Forest energy for livelihoods

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1.0 Introduction

There are five broad energy sources namely biomass, fossil fuels, electricity, solar and wind. Renewable energy is energy generated from natural resources which are naturally replenished. Some natural renewable resources such as geothermal power, fresh water, timber, and biomass must be carefully managed to avoid exceeding the world's capacity to replenish them.

In developing countries, woodfuel is the major source of cooking and heating where about 2 billion people rely solely on fuel wood for cooking (FAO, 2005). This figure demonstrates the critical importance of wood energy in meeting energy requirements in these countries. It is estimated that about 90% of Kenyan rural households use woodfuel either as firewood or charcoal (Ministry of Energy, 2002). Woodfuel meets over 93% of rural household energy needs whilst charcoal is the dominant fuel in urban households (Theuri, 2002). Besides being the standard cooking fuel for the majority of Kenyan households, fuel wood is also important energy source for small-scale rural industries such as tobacco curing, tea drying, brick making, fish smoking, and bakeries among others. A comprehensive biomass study undertaken in 2000 revealed that the principal sources of fuel wood were agro-forestry (84%), biomass in trust lands (8%) and gazetted forests (8%) [Status of Environment report, 2004].

The major sources of electricity in the country are hydropower; thermal power and geothermal. The minor sources are biomass-based co-generation, solar photovoltaic, wind and mini/micro hydropower. However, electricity's distribution nationally is quite low at 15% (Status of Environment report, 2004).

2.0 The importance of forests

Forests rank high as one of the important national assets for economic, environmental, social and cultural values. Despite the proportionately small area covered by the closed canopy forest compared to the overall country's surface area, forests will continue to play a significant role by providing a wide variety of resources for human development. They provide utility products such as timber for the construction sector, transmission poles for the energy and communication sector, fuel wood for the tea industry among other uses, and also for subsistence utilization by the communities as well as paper for the education and print media sectors. Forests also provide a wide variety of non-wood products. They are important in conservation of biological diversity, regulation of water supplies, and carbon dioxide sequestration in addition to being a major habitat for wildlife, which promotes tourism. The

hydroelectric power stations are located in major forest water catchment areas. Moreover these major rivers also provide water to support irrigation schemes that are important for agricultural sector development.

Close to three-quarters of Kenya's electricity is derived from hydropower. Forests contribute to the availability of water for electrical power generation, especially because of their role as water catchments and in reducing siltation of hydroelectric dams. About 70 percent of the national energy consumption in the country comes from wood (Ministry of Energy, 2002).

2.1 The status of forests in Kenya

Kenya is a relatively dry country (80% of total land area is arid and semi-arid). The state of dry land forest resources is reminiscent of wasteful use patterns and degradation mainly through overgrazing, overexploitation of trees for the acquisition of fuel wood and charcoal particularly in the neighbourhood of towns and refugee camps.

The Food and Agricultural Organisation (FAO) provides parameters within which forests should be defined as follows: Tree crown cover of between 10 – 30%; tree height of 2 metres and above; land area of more than 0.1 Ha. Following these parametric limits, Kenya has defined a forest to constitute forested land area where crown cover is 30% or more, trees grow to 2 metres and above and a minimum land area of 0.1 Ha.

Kenya has 3.467 million ha of forest cover which is equivalent to 5.9% of land area. Out of this, 1.417 million ha or 2.4% of total land area comprises of indigenous closed canopy forests, mangroves and plantations in both public and private lands. Table 1 below provides the forest cover types in Kenya as reported in Forest Resource Assessment (FRA) 2010 country report.

Table 1: Forest Cover Analysis

Category of forest cover type	Area ('000 Ha)				Remarks
	1990	2000	2005	2008	
1. Indigenous closed canopy	1,240	1,190	1,165	1,140	Decreased forest cover (25,000 Ha) in 2005-08 period is due to forest invasions in Cherangany, Mau, Samburu
2. Mangroves	54	54	54	54	Kilifi, Malindi, Lamu districts
3. Industrial plantation forests	170	134	119	109	This is in addition to 16,000 Ha of unplanted designated areas
4. Private plantation forests	68	78	83	90	Increasing trend due to accelerated commercial planting by private sector and farmers
Sub-total closed canopy forests	**1,532**	**1,456**	**1,421**	**1,395**	**2.4% of land area**
5. Woodlands	2,150	2,100	2,075	2,050	Spread mainly in the ASALs
Sub-total of forest areas	**3,682**	**3,556**	**3,496**	**3,443**	**5.9% of land area**
6. Bush-land	24,800	24,635	24,570	24,510	In ASALs, high and medium rainfall areas
7. Grasslands	10,730	10,485	10,350	10,350	Mainly the savannah
8. Settlements	8, 256	8,192	8,152	8,202	
9. Trees on farmlands	9,420	10,020	10,320	10,385	Mainly in high and medium rainfall areas
10. Inland water bodies	1,123	1,123	1,123	1,123	
Total Land Area, Kenya	**58,037**	**58,037**	**58,037**	**58,037**	**100%**

