



Bioenergy value chain research and development Stakes and Opportunities

FARA Discussion Paper

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Summary

There is an increasing interest in biofuels as an alternative source of energy and as a means of reducing the production of greenhouse gases which contribute to global warming. However, biofuels as alternative energy source among other key factors have contributed to the current food crisis and debate.

Access to affordable energy is essential for the reduction of poverty and economic growth. Rising oil prices and fear of future shortages combined with a greater awareness of climate change has focused attention on the need to diversify energy sources. Most African countries have the potential to develop alternative energy sources with both economic and environmental benefits. Many African countries have their own immediate needs for import substitution but there are also potential export markets in Europe and the USA, which other developing regions are capitalizing on. Bioenergy production could attract investment and provide rural employment and income generation and thus help curb urban migration.

In view of its food shortages and rapidly increasing commodity prices Africa must maintain a careful balance between ensuring food and energy security. Energy demand in Africa is growing rapidly due to the triple pressures of rapid population growth, increased urbanization and industrialization. However, increased global energy demand has led to increased food prices as a result of the triple effects of increased use of biofuels, increase in population, and the high cost of fossil fuel products. To ensure that this does not unduly disrupt the food-energy balance, governments must develop comprehensive plans and guidelines in the promotion of biofuels as alternate sources of energy. Research is therefore required to identify opportunities for biofuel production in areas that are marginal for food production and for using crops such as sweet sorghum and other crop byproducts instead of grains for biofuel production. In both cases research will also be required to increase productivity per unit area of crop variety, land, labour and capital for both food and biofuels.

There are many potential sources of biofuels including sugar cane, cassava and sweet sorghum for the production of alcohol as a substitute to gasoline and the oil producing crops such as cotton (cottonseed), oil palm, Jatropha, Euphorbia tirucalli. The agronomy of some of these, such as cotton, sugar cane and cassava, is well known but others including (Jatropha, Euphorbia tirucally) require genetic improvement, farming techniques to intensify production, improving the quality of products, and to develop viable technologies for extracting and utilizing the biofuels produced.

Research is also required to reduce the dependency on firewood and charcoal which currently provide 80% of Sub Saharan African household energy needs by improving both the development and dissemination of improved stoves using fuel oils or ethanol and the applicability alternatives such as methane production and solar heating that would be less environmentally destructive. Research is equally needed to develop non transport biofuels for use in small scale rural electricity production for diesel in small generators and stoves and lanterns using methane or Straight Vegetable Oils (SVO).

In order to create crucial mass and avoid duplication, the research should be conducted at selected centres which have the greatest comparative advantage on different sources of biofuels. These R&D efforts should be strategically placed within the context of an integrated alternative and renewal energy research for development undertaken by other sector stakeholders.

1. Introduction: Energy key to Africa's prosperity

Africa is the largest and most populous continent in the world after Asia. Covering 20.4% of the available land area worldwide, it is home to over 900 million people distributed over 53 countries. Despite the continent having about 14% of the world's population and producing 7% of the world's commercial energy, it consumes only 3% of that energy and exports more than half of its production (Davidson & Sokona, 2002).

Africa continues to face great challenges; it is still far from achieving the Millennium Development Goals (MDGs). To date around half of Africa's population live in absolute poverty with about 70% depending on traditional biomass as their only source of fuel. The lack of access to reliable, clean and affordable energy services in Africa is seriously hampering all efforts for more economic growth and less poverty. It is estimated that, with the exception of South Africa and Egypt, the majority of African countries are only able to provide direct access to electricity to 20% of their peoples. This number is as low as 5% in some countries. Most of the existing power plants and transmission equipment were constructed in the 1950s & 1960s, and in the absence of proper maintenance have deteriorated over the last several decades; the degradation has forced many utility companies to operate at small fractions of their installed capacity.

Access to energy is essential for the reduction of poverty and the promotion of economic growth. Communication technologies, industrialization, agricultural improvement require abundant, reliable, and cost-effective energy access. Energy security and access to energy are also crucial for social improvement, (education expansion of municipal water systems) and are necessary to the building of peace and democracy.

Rising oil prices and fear of future resource shortages combined with a greater awareness of climate change and the need to diversify energy sources have brought the issue to general attention. By investing in the long-term energy solutions that alternative energy sources offer, most African nations would benefit significantly in the long term by avoiding the pending economic problems developed countries are currently facing.

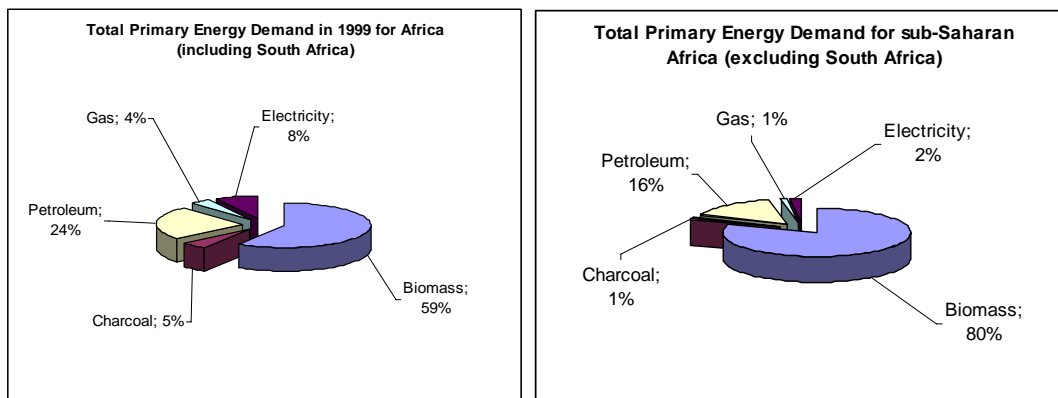
Global demand in energy will increase by 55% by 2030. Although in many ways fossil fuels provide a simple, easy to use energy source that powered the industrialization of most modern nations, the issues associated with the widespread use of fossil fuels are now numerous, and are some of the world's most difficult and large scale global political, economic, health and environmental problems. The looming energy crisis results from consuming these fossil fuels at a rate which is unsustainable, with the global demand for fossil fuels expected to increase every year for the next several decades, compounding further existing problems.

While a great number of projects are currently underway to expand and connect the existing grid networks, there are too many problems to make this a realistic option for the vast majority of people in Africa, especially those who live in rural locations. Distributed generation using renewable energy systems is the only practical solution to meet rural electrification needs.

