemausuor, F, 2008. Guidebook on modern bioenergy conversion technologies in Africa. www.energycenter.knust.edu.gh/downloads (Accessed 20th Dec 2011)

CII. 2005. Development of small ESCOs to undertake biomass gasification projects for industrial applications. Report prepared for MNES. Confederation of Indian Industries.

Dasappa S., 2007. Summary of discussion paper on status, potential and challenges of promoting biomass gasification technologies for industrial applications in Africa for AU/Brazil/ UNIDO High Level Seminar on Biofuels in Africa, Addis Ababa, 30th July – 1st Aug 2007).

Developing Energy Enterprises Project East Africa (DEEP EA), 2010. Technology Factsheet: Gasifier Stove. GVEP International.

Development and Enegy in Africa, 2008. Development and Energy in Africa (DEA) Project: Tanzania Background Paper. http://deafrica.net/Country%20Background/ Tanzania%20Background%20Paper.pdf (accessed 30th January 2012)

FAO, 2000. The Global Forest Resources Assessment 2000 (FRA 2000).

FAOSTAT, 2011. Food production quantity, 2009. http://faostat.fao.org/site/567/ DesktopDefault.aspx?PageID=567#ancor (Accessed 25th Dec 2011)

Ghosh D, Sagar A and V V N Kishore. 2003. Scaling-up biomass gasifier use: applications, barriers and interventions. World Bank. http://1nweb18.worldbank.org/ essd/envext.nsf/46ByDocName/

GoK, 2010. National Climate Change Response Strategy. Government Printer. Ministry of Environment and Natural Resources. Nairobi.

Kartha, S., Leach, G. and Rajan, S., 2005. Advancing bio-energy for sustainable development: Guideline for policymakers and investors. Energy Sector Management Assistance Programme, World Bank Report, 300/05.

Karlsson, S. and Malm D., 2005. Förnybar Naturgas – Förgasning av biobränslen för framställning av metan eller vätgas. Malmö: Svenskt gastekniskt center.

Kassenga, G.R. 1997. Promotion of Renewable Energy Technologies in Tanzania. Resources, Conservation and Recycling. Vol. 19 No. 4; pp. 257 - 263.

Kusekwa M. A., 2011. A Review on the Renewable Energy Resources for Rural Application in Tanzania. Dar-es Salaam Institute of Technology, Dar es Salaam.

Larson, E., 2008. Biofuel Production Technologies, Status, Prospects and Implications for Trade and Development. New York and Geneva: UNCTAD.

Liwimbi, D., 2007. Ethanol: The Spirit of Success. Ethanol Company Limited. Dwanga.

Maithel, S., 2009. Biomass Energy Resource Assessment Handbook. Asian and Pacific Centre for Transfer of Technology (APCTT). Economic and Social Commission for Asia and the Pacific (ESCAP).

Mkilaha, I. S. N. and John, G. R. (2001): Prospects of coal Utilization in Tanzania. IET Seminar proceedings, Arusha, Tanzania, pp. 153 – 160.

MNRE, 2008. Revised Guidelines for VESP projects. New Delhi: Ministry of New and Renewable Energy.

Ministry of Water, Energy and Mines (MoWEM), 2006. Sectoral Policy of Ministry of Water, Energy and Mines of Republic of Burundi, March 2006.

Ministry of Energy (MoE), 2004. Draft National Energy Policy. MoE, Nairobi.

Ministry of Energy and Mineral Development (MEMD), 2002. The Energy Policy for Uganda, MEMD, Kampala.

Ministry of Energy and Minerals (MoEM), 2005. Tanzania Rural Electrification Strategy: Draft Master Plan and Programme Report (phase 1). Africa Development Bank, April 2005.

Ministry of Energy and Minerals (MoEM), 2003. The National Energy Policy. MoEM, Dar es Salaam.

RoR, 2006. Sectoral Policy of Ministry of Water, Energy and Mines of Republic of Burundi.

OECD/IEA, 2007. IEA Energy Technology Essentials: Biomass for Power Generation and CHP. www.iea.org/Textbase/techno/essentials.htm (Accessed 28th Oct 2011).

Olofsson, I., Nordin, A., Söderlind, U. (2005) Initial Review and Evaluation of Process Technologies and Systems Suitable for Cost-Efficient Medium Scale Gasification for Biomass to Liquid Fuels. Umeå : Energy Technology & Thermal Process Chemistry, University of Umeå.

Onchieku, J.M., Odongo, F., Ondieki, M.M.C., Gladys, K.M., Mayaka, A., Wanjiku, J. and Chiteva, R. (Eds.), 2011. Biomass gasification and technology utilization: Proceedings of biomass gasification workshop, Wida Highway Motel, Kenya, 24th – 27th May 2011.