Source: Kenya Forest Service Strategic Plan 2009/10 – 2013/14

Table 1 also indicates that Kenya has 10.385 million ha with trees on farmlands. It is estimated that the farmlands have wood stocking of about 9.7 m^3/ha. The bushlands cover 24.51 million ha and together with the woodlands are major sources of wood biomass in Kenya.

Much of the closed canopy forest has been depleted due to internal and external influences. The external influence is due to the need for more agricultural land, short term political interests leading to invasion of gazetted forests, conflicts on resource use as well unwarranted land use changes paving way to degradation, diminished re-afforestation efforts as well as archaic forest policies and legislation. Internal influences include a weak extension forest service, inadequate policing personnel translating into large unmanageable areas of patrol which is further worsened by lack of transport, weapons and tools of work, and unserviceable and outdated communication network, poor dissemination of research information, low staff morale due to difficult field working conditions.

Continued losses of forests and associated resources have had far reaching negative effects on the country's economy and welfare of Kenyans. Some of the consequences are: inadequate supply of timber and other wood products affecting industrialization, employment creation, and loss of biodiversity, destruction of water catchments functions manifested in reduced water supply for domestic and industrial consumption.

3.0 The status of the energy resources

Biomass energy resources are derived from forests - closed forests, woodlands, bush lands, grasslands, farmlands and plantations as well as from agricultural and industrial residues.

Currently, there exists a growing imbalance between supply and demand of biomass energy.

In 2000, the biomass demand stood at 34.3 million tonnes as compared to an estimated sustainable supply of 15 million, thereby indicating a deficit of over 56%, while the current deficit is estimated at 60% (Status of Environment report, 2004). The principal drivers of biomass energy demand are population growth, lack of access to energy substitutes and the growing incidence of poverty among Kenyans. Biomass energy supply and demand imbalance is exerting considerable pressure on the remaining forest and vegetation stocks, thereby accelerating the processes of land degradation and desertification. In addition, the production of biomass energy poses a threat to competing land use systems such as agriculture, forestry and human settlements.

Among the components of the biomass energy, charcoal is an important fuel, particularly for urban dwellers. Since charcoal production depends on woody biomass, its rising demand is associated with the increasing levels of deforestation. In areas adjacent to major urban centres, charcoal trade is active. Effective regulation of the charcoal industry remains one of the key challenges facing the government.

3.1 Status of Electricity

Forests are water catchment areas and are sources of many rivers in the country. Hydroelectric generation infrastructure requires a dam and reservoir. These dams are feed by rivers and thus the relationship to forests. Electricity is crucial to Kenya's economy given its versatility in application. However, its consumption is extremely low at 121 kWh/capita, while national access rate at about 15% (about 1 in 5 people have access to electricity) is below the average 32 % for developing economies. The generation system has an installed capacity of 1,239 MW, comprising 677 MW of domestic hydropower (55%), with 30 MW (2%) being imported from Uganda, 125 MW Geothermal (10%), and 407 MW oil-fired thermal (33%) [Status of Environment report, 2004].

However, under severe drought such as was experienced recently in (2008/9), the effective capacity of the hydropower plants would be reduced from 639 MW to 501 MW. Also forest degradation leads to low water levels in the rivers. This is currently being noted in the Mau Forest where rivers have now reduced amounts of water. For instance Sondu River feeding the Sondu/Miriu Hydropower project has its origins from the Mau catchments. If the forest encroachment is not curbed then this Sondu/Miriu power project is threaten with closure.

Prolonged drought can also affect geothermal power generation. Geothermal power is produced from a mixture of high-temperature water and steam over 250°C extracted from deep underground reservoirs. Therefore, prolonged drought can affect the replenishing of these underground reservoirs and thus affect the geothermal power generation in the long term.

3.2 Energy consumption patterns demand and supply

Firewood: In 2000, the average annual firewood consumption in both rural and urban areas was 3,394 and 2,701 kg per household respectively. The corresponding per capita consumption was 741 and 691 kg respectively. At the agro-ecological zone level, consumption of firewood was observed to be higher in the medium potential zones compared to the high and low potential zones. The respective consumption of firewood in 2000 was 3099, 3721 and 3394 kg per household per year for high, medium and low potential zones respectively (Ministry of Energy, 2002).