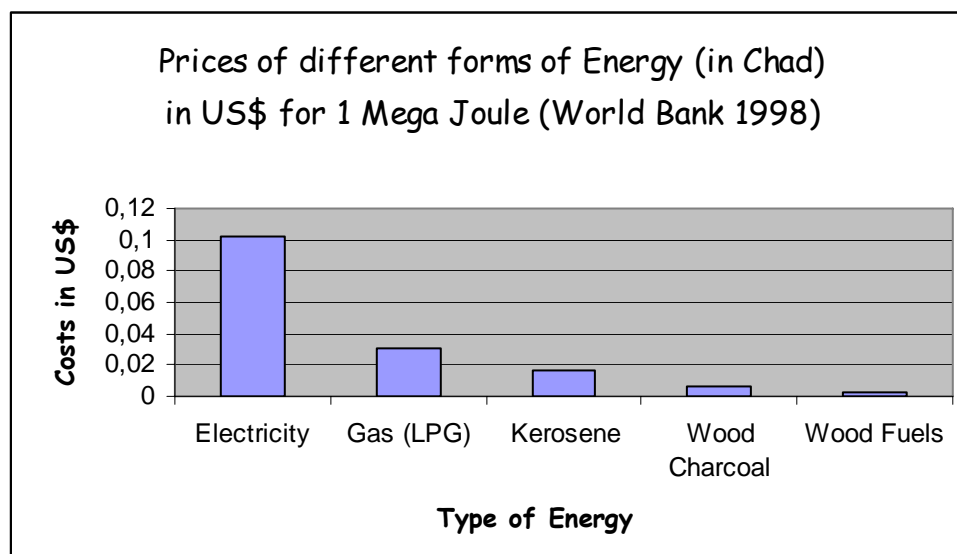
2. Energy Demand in sub-Saharan Africa

Africa is the lowest consumer of energy in the world. An African uses only one eleventh, one sixth, and half of the energy used by a North American, a European, and a Latin American, respectively. Even within Africa there are lots of differences between sub-regions. Over 70% of oil and 60% of natural gas consumed in Africa are used in four countries, namely Algeria, Libya, Egypt and Nigeria. South Africa uses about 93% of the coal produced on the continent.

The situation in sub-Saharan Africa is substantially different as this region depends heavily on inefficient traditional biomass, in the form of firewood and charcoal, which accounts for over 60% (80% if we exclude South Africa) primary energy demand (S; Karekezi, 2003; J.P. Laude, 2007). Even oil-rich sub-Saharan African countries continue to rely on biomass energy to meet the bulk of their household energy requirements. This use is inefficient and in some areas puts pressure on biomass resources. There is an urgent need for substantial increases in energy consumption in sub-Saharan Africa to be competitive with other developing regions.



Electricity is by far the most expensive form of energy. It is therefore understandable that households prefer to use wood fuels, wood charcoal and even kerosene or gas stoves for cooking (Word Bank, SAR-HEP, 17780-CD May 1998).



The structure of the demand of energy in sub-Saharan Africa opens three major opportunities to bioenergies and biofuels:



- **Reduce the use of fuel wood & charcoal** which presently account for 80% of the total energy demand. Charcoal and fire wood are the primary fuel for the urban poor as well as for the rural population. Steadily rising wood consumption for cooking purposes results in deforestation of large areas creating severe ecological, economical and sociological problems.

Charcoal production relies on rudimentary earth kiln which is contributing to deforestation and land degradation on most of the peri urban regions of sub Saharan Africa. Gelfuel from Ethanol (mixed with a thickening agent), improved charcoal, plant oils and small-scaled biogas technologies using crop wastes and animal dung are promising alternative energy sources offering a variety of economical and ecological advantages. There are also more efficient ways of making charcoal including briquettes and this can be done from waste and renewable wood in plantations and invasive species. Improvement and dissemination of fuel-efficient cookstoves for urban and rural households are also an important development issue to significantly reduce the firewood consumption.

- **Reduce the importation of fossil fuel products** used for transportation and electricity production by developing liquid biofuels made from biomass as a way of reducing Greenhouse Gas (GHG) emissions, save foreign exchange, stimulate rural development and create jobs. The recent increase in the world oil price has prompted countries to consider biofuels option.

- **Produce more biofuel crops for exportation.** The demand for biofuels in the USA, Europe, and other developed nations is partly driven by the need to replace fossil fuels and lessen dependence on high-priced imported oil. The goals being set are ambitious as the European Union (EU) has set targets of 10% biofuels in vehicle fuel by 2020. The USA has called for the production of 35 billion gallons of biofuels by 2017, which would displace 17% of projected US petrol consumption. Since it is unlikely that Europe will be able to produce enough biodiesel to meet those targets or that the USA will be able to produce enough ethanol for its needs, developing nations are actively pursuing biofuel markets (David Boddiger, 2007).

3. Why Biofuels?

Liquid biofuels made from biomass are attracting increasing interest in developing countries. This enthusiasm is based on five key advantages that modern biofuels offer compared to fossil fuels and/or other renewable energy sources (J.F.M. Castro, 2007):

- **Widely available resource:** Biomass resources are diverse and widespread, often in large volumes. Biofuels can be produced, in principle, wherever trees and food are grown and wherever food and fiber are processed. This is in marked contrast to

the geographic concentration of the oil and gas resources that drive today's industrial activity.

- *Available on demand:* Biomass is a form of stored energy and can therefore provide energy at all times, without the need for expensive storage devices such as batteries. In this respect biofuels are like fossil fuels and differ markedly from intermittent renewable energy sources such as solar, wind, wave and hydropower, with their nightly, seasonal or sporadic supply shut-downs.
- *Convertible to convenient forms:* Biomass can provide all the major energy carriers – electricity, gases, liquid fuels for transport and stationary uses, and heat, and it is well-suited to doing this on a decentralized (stand-alone) basis. Biomass can therefore provide an energy substitute for fossil fuels or other energy supplies in many contexts; and is well-suited to supply the fuels and power at small scales that are needed to underpin poverty reduction, rural development and growth for the two billion or so people who now lack access to modern forms of energy.
- *A potential to contribute to greenhouse gas reductions and other environmental objectives:* In contrast to fossil fuels, biofuels production and use emit little or no carbon dioxide, a potent greenhouse gas.
- *Source of rural livelihoods:* Much of the value added and income-generation from biofuels systems is retained locally and can help to reduce rural poverty – in sharp contrast to fossil fuel or central electricity production and distribution systems, and to many other renewable energy technologies. In developing countries, modern biofuels can provide a basis for rural employment and income generation, thus helping to revitalize rural economies and curb urban migration.

Because of the important role played by fossil fuels in the build-up of greenhouse gases in the atmosphere (it is estimated that the energy sector accounts for about half of the global emissions of green-house gases) and concomitant climate change concerns, renewable energies are perceived to constitute an important option to mitigate and abate the emissions of greenhouse gases¹.