Parasnis, A., 2010. Applications of Pyrolysis and Gasification - The Best from Waste. Sustainable Solid Waste Management April 18, Kolkata.

PRSP, 2003. Strategic Framework Accelerating for Economic and Reducing Poverty (PRSP), Kigali.

Reuters, 2011. Government picks Chinese firm Fenxi for coal mining. Standard Media Group. http://www.standardmedia.co.ke/InsidePage.php?id=2000048237&cid=14&j=&m=&d= (Accessed 30th January 2012)

Salami, Adeleke; Kamara, Abdul B.; Brixiova, Zuzana, 2010. Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities, Working Papers Series N° 105 African Development Bank, Tunis, Tunisia.

Schwietzke S., Ladisch, M., Russo, L., Kwant, K., Mäkinen, T., Kavalov, B., Maniatis, K., Zwart, R., Shahanan, G., Sipila, K., Grabowski, P., Telenius, B., White, M., and Brown, A., 2008. Analysis and Identification of Gaps in Research for the Production of Second-Generation Liquid Transportation Biofuels. Paris: IEA Bio-energy.

Stassen, H.E., 1995. Small scale biomass gasifiers for heat and power – A Global Review. World Bank Technical Paper number 296.

TERI, 2010. The Development and Implementation of Biomass Gasification

Pilot Activities. http://www.teriin.org/upfiles/projects/ES/ES2004BE39.pdf (accessed 25th Nov 2011).

Tumuhimbise J. 2012. Status of Biomass Gasification in Uganda. Pers. Comm. Ministry of Energy and Mineral Development, Uganda.

UNDP-UNEP, 2009. Harnessing Carbon Finance to Promote Sustainable Forestry, Agro-Forestry and Bio-Energy. New York and Nairobi: UNDP-UNEP.

UNEP, 2009. Converting Waste Agricultural Biomass into a Resource

Compendium of Technologies. UNEP Osaka/Shiga.

Waste Management World, 2011. 40 MW Biomass Gasification Facility to Benefit Ugandan Coffee Industry. http://www.waste-management-world.com/index/display/article-display/3240177808/articles/waste-management-world/waste-to-energy/2011/02/40_MW_Biomass_Gasification_Facility_to_Benefit_Ugandan_Coffee_Industry.html (Accessed 02 Dec 2011).

Practical Action Consulting (PAC) is the dynamic consulting arm of the international NGO, Practical Action. For over 40 years, Practical Action has been using technology to challenge poverty, and empowering poor communities to build sustainable, practical solutions to work their own way out of poverty. PAC takes the lessons learned from the work of Practical Action and pushes them out across a much broader geographic region in pursuit of scale and influence.

For more information visit www.practicalaction.org/consulting

ACTS is noted for being the first African independent think-tank on the application of science and technology to development. The founders of ACTS had the vision of an organization that would steer Africa from the depths of poverty and dependence on the West to ideas-based development, focusing mainly on development and influencing of policies that would help Africa assert itself in the various fora, that discussed emerging new technologies and issues to do with Biotechnology, Biosafety, Climate Change and the Environment.

A leader in forestry research, KEFRI is a public institution established under the Kenya Science and Technology Act, Cap 250 of the Laws of Kenya. KEFRI's mandate is to conduct research in forestry, co-operate with other research bodies within and outside Kenya carrying out similar research, liaise with other organisations and institutions of higher learning in training on matters of forestry research, and disseminate research findings. Its mission is to enhance the social and economic welfare of Kenyans through user-oriented research for sustainable development of forests and allied natural resources.

The KFS is a public institution established under the Forest Act, 2005, with a mandate to contribute to the growth of the natural resource sector by enhancing development, conservation and management of all forest resources in Kenya. The KFS has five national level departments involved in activity implementation: Natural Forest Conservation and Management; Forest Plantations, Enterprise and Licensing; Forest Extension; Enforcement and Compliance; Corporate Division. Among other departmental activities the Service promotes community involvement in forest conservation and management through Community Forest Associations (CFAs), licensing of various activities and ventures, and conservancy management through 10 regional conservancies with one Forest Conservation Committee (FCC) each.

PISCES is a research project funded by the Department for International Development of the United Kingdom (UK). Project implementation started in July 2007. The purpose of the project is to increase available knowledge and understanding of policy relevant trade-offs between energy, food and water security for livelihoods in relation to bioenergy. PISCES is a Research Programme Consortium whose members include African Centre for Technology Studies (ACTS, lead) Kenya; Practical Action Consulting UK, Eastern Africa, and Sri Lanka; the University of Dar es Salaam, Tanzania; M.S. Swaminathan Research Foundation (MSSRF), India; and the University of Edinburgh, UK.

For more information contact project manager Bernard O. Muok at b.muok@acts.or.ke and visit http://www.pisces.or.ke