Charcoal: On average, the urban charcoal consumption in 2000 was 156 and 152 kg per capita for rural and urban dwellers respectively (Ministry of Energy, 2002). The study revealed that contrary to the popular view that charcoal is a fuel for the low income urban dwellers, 83% of high income groups regularly used charcoal, meaning that charcoal is consumed by all categories of urban dwellers. It is important to note that the Kenya ceramic stove which was introduced in the 1980s had an acceptance level of 47% by 2000. There is a biomass supply deficit in all the provinces as evidenced by the widespread depletion of existing biomass stocks. As such there is need to put in place an appropriate strategy for sustainable conservation and utilization of wood biomass.

Electricity: Currently, only 15% of all Kenyan households have access to electricity. Of the people living in urban areas only about 50% currently access electricity, while in the rural areas it is about 4%. At the household level, electricity is used for lighting (99%), entertainment (90%), ironing (69%), refrigeration (35%), water heating (26%), domestic cooking (24%), home businesses (16%) and house heating (9%). Most of the urban households with access to electricity are in the high and middle-income groups. Only 26% of the lowest income group has access to electricity. The national average consumption is 694 kWh and the corresponding per capita consumption of 216 kWh and 115 kWh for urban and rural households respectively

4.0 Impacts of energy resources utilization on forests

Energy exploitation contributes to deforestation and land degradation. Kenya is facing two major challenges in the context of energy-land use nexus. These have to do with how to balance the land use requirements for urbanization, human settlement and agriculture on one hand, and energy production and supply on the other. The environmental consequences of deforestation and land degradation are severe as they lead to ecological instability, loss of agricultural production, desertification, climate change and loss of biodiversity. For this reason, there is evidence that should the current energy consumption patterns continue; the quest for sustainable energy development will remain an illusion. The government has instituted measures, which are meant to forestall or minimize the environmental effects of energy production and use. For instance, the National Development Plans have consistently highlighted the need to ensure a balance between energy development and environmental protection. The current energy policy (Sessional Paper No. 4 of 2004) emphasizes the need

for integrated energy planning to ensure that all other significant sectoral concerns are addressed.

The current demand for biomass energy far outstrips the sustainable supply by almost 60% (Status of Environment report, 2004). Inevitably, the continued high dependence on biomass resource to provide energy to majority of Kenyans means its demand will undoubtedly continue to rise leading to the felling of more trees for fuelwood and for charcoal production. This in turn exerts pressure on biomass resources as well as on arable land in an already deteriorating environment, thus jeopardizing economic growth prospects especially for the most vulnerable groups of the population, namely women and children.

At the same time, the rapid urbanization phenomenon compounds the biomass supply problem, particularly charcoal to meet the soaring demand against a background of declining biomass cover. The issue of charcoal is a pertinent concern in the energy-land use nexus context. Incidentally, most charcoal is produced from shrub-lands, rangelands and wooded savannah areas. While the impact of charcoal production on forests and woodlands is certainly negative, there is a fundamental difficulty to quantify it owing to its apparent low national priority rating.

Most charcoal production involves clear-cutting, while other production involves selective harvesting. In other cases, some tree removals are purely for commercial charcoal production, while in others the trees are cleared to create additional agricultural or pastoral land, with charcoal simply being a by-product of the land clearance. Commercial charcoal production in some areas has led to deforestation of large tracts of wooded savannah (Ecoforum, 2002).

An alternative source of charcoal increasingly gaining recognition is from agricultural wastes such as coffee husks. These sources should be promoted as means of saving further destruction of woodlands and forests.

4.1 Implications of Electricity demand and supply on the forests/environment

Although hydropower is regarded as being environmentally benign, the hydroelectric generation infrastructure requires a dam and a reservoir. The construction of these structures destroys the natural ecosystem and displaces human populations taking up sizeable chunks of productive land. For example, the construction of Masinga Dam reservoir displaced over 1,000 families (ELC, 1985), while the construction of Kamburu, Kindaruma and Masinga hydro dams flooded an area of 15, 10 and 120 km2, respectively (ELC, 1985). In addition,

about 5 km strip of land on both sides of the river is set-aside for immediate catchment protection and access to the facilities.

Elsewhere, Kiambere dam inundates an area of 25 km2 and a further 100 km2 is set aside as a buffer zone for its protection (Kenya/Canada Energy Advisory Project, 1992). During the construction of Kiambere Dam, more than 5,000 families were displaced. Nonetheless, after construction of hydropower water reservoirs, new opportunities for fisheries were created.

However, socio-cultural impacts have been experienced in the affected areas. For instance, the emergence of 'Kisumu Ndogo' fishermen's villages in the vicinity of the Masinga hydropower facilities, apart from increased fish availability, created socio-cultural change.