Africa's contribution to global greenhouse gas (GHG) emissions is not really important, (about 3% of the global GHG emissions). Nevertheless contributing to still reduce this rate is a major objective of the continent as the continent is one of the most vulnerable to the impacts of climate change. Africa plays an important role in the capture of carbon and the fact that it is losing its rainforests faster than Brazil must be an important concern for the rest of the world. In contrast to the industrialized world which is worried by the long-term global environmental impact of current patterns of energy production and use, African countries are much more preoccupied with the immediate problems of meeting the long-standing and pressing demands for a minimum level of energy for the majority of their poor - many of whom have no electricity and continue to rely on inefficient and environmentally hazardous unprocessed biomass fuels. Africa is likely to be disproportionately affected by the impacts of climate change. Of particular concern is the dependence of the poor in Africa on rain-fed agriculture, which is believed to be already

¹ United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in 1992 and United Nations Framework Convention on Climate Change (UNFCCC) (United Nations, 1992).

under threat from unpredictable weather patterns triggered by what appears to be climate change.

The consensus around the further development of renewable energies appears to be growing. During the Johannesburg World Summit on Sustainable Development (WSSD) in 2002, top priority was given to the renewable energies and other alternative forms of energy services. One of the targets proposed at WSSD was for every country to commit itself to meeting 10% of its national energy supply from renewable energies. The international energy community is showing an increased interest in biofuels as biofuels can be considered both as a sustainable source of energy, an alternative for reducing oil-dependency, a technical option to respond to climate change and also a way to protect existing biomass (wood fuel).

4. Would biofuel crops threaten food security?

The developed world's demand for biofuels presents both opportunity and risk for African countries to bridge the gap between rich and poor nations by producing more biofuel crops for export. With the increase of fossil fuels prices (over US\$ 115 per barrel in April 2008), ethanol and bio diesel industries are becoming economically very profitable and may offer high prices for agricultural raw materials (sugar cane, corn, cassava, vegetable oils...). This increased international demand for biofuels and agricultural raw materials has an impact on world prices for these products. Higher commodity prices would potentially increase incomes of farmers but it will also increase the cost of basic food commodities and this is evident in the current food crisis and debate. This represents a real opportunity and risk for developing countries, since three quarters of their population live in rural areas, mostly relying directly or indirectly on agriculture. Historically, when there is a food crisis, high prices are followed by significant investment in agricultural productivity growth; when the production increases, the prices come down. The world has considerable capacity to grow more food through investments. There is a great concern about the poorest countries in Africa, largely due to a general neglect of agriculture for the last 20 to 25 years. The main challenge is to increase productivity and production of food staples, as population growth will double in the next 20 years. (Peter Hazell, 2008, IFAD's Governing Council).

Biofuel development (first generation – crops that have traditionally been used for food such as sugarcane, cassava, sorghum, palm oil...) will compete with food production and even the non food biofuels crops (second generation – sweet sorghum, wood chips, switch grasses) will compete with food crops for land and water. In some places, biofuels developments have led to increased palm oil production, often at the expense of dwindling rainforests, which have been cleared to create new plantations.

At national level, poor consumers in urban areas and poorer farmers who are food consumers could be food insecure. At macroeconomic level, low income countries which are net food importing will be affected by an increase in food import bill, especially where they have low foreign currency reserves.

It is essentially at national level that corrective measures must be considered. Biofuels policy options should exclude certain staple food crops or focus on non food crops. Biofuels production should be based on higher agricultural productivity/production and also by increasing agricultural land area within environmentally sustainable limits.

Proponents of biofuels state that: "Biofuels could attract investment that would support agricultural improvements across the board, which would benefit food production,

accelerate rural economic development, and alleviate poverty and migration to the cities.” The potential for farmers’ wages to increase in developing countries is real, but the possibility also exists that food prices will increase and create even more hardships on poor consumers. The International Food Policy Research Institute (IFPRI) predicts that “in both current and longer term projections an upward expansion in food prices is likely and the number of food insecure people would rise by over 16 million for every percentage increase in the real prices of staple foods”. There are obviously conflicting interests among developing countries (net agricultural exporters vs importers) and even among population groups (net food producers – rural population vs consumers – urban population).

At the International Conference on Biofuel, Brussels, July 2007 the EC Chairperson (Jose Manuel Barroso) recognized that biofuels have a potential downside. “Our aim must be to develop an EU biofuels policy which meets our objectives on security of supply and climate change, while ensuring sustainable development. What we must not do is pursue a policy which simply shifts environmental problems from one sector to another or from one continent to another”.

There are hopes for full-scale development of second-generation biofuels, which do not directly threaten food sources and will require less water resources. But such a solution is at least a decade away. For the meantime, sustainable biofuel development will require guidelines and planning by governments. Governments (as in Mozambique) “have to encourage peasant farmers to grow oil plants which do not conflict with food production”. Greater research mobilisation is needed to develop technologies that will increase productivity of agriculture per unit of land and labour, to meet growing global demand for both food and biofuels (C.B.L. Jumbe, 2007).

Rural development and poverty reduction in rural areas are critical to reach Millennium Development Goals (MDGs) in developing countries where poverty rates are highest in rural areas. *Biofuels development policies* will help to minimize the “clash” between food security and energy crops production provided that they address most of socio-economic elements using positive impacts to compensate negative impacts:

The following positive impacts:

- Improved energy security with a higher proportion of indigenous energy supply;
- Improved access to energy in rural areas with decentralized fuel production units
- Development of value adding industries in rural areas;
- Development of new land areas with some energy crops which accept very poor quality of land or degraded soils under arid climatic conditions;
- Increased farmers’ incomes;
- Crops diversification with new markets and jobs creation;
- Limitation of Green House Gas (GHG) emissions – Climate change mitigation;
- Access to carbon funds (Clean Development Mechanisms);

Might compensate the following measures to limit & control negative impacts:

- Specific supports to poorest urban population and poorest farmers;
- Regulation tool for some staple foods;
- Incentive measures to promote non food bioenergy crops;
- Apply new land use regulations to protect: forest, biodiversity ecosystems and land with high carbon stock or high biodiversity...
- Development of Standard for biofuels products;
- Enforcement of labour policies promoting decent work;
- compensate negative environmental effects if any;

Higher prices of agricultural products benefit farmers as they offer farmers a significant opportunity to increase their incomes. Bio energy can be an opportunity for the rural poor since it represents a fast growing market for agricultural products. Policies in developing countries need to ensure that lower-income groups, more vulnerable groups and poor farmers are not penalized by the development of bio energy. Bio fuels development has to be pro-poor, pro-women, pro-environment and pro-livelihoods. (M.S. Swaminathan, Rodney Cooke, 2008, IFAD's Governing Council)

5. Overview of the most relevant Liquid Biofuels in the sub-Saharan Africa context

Biofuels are products from biological origin that have been converted into liquid. Bio-ethanol, Straight Vegetable Oils and bio-diesel (esterification of the plant oils) are the most common forms of liquid biofuels. At world level ethanol represents 90% of the production and use of biofuels. Between 2000 and 2005, global ethanol production doubled, whereas biodiesel production was multiplied by four and mainly in Europe. The fact that the growing European biofuels market is to be supplied partly by imports provides market opportunities but also risks for developing countries. Ethanol, Straight Vegetable Oils and biodiesel can be produced in sub Saharan African. Technology should generally not be a major obstacle for developing countries to engage in such production both for national purpose and for exports.

5.1. Bio-Ethanol

5.1.1. Bio-Ethanol Production

Ethanol (C_2H_5OH) can be used in gasoline vehicles with minor adaptations. Bio-Ethanol is an alcohol-based alternative fuel produced by fermenting and distilling biomass with high sugar content such as sugarcane, molasses (a residual product of sugar production). Another way is to ferment and distillate sugar starch crops that have first been converted into simple sugars (saccharification). In sub Saharan Africa the feedstocks for this include corn, sweet sorghum and cassava. Bio-Ethanol can also be produced from "cellulosic biomass" such as trees and grasses. New technologies to convert cellulose to ethanol, such as Cellulosic Hydrolysis, could provide much higher positive energy ratios of 2 to 3 times more energy in the ethanol produced than energy input. Cellulose to ethanol production could also run on any cellulose and hemicellulose source from farm waste, hay/grass, basically any plant matter including wood, cardboard and paper. Cellulose to bio-ethanol production is still in development.

Ethanol (ethyl alcohol, grain alcohol) is a clear, colorless liquid with a characteristic, agreeable odor. Ethanol has a density of 0.789 g/ml at 20°C, boils at 78.5°C, and melts at -114.1°C, (at the melting point the solid and liquid phase exist in equilibrium). Ethanol can reach 96% purity by volume by distillation, and is as clear as water. Ethanol in water cannot be purified beyond 96% by distillation. This concentration (called azeotropic) is enough for straight-ethanol combustion. For the blending with gasoline, purities of 99.5 to 99.9% are required, depending on temperature, to avoid separation. These purities are produced using additional industrial processes.

For the sub Saharan region 3 main crops are particularly interesting for Bio-Ethanol production: sugar cane, sweet sorghum and cassava.



Sugar Cane (*Saccharum Officinarum*) is a genus of tall perennial grasses (Family poaceae, tribe Andropogoneae) native to warm temperate to tropical regions of the old world. They have stout, jointed, fibrous stalks that are rich in sugar and can measure more than 3 meters tall. About 200 countries grow the crop to produce 1,324 million tons (de Carvalho, 2005). The world's largest producer of sugar cane by far is Brazil.

The sugar cane is considered as the most efficient specie in terms of biomass production. Sugar cane juice and molasses can be fermented to produce ethanol. One tonne of sugar cane can produce around 100 liters of alcohol and 350 kg bagasse which on burning produces direct energy of which 60% is necessary to process alcohol. Average sugar cane yield can vary from 60 t/ha to more than 100 t/ha (6,000-10,000 liters alcohol per ha).



Cassava (*Manihot esculenta*) is a woody shrub of the Euphorbiaceae (spurge family) native to South America that is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root, a major source of carbohydrates. World production was estimated to be 182 million tonnes in 2002, sub Saharan is the largest center of production with 99 million tonnes.

Cassava is grown primarily for the tubers which are used as food stuff. From the cassava tuber are obtained starch, flour, tapioca, etc. The alcohol production from Cassava roots depends on the starch (carbohydrate) content. The fresh roots contain about 25-30% starch and 5% sugar. As a guide, cassava roots at 30% starch content will produce around 250 liters of alcohol (96%) per tonne of root. Cassava has one of the highest rates of CO₂ fixation. This means that cassava makes for a super crop when it comes to both CO₂ fixation and carbohydrate production, the feedstock for ethanol.



Sweet Sorghum (*Sorghum bicolor*) is a cane-like plant with high sugar content. Sweet sorghum is very drought and heat tolerant and is suitable for arid regions. African slaves introduced the crop in USA in the early part of the 17th century. Production in USA is continuously decreasing. Ethanol production from traditional varieties is of about 3000 liters per hectare (2 tonnes grains + stalks).

Farmers get greater income from sweet sorghum as they sell the stalks to distilleries and the grain for food and feed.

Researchers at the International Institute for the Semi Arid Tropics (ICRISAT) have developed sweet sorghum for the production of ethanol. The new hybrid varieties have very high sugar content. Growing period (about 4 months) and water requirement (4000 m³ per cycle) are 4 times lower than those of sugar cane. Grain production can reach 5 tonnes per hectare and 45 tonnes for cane (grains + stalks). Ethanol productivity is estimated at 40 liters per tonne of millable cane yield (1800 liters alcohol per hectare).

5.1.2. Bio-Ethanol Use

The use of bio-ethanol as a fuel in transportation was formerly mainly to increase the octane level and improve the emissions quality of gasoline, but today it is increasingly being used as a partial or total replacement for gasoline in cars and other road vehicles. Bio-Ethanol, with an octane rating of 113, far surpasses regular gasoline and precludes needs for other additives as tetra ethyl lead, benzene and methyl tert-butyl ether (MTBE) which cause important air pollution. If 10 to 20% ethanol is mixed with gasoline, no engine modification is typically needed. Many modern cars can run on the mixture very reliably. Since 2000, an increasing number of vehicles in the world are manufactured with engines which can run on any gasoline from 0% ethanol up to 100% ethanol without modification. Many cars are designed to be dual fuel or flexible fuel vehicles, since they can automatically detect the type of fuel and change the engine's behaviour, principally air-to-fuel ratio and ignition timing to compensate for the different octane levels of the fuel in the engine cylinders.

Ethanol (either straight or jellified) can also be used in households for cooking as a substitute for wood, charcoal or kerosene and for lighting as a substitute for kerosene. Gelfuel is currently being distributed in several countries in Africa as a fuel for cooking. To produce gelfuel, ethanol is mixed with a thickening agent (for example cellulose) and water through a very simple technical process, resulting in a combustible gel. Gelfuel has several advantages compared to straight ethanol: one can not drink it, it is easier and less dangerous to store, sell and transport, and it is less likely to have fire in the household because if the stove falls the burning gel does not spread. The main disadvantage is that it is up to 25% more expensive than straight ethanol, and this makes it less competitive. Also, nowadays straight cheap ethanol burners that are very efficient and safer have been developed.