4.2 Policies related to wood energy

A Policy is a statement of the government guiding principles and goals in addressing a public issue. Policy provides means where citizen can hold their government to account for its actions concerning issues of public interests (Lukeki et al., 2006). Policies related to wood energy in Kenya are largely in forestry and energy sectors and generally aims at ensuring sustainable and affordable supply of wood energy, mainly for subsistence use**.** The two agencies, which are vested with the wood energy policies in Kenya, are Ministry of Energy and Ministry of Forestry and Wildlife and therefore it is important to develop a closer coordination and collaboration between these agencies for sustainable woodfuel supply and demand (Kareko and Githiomi, 2001). The activities of these agencies relative to their role in sustainable woodfuel development need to be reviewed to determine which agency among them should be the lead agency.

Although it is legal to buy, use and sell charcoal, it remains illegal to produce, transport and even export it. This illegality does not arise from statute books but from ad hoc presidential and ministerial decrees banning production and transportation unless with a permit. In the absence of affordable alternatives energy sources in the near future, banning charcoal production will not work and its business will only be driven underground illegally. KFS is currently working on charcoal regulations which will legalize the charcoal trade. Since most firewood for charcoal making is obtained free of charge from trust lands, there is no incentive for commercial tree growing for charcoal making in these areas. Without policy intervention, trust land, communal lands and government forests will continue to be the main source of charcoal supply in Kenyan markets in foreseeable future (ESDA, 2005).

The Forest Act 2005 is very supportive to the realization of the policy objectives that promote woodfuel production through provision of a wide range of incentives to private sector investment in forestry development (Republic of Kenya, 2005a). Other relevant

provisions relate to the regulation of forest resource harvesting and marketing through issuance of certificate of origin and movement permits geared to reducing theft from farms and government forests. Also the act calls for partnerships with woodfuel consumers and farmers through contract tree farming schemes.

The Ministry of Energy published a draft energy policy document (Ministry of Energy, 2004), which tends to put more emphasis on commercial energy (fossil and electricity), denying biomass energy the comprehensive treatment it deserves. The main objective of this policy is to lay a framework upon which cost-effective, affordable and adequate quality energy services are made available to the community on a sustainable basis. The policy recognizes that economic growth to a large extent is dependent on performance of energy sector as the main driving force to development (Ministry of Energy, 2004). The energy policy also supports development of wood energy through promotion of energy efficient devices and conservation as well as prudent environmental health and safety practices. It recognizes that wood energy can be used as a tool to accelerate economic empowerment for urban and rural development and enhance security of energy supply which is supported by energy Act 2006 (Republic of Kenya, 2005b). Woodfuel is not prominently addressed in energy Act like the conventional energy forms. Lack of effective policies in wood energy means that revenue from taxes or penalty is not forthcoming and hence there is little support for the implementation of positive policy initiatives. It is estimated that the total annual income from charcoal trade is KSh 32 billion, which can give annual taxation revenue of KSh 5.1 billion (ESDA, 2005). However this revenue is not collected by government as there is no legislation supporting charcoal production.

Over 70% of the total energy used in various sectors in Kenya comes from wood, which makes it a very important source of energy (Ministry of Energy, 2002). Wood energy also relates to many other policy areas like; agriculture, environment, industry and lands. The overall objective of the Land Policy is to ensure land and associated resources are used and managed efficiently, productively and sustainably to reduce poverty in line with government overall development objectives. The lack of comprehensive land use policy has led to difficulties in land use management, tenure reforms and environment protection (Ministry of Lands, 2008). This has resulted to deforestation leading to deficient wood energy supply, land degradation and conflicts in land use resources among many others.

The overall goal to environmental policy is to integrate environmental concern to national planning and management processes and provide guidelines for environmentally sustainable development. Environmental Management and Coordination Act, 1999 (EMCA), provided national environmental principles and guidance (Republic of Kenya, 2000). This

Act has addressed environmental issues that were previously not considered in developments. It further deals with cross-sectoral issues such as overall environmental policy formulation, environmental planning, protection and conservation of environment, environmental impact assessment, environmental audit and monitoring, and institutional coordination and conflict resolution. Section 49 of the EMCA Act provides that National Environment Management Authority (NEMA) in consultation with relevant lead agencies will promote the use of renewable sources of energy through research in appropriate renewable sources of energy and taking measures to encourage the planting of trees and woodlots by individual land users, institutions and community groups (Republic of Kenya, 2000).