5.1.3. Bio-Ethanol Energy Balance and environmental effects

There are heated discussions about the issue of whether biofuels have a positive energy balance, i.e. do they deliver more energy than the energy which is put into their production. In tropical regions with abundant water and land resources, such as Brazil, the viability of production of bio-ethanol from sugarcane is no longer called into question as only 0.12 MJ (mega joule) of fossil fuels are needed to produce one unit of ethanol from sugarcane, an energy balance of 8.3. The production of one MJ of ethanol from corn requires the input of 0.74 MJ of fossil fuels, thus the energy balance is 1.35. The discussion is particularly heavy around the net benefits of the production of ethanol from corn in the USA (J.F.M. Castro 2007) and the ethanol production programmes in the SA are avenues to subsidize mid-west farmers that otherwise would have gone out of the business. It should be noted that the production of gasoline has a negative energy balance, for every MJ of gasoline delivered it requires 1.23 MJ of fossil fuels as this is the price to pay to have a highly convenient fuel (Michael Wang).

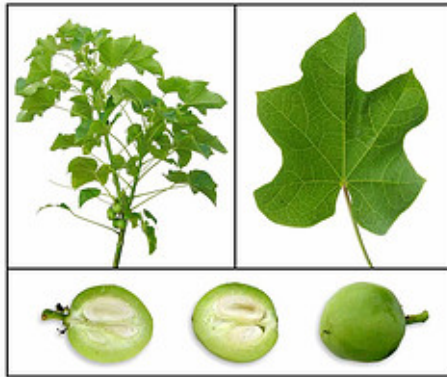
For the whole chain of sugarcane production and transformation, including crop growing, sugar production, direct energy production from burning the molasses and production and

use of the bio-ethanol in gasoline in thermal engines, the overall balance between sequestration and emission of CO₂ is positive as 207 kg CO₂ per metric tonne of sugarcane is avoided (de Carvalho, 2005). Comparable positive balance for CO₂ can be expected for ethanol production and use from Cassava and sweet sorghum.

5.2. Oleaginous Oils

5.2.1. Vegetable Oils production

Plant oils can be used without major problems in diesel engines. Actually, Rudolf Diesel designed the machine he built to be fuelled by plant oils. Plant oil based fuels, can be straight oils without modification and biodiesel (fatty acid methyl ester); the plant oil is put through a process called esterification. Plant oils consist mainly of glycerides of fatty acid. In sub Saharan Africa, oils can be obtained mainly from a variety of sources, the most important among them are: palm oil, cotton seed, Jatropha, and *Euphorbia tirucalli*.



***Jatropha curcas* L.** (Physic nut). Jatropha is a drought-resistant small tree of the Euphorbiaceae family, native to South America, which is widely cultivated in the tropics. The oil in Jatropha seeds is toxic to humans and animals; they are therefore unsuitable for either food or feed. Jatropha plants are frequently used as hedges to protect plants in gardens and fields from grazing animals. The plant is adapted to extreme growing conditions.

Jatropha starts to produce fruits and seeds from 5 months and can continue producing for more than 50 years. Jatropha seeds contain 35% oil. Seed production is extremely fluctuating depending on cropping conditions and climates. Yield of 4-6 tonnes of seeds per hectare can be considered as average (extensive cropping); oil production is about 1800 liters per hectare.



Cottonseed. Cotton is a soft, staple fiber that grows around the seed of the cotton plant (*Malvaceae Gossypium sp.*), a shrub native to tropical and subtropical regions around the world. Fibers representing 85% of the commercial value of the crop is most often spun into yarn or thread and used to make a soft, breathable textile, which is the most widely used natural-fiber cloth in clothing today.

Cottonseed is extracted from the seeds of the cotton plant after the cotton lint has been removed. Seeds represent 50% of the cotton capsules (seed + Fibers + lint). On average 100 kg of seeds produce 20 liters of oil.



The African Oil palms (*Elaeis guineensis*) is native to West Africa. Mature trees are single stemmed, and grow to 20 m tall. The flowers are produced in dense clusters. The fruit comprises an oily, fleshy outer layer (pericarp) with a single seed (kernel) also rich in oil. For each hectare of oil palm, which is harvested year-round, the annual production averages 10 tonnes of fruit, which yields 3000 liters of pericarp oil and 250 liters of high quality kernel oil.



The Euphorbia tirucalli, (Pencil tree). *Euphorbia tirucalli* is an unarmed shrub or small tree with succulent branchlets produced in whorls, green, with white latex. *E tirucalli* is a widely planted hedge plant, long, used in agroforestry systems in East Africa. It is normally found in dry bush lands thickets and naturalizes easily in brushwood, open woodland and grassland.

E. tirucalli used as a source of hydrocarbon has been investigated for long. The sap called latex is similar to that of the rubber tree.

The hydrocarbon molecules in the Euphorbia latex have a size distribution very much like those in petroleum, so that after separating them from water, they can be refined into gasoline. The plants are simply to be cut near the ground and crushed in a mill like sugar cane. After removing the water, we get a crude oil void of sulfur. Oil production can vary between 3,000 to 16,000 liters per hectare (20-100 barrels/ha) depending on cropping conditions.

5.2.2. Vegetable Oils use

Gross calorific values of Plant oils are in general only 10 percent lower than those of diesel oil. Vegetable oils are more viscous (thicker) than diesel at moderate temperatures, they burn slower (have a larger ignition delay). Vegetable oils have acceptable cetane values, which measure the fuel's ignition quality. Sub-Saharan Africa plant oils have very similar physical, chemical and performance characteristics as the rapeseed oil in Europe largely used as biofuel.

Table 1: Physical properties of selected plant oils and petro-diesel oil (J.F.M. de Castro, 2007)

Oil type	Density 20°C	Viscosity 20-40°C	Flash Point °C	Cetane value	Energy value MJ/kg
Petroleum Diesel	0.836	7.5	93	50	43.8
Cottonseed oil	0.921	73	243	34	36.8
Palm oil	0.945	60	280	39	36.9
Jatropha oil	0.920	77	236	35	38.8
Rapeseed oil	0.920	78	285	36	37.4

The obvious substitutes for petroleum are plant oils and fats as they have the same base chemical structure as petroleum. Fossil fuels were plants once, millions of years ago, and

so it makes sense that both the fossil fuels we use today and oils produced by plants are chemically similar. Both are made up of chains of chemicals known as hydrocarbons. A hydrocarbon is a carbon atom surrounded by hydrogen atoms. Methane, the simplest hydrocarbon, is a single carbon atom surrounded by four hydrogen atoms. Gasoline varies from 7 to 10 hydrocarbons long. The word “octane” means eight in a chain.

The shorter the chain of carbons, the more explosive the fuel, and the more power it offers an engine. Plant oils are 14 to 18 carbons in length. Fossil diesel fuel is 15 carbons long, which is close to the same size as plant oils. This is why we can't burn vegetable oil in today's gasoline engines because their hydrocarbon chains are too long. Shorter-chain vegetable oils do exist: “Coconut oil and other tropical oils might make a reasonable gasoline – like fuel”. It might also be possible to transgenetically modify crops to produce plants with those lengths of fatty acids. Hydrocarbon chains have also a number of applications as inks, paints, solvers, plastics, coatings, adhesives, etc Chemists have known for decades how to alter the hydrocarbon chains through cracking and reforming processes.

Straight Vegetable Oils (SVO) can be directly used in diesel engines having indirect injection with pre-chambers. Direct injection diesel can also run on SVO, but some modifications have to be made to the engines. Instead of adapting the engine to run on SVO, the oil can also be chemically treated to produce biodiesel for any diesel engine, and the SVO can be converted to biodiesel with a simple trans-esterification process. The resulting biodiesel can be used in any diesel engine without adaptations. The production of biodiesel is essentially a simple chemical process. The vegetable oil molecules (triglycerides) are cut to pieces and connected to alcohol (methanol or ethanol) molecules to form methyl or ethyl esters. Glycerine is formed as a side product. This requires the addition of methanol (or ethanol) and caustic soda, increasing the cost of the final product. This process requires the use of electricity, and therefore biodiesel production is typically feasible on a large scale, at centralised production plants. Biodiesel mixes readily with petroleum diesel at any blend level, making it a very flexible fuel additive. Engine performance with biodiesel and biodiesel blends is virtually the same as with straight petroleum diesel.

In most rural, and many urban and peri-urban areas of developing countries, wood is still the main source of energy. Steadily rising wood consumption for cooking purposes results in deforestation of large areas creating severe ecological, economical and sociological problems. In order to protect the environment, it is urgently required to find a substitute for the use of firewood for cooking purposes. Introduction of fuel-efficient stoves can significantly reduce the firewood consumption. Plant oils are a promising alternative energy source offering a variety of economical and ecological advantages.

Plant oils can be used in very simple stoves, which can be made out of recycled metal cans and cost few dollars. These burners can be put inside other existing (improved) stove or mounted in an appropriate frame. SVO can also be used to produce light in very simple lamps that can be manufactured locally. This would allow for the substitution of kerosene that has often to be transported over large distances, is expensive, which supply is unreliable, and has to be imported in most African countries.

There is a huge demand for scientists to develop vegetable oil transformation to help create other new products out of plant materials. The need for fossil oils will never disappear completely but we shall be saving fossil oils to make more and more products through vegetable oils. To reduce biomass destruction a research priority should be given

to plant oils and/or ethanol production and use for cooking and lighting as well for electricity production in remote rural areas.

5.2.3. Vegetable oils energy balance and environmental effects

Much less is known about the energy balances of the production of biodiesel as compared to ethanol. For biodiesel these energy balances depend greatly on the source of the oil and, as in the case of ethanol, on the climate. Palm oil having the largest oil yield per hectare has probably the most favorable energy balance. On the other hand, palm oil plantations have been up to now mostly created by imposing severe environmental damages to rain forests. For *Jatropha*, very little is known because there is less experience and because *Jatropha* has not been cultivated on large scale up to now. It has been reported that *Jatropha* requires 10% of the energy contained in the oil as energy input for production and processing (Henning 1998).

In fact, one of biodiesels greatest benefit is that it requires no change to the immediate market infrastructure namely, public transport (buses) and commercial transport (freight trucks). Biodiesel can be used either as blend with petroleum diesel or as a pure fuel. However, due to the limited supply of biodiesel today, as well as the non-linear emission benefits of burning biodiesel, it is actually more environmentally beneficial to fuel 5 vehicles with a blended biodiesel (20% biodiesel / 80% petroleum diesel) than one vehicle with 100% biodiesel.

Biofuels are recognized for their environmental benefits, they are renewable, non-toxic, biodegradable, free of sulfur, and with 60% less carbon dioxide. Biodiesels emit 91% fewer greenhouse gases and 50% less particulate matter than petroleum diesel. Biodiesels are 11% oxygen by weight and, therefore burn more completely than petroleum diesel. In fact, a 20% blend with petroleum diesel in trucks and buses would eliminate the black smoke (unburned fuel) emitted during acceleration. Biodiesels are safe to transport, to handle and to store. Biodiesels can also help reduce public health risks associated with air pollution.

For every unit of fossil energy used to produce plant oil based biodiesel, 3.37 units of biodiesel energy are created. Biodiesels not only reduce the amount of carbon dioxide (CO₂) released into the atmosphere, but the crops used to produce biodiesel absorb also large amounts of CO₂ as they grow.

6. Clean Development Mechanism, Carbon funds & Carbon market

6.1. Background

Climate change emerged on the political agenda in the mid-1980s with the increasing scientific evidence of human interference in the global climate system and with growing public concern about the environment. The United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) established the intergovernmental Panel on Climate Change (IPCC) to provide policy makers with authoritative scientific information in 1988. Negotiations to formulate an international treaty on global climate protection began in 1991 and resulted in the completion, by May 1992, of the United Nations Framework Convention on Climate Change (UNFCCC).

The Convention sets an ultimate objective of stabilizing atmospheric concentrations of greenhouse gases² at safe levels. To achieve this objective, all countries have a general commitment to address climate change, adapt to its effects, and report their actions to implement the convention. The Convention divides countries into two groups: Annex I Parties, the industrialized countries who have historically contributed the most to climate change, and non-Annex I Parties, which include primarily the developing countries. The principles of equity and “common but differentiated responsibilities” contained in the Convention require developed countries to take the lead in returning their greenhouse gas emissions to 1990 levels by the year 2000.

6.2. Clean Development Mechanism and Cooperative Mechanisms

The Protocol establishes three cooperative mechanisms designed to help developed countries reduce the costs of meeting their emissions targets by achieving emission reductions at lower costs in other countries than they could domestically. These are the following:

- International Emissions Trading permits countries to transfer parts of their “allowed emissions” (assigned amount units).
- Joint Implementation (JI) allows countries to claim credit for emission reduction that arise from investment in other industrialized countries, which result in a transfer of “emission reduction units” between countries.
- Clean Development Mechanism (CDM) allows emission reduction projects that assist developing countries in achieving sustainable development and that generate “certified emission reductions – CER” for use by the investing countries or companies.