The main goals of agricultural policy in Kenya is increasing productivity and income growth especially for small holders and also enhancing food security (Republic of Kenya, 2005). This is aimed to be achieved through increasing land productivity as well as income through taking farming as a business enterprise as opposed to subsistence (Alila and Rosemary, 2006). The Agriculture policy supports biomass energy development in that it aims at revitalizing agriculture through developing incentives for establishment of agro-processing and rural industries in rural areas where woodfuel is the potential source of energy. The policy promotes agro-forestry as it has potential of increasing woodfuel production for domestic consumption and as well as agro-processing and post harvesting drying. The agriculture sector is indirectly related to energy sector as far as the biomass energy is concerned as most of the biomass energy comes from farms.

Other related policies on wood energy include the newly launched Vision 2030 which recognizes that energy is critical in achieving socio-economic transformation and industrial policy which recognizes that the supply of steady, predictable, quality and affordable energy among others is a major ingredient to catalyze industrialization process (Republic of Kenya, 2007).

5.0 Threats to the provision of energy resources for livelihoods

The energy resource is threatened by the interaction of a multiplicity of factors such as population pressure, rural urban migration, unstable fossil fuel prices, unaffordable cost of alternatives, lack of access to alternative energy sources, ineffective legal and regulatory framework, competing land uses, inefficient transformation and end-use technologies, increased frequency of extreme weather episodes and unemployment

The main threats that have faced sustainable management and conservation of Kenya's forest emanated from:

a. Poor legislative framework and political interference.

The Forests Act (cap 385), which was replaced by the Forests Act 2005, allowed the degazettement of forests by the Minister without any consultation, apart from a 28-days notice. This was used to reduce the forest area in Kenya with forests being converted to human settlements and agriculture. Most of the de-gazettements were unwise and occurred in critical water catchments such as the Mau and Mt Kenya. Political interference has been the underlying cause of these degazettements commonly referred to as forest excisions. The excisions gained momentum in the 1990s when forest loss through excisions averaged 5000ha annually. In some cases illegal allocations have occurred with no excision taking place or resolutions being passed to set aside forest land for other used in the case of local authority forests. The Forests Act 2005 addresses the problem of excisions.

b. Encroachment and illegal cultivation

The illegal expansion of farms into forests also poses the biggest threat to indigenous forest conservation. Forests are situated in high human population density areas and are thus threatened by illegal cultivation.

c. Illegal logging and charcoal burning

Most forests are affected by illegal logging and charcoal burning which contributes to unsustainable energy resources and thus affecting livelihoods.

d. Poor understanding of the benefits accrued from forests especially by communities

Where benefits accruing from forests are not well understood or appreciated by community members, the communities have little motivation to protect the forests. Consequently, they watch, connive, while others take part in forest destruction. Others request for forests to be excised for other uses.

6.0 Opportunities in the supply of renewable energy for livelihoods

As charcoal becomes an important tradable commodity, there is an opportunity for governments to recognize and regularize charcoal production by putting in place long-term plans for sustainable production, while at the same time creating a supportive legal and economic framework for micro- and small and medium enterprises (SMEs) development. Increasing efficiency and ensuring that the development of this sector does not accelerate

deforestation requires appropriate policy interventions. There is ongoing research to develop more efficient charcoal production methods using improved kilns in a number of countries in Eastern and Southern Africa. In Kenya there are projects that have been started where farmers are growing trees for charcoal production. These projects have also established efficient charcoal kilns.

6.1 Growing trees for charcoal production

There are community groups in Madiany Division, Rarieda, Bondo who have planted *Acacia xanthphloea* and *A. Polyacantha* for charcoal production. The project started in 2002. The fuel wood is then converted to charcoal using efficient masonry kilns – half orange kilns.

Plate 1: Six-year old *Acacia xanthophloea* in Madiany Division, Rarieda, Bondo

Plate 2: A half orange kiln in Madiany Division, Rarieda made of fired earth bricks

6.2 Wind energy

Kenya is endowed with significant amounts of other renewable energy sources, which include, wind energy. Wind energy has been used in Kenya primarily for water lifting since the beginning of the 19th Century, but its use declined with the advent of oil fired internal combustion engines, which are flexible and more convenient to use. However, with the rising cost of oil, the exploitation of wind energy is becoming increasingly more attractive particularly in areas remote from the grid and oil supply outlets. The country has a wind farm at Ngong hills (Plate 1). The station was commissioned in 1993 as a donation from the Belgian Government and has been running since (KenGen website). Every afternoon the gentle morning breeze that sweeps up from the Rift Valley grows into a strong wind and by nightfall it has become a blustering gale.

Plate 3: A wind farm in the Ngong hills

A wind power plant in Marsabit District has been projected to be constructed. The project is called The Lake Turkana Wind Power Project which will operate a 300MW wind power plant near Lake Turkana in the Great Rift Valley. The wind farm will comprise 367 turbines of 850KW capacity each to maximize the very high wind speed in the Turkana corridor low jetstream corridor (AFDB, 2009). The average wind speed was recorded at an impressive 11 m/s (as compared with a high average in Europe of 7 m/s). The clean power output generated will supply energy to Kenya's national grid to contribute up to 25% of the existing national installed power and will be connected at Suswa, near Naivasha. Average electricity production is estimated at 1,440 GWh per year. The project site is located at the South-

Eastern end of Lake Turkana (between two high ranging mountains) in an uninhabited, rocky, desert area that has annual average rainfall of less than 300 mm.

This project will be the biggest energy project involving exploitation of wind resource for generation of electric power in Kenya and the whole of the Africa Continent. Until now, only North African countries such as Morocco and Egypt have harnessed wind power for commercial purposes on any real scale on the continent.

To promote investment in wind energy generation, the Ministry of Energy has completed preparation of a National Wind Resource Atlas. As revealed by the atlas study, wind energy potential for power generation shows varying temporal and spatial distribution. Generally, most areas in the country are endowed with less than 300 Watts m_2. To ensure security of supply, the government is promoting the development of wind-diesel hybrid systems for electricity generation in areas remote from the national grid. A total of 550 kilowatts have been installed, generating about 0.4 gigawatt-hours of electrical power (State of environment report 2004). .

There are studies going on about placing wind turbines in and around forests. For instance there are thought of setting up these turbines in the Virgina's National Forests in the Eastern seaboard of the United States (Associated Press, 2009). Majority of the wind energy in the US is generated in the western side of the country. However, it is meeting some resistance.

Other studies have been carried out in Denmark.

The efficiency of operating wind power plants in combination with forest plantations is examined in Russia (Petrov, V. I., S. Yu. Turko, and Yu. I. Vasil'ev, 2009).

Conditions for selecting a site for wind power are:

- Good wind,
- Access to transmission lines,
- Accessibility, to get equipment to the site,
- Social impact of human and animal welfare established

6.3 Co-generation Using Bagasse

Co-generation using bagasse as a primary fuel is common practice in the domestic sugar industry. The industry comprising seven sugar companies produces a combined average of 1.8 million tonnes of bagasse with fibre contents of about 18% by weight annually. Out of this quantity, about 56% is used in co-generation using an installed capacity of 25 MW and

the balance disposed at cost. Mumias is the only sugar company among the seven factories that is self-sufficient in electricity production from its bagasse and has the capacity to sell the surplus 2 MW to the national grid

6.4 Gasification

Using invasive plant species such as *Prosopis juliflora* and *Lantana camara*

Gasification is the thermal treatment of solid fuels ("feedstock") into a gaseous form while retaining most of the energy in the original fuel. In contrast to incineration, where fuel is burned under high temperatures to produce heat energy, gasification converts the hydrocarbons in solid fuels under controlled temperature and oxygen conditions to produce viable fuel known as syngas. Syngas contains most of the energy potential of the original fuel and can drive a variety of energy generating applications. The resulting synthesis gas is cleansed and then used to fire an electric power plant and/or converted into high-value products such as synthetic fuels, chemicals, and fertilizers.

6.5 Biodiesel

Kenya does not have any known reserves for fossil fuels and therefore imports all liquid fuels. Diesel makes up 60% of the total oil imported into the country. There are opportunities is producing biodiesel from tree seed oil. Tree species whose seeds have potential in producing oil are many. In Kenya the following species have been seen to have that potential. Seeds from *Croton megalocarpus, Jatropha curcas, Thevetia peruviana* (yellow oleander), *Riccinus communis L.* (castor)

Croton megalocarpus

This is an indigenous (East Africa) upper-storey forest tree from the family *Euphorbiaceae,* that grows to 35 m or more. Its range is the semi-arid and sub-humid highlands, at altitudes between 1200 and 2450 m, with an annual rainfall of about 800 to 1600 mm and average annual temperatures varying between 11 and 26°C (Thijssen R., 1996**).** Trees of this species are found in forests and often on farms, where they play a major role as boundary markers, windbreaks, shade trees and fuelwood producers. It is also found in moist upland forest, dense woodland (especially riverine or near springs) and scattered tree grassland (Hines, D.A. and K. Eckman, 1993).

The leaves, roots, and bark are used to treat stomach problems and pneumonia. The seeds have a high oil content (30%) and high protein content (50%) (Hines, D.A. and K. Eckman,1993). The oil extract is reported to be a forceful purgative. The tree makes a good live fence and is highly regarded as firewood; the leaves are used for mulch and green manure.