The mechanisms give countries and private sector companies the opportunity to reduce emissions anywhere in the world – wherever the cost is lowest – and they can then count these reductions towards their own targets. Any such reduction, however, should be supplementary to domestic actions in the developed countries. Through emission reduction projects, the mechanisms could stimulate international investment and provide the essential resources for cleaner economic growth in all parts of the world. The CDM, in particular, aims to assist developing countries in achieving sustainable development by promoting environmentally friendly investment from industrialized country governments and businesses.

The funding channeled through the CDM should assist developing countries in reaching some of their economic, social, environmental and sustainable development objectives, such as cleaner air and water, improved land-use, accompanied by social benefits such as rural development, employment, and poverty alleviation and in many cases, reduced dependence on imported fossil fuels. In addition to catalyzing green investment priorities in developing countries, the CDM offers an opportunity to make progress simultaneously on climate, development, and local environmental issues. For developing countries that might otherwise be preoccupied with immediate economic and social needs, the prospect of such benefits should provide a strong incentive to participate in the CDM.

² The targets cover six main greenhouse gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydro fluorocarbons (HFCs); per fluorocarbons (PFCs); and sulphur hexafluoride (SF₆). The Protocol also allows these countries the option of deciding which of the six gases will form part of their national emissions reduction strategy. Some activities in the land-use change and forestry sector, such as afforestation and reforestation, that absorb carbon dioxide from the atmosphere, are also covered.

CDM projects must satisfy two critical criteria: i) reductions in emissions that are additional to any that would occur in the absence of the project activity; and ii) sustainable development (SD).

Sustainable Development may be broadly categorized as:

- Social criteria - where the project improves the quality of life, alleviates poverty, and improves equity;
- Economic criteria - the project provides financial returns to local entities, results in positive impact on balance of payments, and disseminate new technology;
- Environmental criteria - the project reduces greenhouse gas emissions and the use of fossil fuels, conserves local resources, reduces pressure on the local environments, provides health and other environmental benefits, and meets energy and environmental policies.

6.3. Clean Development Mechanism value and benefits

The basic principle of the Clean Development Mechanism (CDM) is simple: developed countries can invest in low-cost abatement opportunities in developing countries and receive credit for the resulting emissions reductions, thus reducing the cutbacks needed within their borders. While the CDM lowers the cost of compliance with the Protocol for developed countries, developing countries will benefit as well, not just from the increased investment flows, but also from the requirement that these investments advance sustainable development goals. The CDM encourages developing countries to participate by promising that development priorities and initiatives will be addressed as part of the package. This recognizes that only through long-term development will all countries be able to play a role in protecting the climate.

From the developing country perspective, the CDM can:

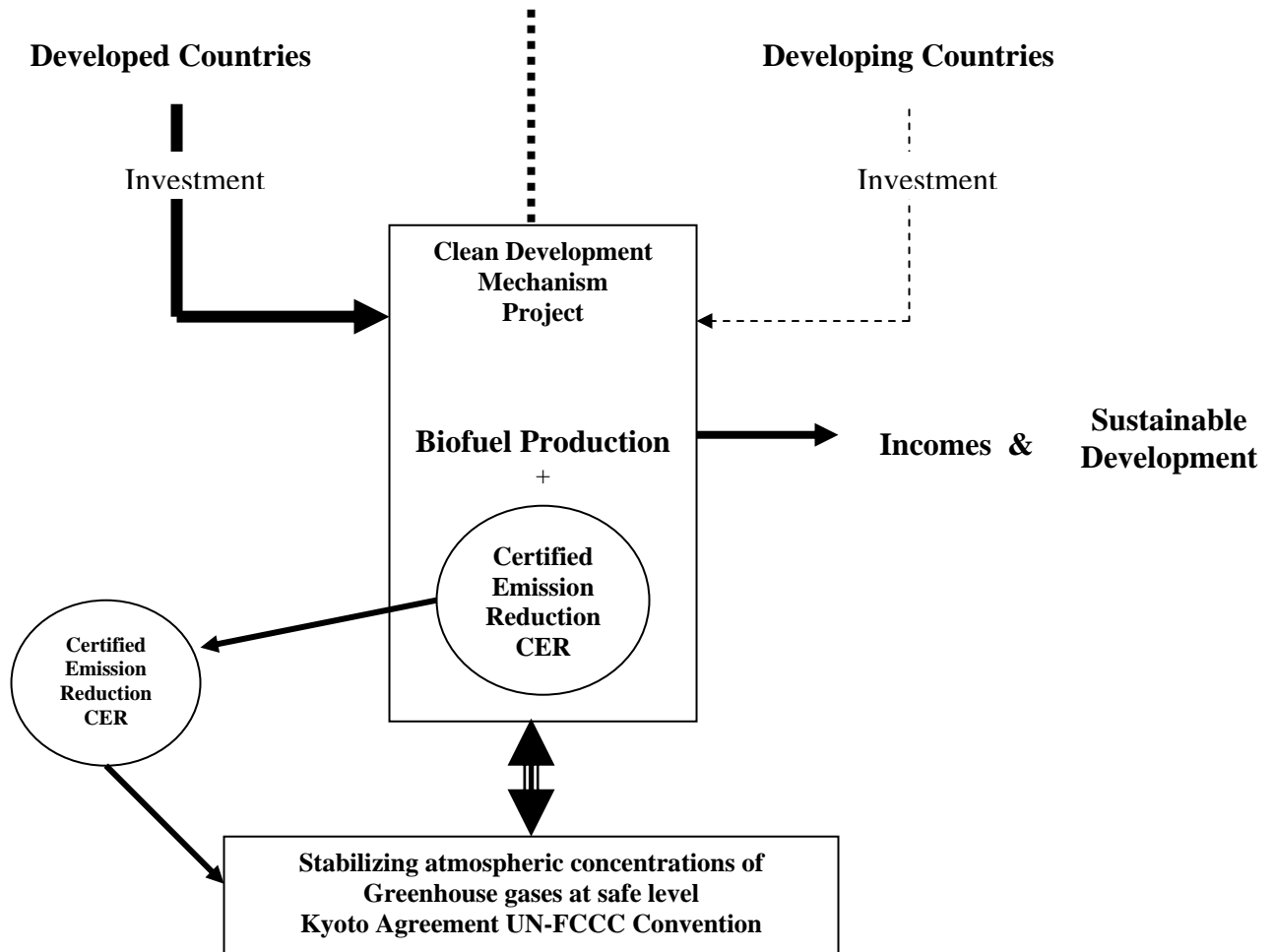
- Attract capital for projects that assist in the shift to a more prosperous but less carbon-intensive economy;
- Encourage and permit the active participation of both private and public sectors;
- Provide a tool for technology transfer, if investment is channeled into projects that replace old and inefficient fossil fuel technology, or create new industries in environmentally sustainable technologies; and,
- Help define investment priorities in projects that meet sustainable development goals (transfer of technology and financial resources; increasing energy efficiency & conservation; sustainable ways of energy production; poverty alleviation through income and employment generation; and, local environmental side benefits).