Jatropha curcas

This is a small tree or shrub with a maximum height of 5 m, *Jatropha curcas* reportedly grows readily in areas of low rainfall (from 250 mm a year) and in poor soils, however, yield is strongly affected by growing conditions. The trees are easy to establish (from seeds or cuttings), grow relatively quickly (producing seed after their second year) and are hardy to drought, although they are relatively sensitive to frost.

The seeds of the Jatropha contain high percentages (30%-35%) of oil, which can be extracted easily for further processing (transesterification) and refinement. This processed oil can then be used in diesel engines after minor modifications -transesterification. To avoid engine modifications the bio-diesel can also be blended with conventional diesel.

The by-products of the bio-diesel processing plant are nitrogen-rich press cake and glycerol, which are said to have good commercial value as fertiliser and as a base for soap and cosmetics respectively. The leaves, root and bark could also have potential for numerous other industrial and pharmaceutical uses.

***Thevetia peruviana* (yellow oleander)**

The seeds of Yellow Oleander contain over 62% a triglyceride pale-yellow non-drying oil (about 20% of whole seed). The oil is being utilized in the manufacture of soaps, paints and cosmetic

***Riccinus communis L*. (castor)**

The castor oil plant *Ricinus communis* (sometimes called mole bean after the belief that the "beans" can be placed in mole tunnels to poison the animals), is a plant species of the *Euphorbiaceae* family. Its seed is the castor bean which, despite its name, is not a true bean. Castor seed is the source of castor oil, which has a wide variety of uses. The seeds

contain between 40% and 60% oil that is rich in triglycerides, mainly ricinolein. They also contain ricin, a poison, which is also present in lower concentrations throughout the plant.

The use of castor seed oil in India has been documented since 2000 BC for use in lamps and in local medicine as a laxative, purgative, and cathartic in Ayurvedic and other ethnomedical systems. Castor seed and its oil have also been used in China for centuries, mainly prescribed in local medicine for internal use or use in dressings. Castor oil has an unusual composition and chemistry, which makes it quite valuable. The castor bean contains 50-55% oil. The oil itself contains a number of fatty acids similar to those in cooking oils, such as oleic acid, linoleic acid, stearic acid and palmitic acid. However, among vegetable oils, castor oil is distinguished by its high content (over 85%) of ricinoleic acid. No other vegetable oil contains so high a proportion of fatty hydroxyacids. Castor oils unsaturated bond, high molecular weight (298), low melting point (5ºC) and very low solidification point (-12ºC to -18ºC) make it industrially useful, most of all for the highest and most stable viscosity of any vegetable oil.
(http://www.ienica.net/crops/castor.htm).

Castor oil maintains its fluidity at both extremely high and low temperatures. This oil and its derivatives have applications in the manufacturing of soaps, lubricants, hydraulic and brake fluids, paints, dyes, coatings, inks, cold resistant plastics, waxes and polishes, nylon, pharmaceuticals and perfumes. In internal combustion engines, castor oil is renowned for its ability to lubricate under extreme conditions and temperatures, such as in air-cooled engines. It is said to be the best lamp oil in use in India, giving an excellent white light, vying in brilliancy with electricity, far superior to petroleum, rape seed, and all other oils, whether vegetable, animal or mineral. In Bangladesh some villagers use castor oil instead of kerosene. (Wikipedia enclyclopedia)

Plate 4: *Jatropha curcas and Croton megalocarpus*

Plate 5: *Croton megalocarpus* Biodiesel crude oil

Plate 6: Oil lamp using *Croton megalocarpus* Biodiesel

6.6 Biomass or eco-energy briquettes

This is a solid cooking fuel made out of organic waste material. It's a round shape with a hollow core. It is an environmentally friendly alternative to charcoal and a cheaper substitute for charcoal or firewood. There are many community groups making briquettes for organic waste. One such group is comprised of women from Kibera who collect fire wood from Ngong forest. They use tree seeds and leaves which usually go to waste.

Plate 7: The circular hollow briquettes from the press laid out to dry before use

The Advantages of biomass briquettes are threefold:

***Economies*:** Since briquettes can be made of almost any dry organic waste – from tree leaves to cereal husks, from scrap paper to banana peels, from saw dust to charcoal fines – input materials are free or quasi-free (the only cost might be that of collection).
Producing one's own briquettes can entirely replace charcoal or firewood purchase and induce substantive savings

***Livelihood improvement*:** Women are traditionally those collecting firewood, transporting heavy packages on long distances everyday. With a painful, time-consuming and sometimes even perilous activity gone, women can now engage in other activities, particularly income generating ones

***Income generation*:** A group of 6 people, with a small working capital start-up investment to buy the tools and the press (around $200), can easily produce fuel for 50 families. Selling the briquettes on the market can answer two needs: generate a substantial income to the producer and substantial savings for the end-user compared to charcoal and wood.

7.0 Recommendations

7.1 Improve wood energy production systems (farm forestry and plantation forests)

Woodfuel production need to be integrated into local farming systems as the agricultural sector has a key role to play in supplementing woodfuel through wood production. This can be supported by development of on-farm management regimes for use at the farm level.

The Kenya Forest Service should develop plantations for woodfuel as a national priority along the same line followed for timber production. The firewood plantations should be established with appropriate fast growing trees which match specific environmental and ecological conditions for maximum productivity.

7.2 Improve wood energy production and utilization technologies

Improved charcoal kilns (with efficiency of > 25%) over 95% of charcoal producers use traditional methods (with 10-20% efficiency). Use of dry wood during carbonisation should also be encouraged. The technologies to be used should be simple, cheap and

easily adopted by charcoal producers like the improved earth kiln developed by KEFRI (Oduor et.al, 2006). This would lead to a reduction of wood needed for charcoal making significantly.

The conservation of wood energy should be given a priority through promotion of improved stoves with higher efficiency. As currently households use 3 stone stoves which are inefficient. The improved stoves to be promoted for adoption should consider users needs which include cooking comfort, convenience, health and safety. The improved stoves should also be of affordable prices.

7.3 Alternative energy opportunities available –

There are opportunities to use various sources of energy as presented in the paper. Policies should explore and extend the use of some these sources to enable Kenyans have access to affordable, clean energy:

- Biomass/ eco-energy briquettes made from forest wastes such as leaves, seeds, and other biomass wastes
- Biodiesel alternatives to kerosene
- Cogeneration from agricultural wastes to feed on to the national electricity grid
- Gasification using invasive plant species to produce electricity to feed into the national grid

7.4 Strengthen wood energy institutional framework

Wood energy development should be integrated into rural energy supply strategies and pursued as common task by all relevant sectors like; agriculture, forestry, energy and industry. The coordination and linkages among the sectors concerned has been weak and need to be strengthened. There is need to identify overlaps and gaps for sectors involved in wood energy development so that the one with comparative advantage in the overlapping areas is complemented.

7.5 Enabling policy and legal framework

For the success of commercial charcoal production and marketing, there is need for clear charcoal policy guidelines which would encourage investments on improved charcoal processing technologies. Charcoal production should be like any other cash crop farming and it should be taxed and reflected as a potential revenue earner for government. This can only be achieved if charcoal and fire wood production and marketing are safeguarded by legislation and given legal status. The fuel substitution

from wood energy to modern sources of energy (LPG, kerosene and electricity) as stated by the energy policy document cannot be very effective due to high initial cost of the modern energy appliances and a subsidy is recommended for initial procurement of the appliances.

8.0 Conclusion

Kenya's forests play many important roles. We have already seen that a large percentage of the country's and even in the region population depend on woodfuel, including fuelwood and charcoal, for their energy requirements. The sustainability of this high dependence is questionable and, increasingly the country is looking at the energy opportunities offered by other resources, including solar and wind energy.

The future thrust of the energy sector may be summarized as follows:

- Increase contribution of renewable energy in the overall national energy supply mix;
- Enact legislative and regulatory framework to guide various energy sub-sector elements such as charcoal, wood energy supply, institutional reforms;
- Enhance partnership and promote privatization of energy utilities to enhance competition and ultimately achieve efficient service delivery;
- Build a critical institutional and human capacity to effectively address current and future challenges to achieve greater efficiency in the energy sector;
- Provide incentives for individuals, businesses and industry to increase wood fuel by encouraging on-farm forestry, solar energy, adopt use of energy efficient stoves and fireplaces;
- Research on charcoal briquettes production using wastes such as farm refuse, sawdust and woodchips. These initiatives can be supported through active private sector involvement;
- Promote integrated energy planning to incorporate energy and land use concerns;
- Inculcate energy efficiency, conservation and environmental audits consistent with the energy policy and EMCA, 1999; and
- In order to reduce the biomass supply and demand imbalance, an ambitious two-pronged strategy is recommended. The establishment of 25,000 ha of fuelwood in gazetted forests areas using improved tree clones; and commercialization of fuelwood production to the tune of 500,000 ha through woodlot development in private farms at a rate of 28,000ha annually, over the next 16 years (Ministry of Energy, 2002). The

former is anticipated to result to an extra supply of over 800,000 tonnes of wood annually.

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