CDM projects will entail not only carbon reduction benefits, but also produce a range of environmental and social benefits within developing countries. Sustainable development benefits could include reductions in air and water pollution through reduced fossil fuel use, especially coal and oil, but also extend to improved water availability, reduced soil erosion and protected biodiversity. For social benefits, many projects would create employment opportunities in target regions or income groups and promote local energy self sufficiency. Therefore carbon abatement and sustainable development goals can be simultaneously pursued.

Table 2: Illustrative example of qualitative assessment of the sustainable development impacts of some possible biofuels projects

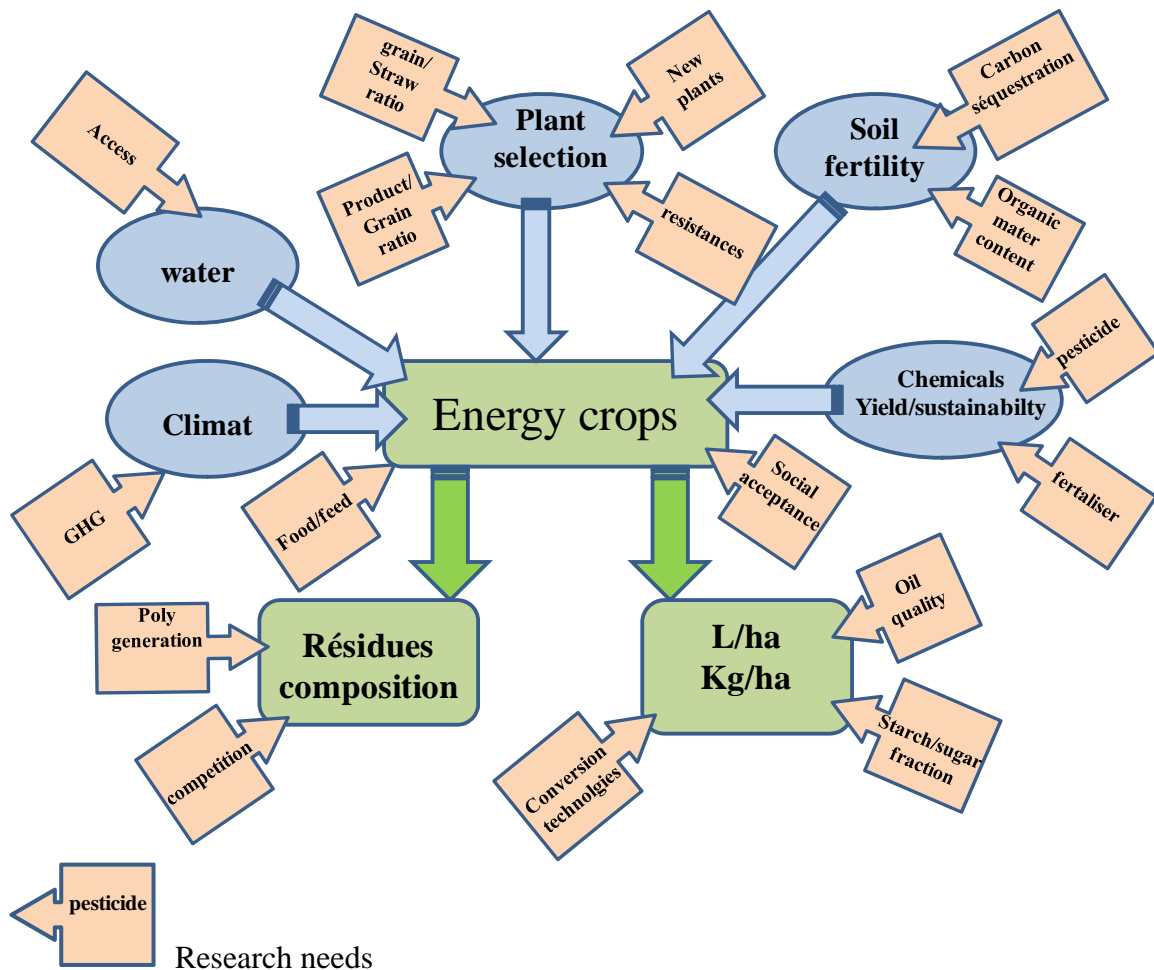
	Project costs	Energy access & affordability	Employment	Environmental impacts	Education	Income generation
Woodfuel for cooking	Replacement of wood fuel cooking device	High cost of wood fuel	Employment related to wood fuel production	- Still high local air pollution with associated health damages - Protection of local biomass		- No power supply for local industry - Households spend less time on energy provision that allows income generation activities
Plant oils production from Jatropha or Euphorbia plantation	- Cost of plantation - Process unit to produce biofuels from plant oils	Access to biofuels for transport, local energy for industry and for cooking & lighting	Employment for plantations, process unit, local energy production. Job created by local industry development	- Reduction of Greenhouse gas emissions - Protection of local biomass	Energy provision will give more time for educational activities	- Power generation for local industry - Biofuels for transport - biofuel for cooking and lighting - Time free for other income generation activities
Ethanol production from Sugar cane or Cassava or....	- Replacement of wood fuel cooking device - Generator set to produce local energy					

Clean Development Mechanism (CDM) projects offer opportunities for creating synergies between climate change policies and sustainable development (SD) policies that encompass major national development priorities. These combined policy goals may be supported through a process in which potential CDM projects are screened against chosen SD criteria representing economic, social, and environmental aspects that host countries find important. Host countries can choose from a long list of potential indicators, including financial and technology transfer, income generation, employment creation, local environmental impacts, health, social development, and equity.



7. What Agricultural Research Upstream and in Accompanying Biofuels Development?

70% of Africa's people still depend on traditional biomass as their only source of fuel. The lack of access to energy services in Africa is a serious constraint to economic growth and poverty alleviation. Most of the sub-Saharan Africa countries depend on importation to cover the petroleum fuel needed for transport and electricity production. Biofuels are a new challenge for Africa. The developed world's demand for biofuels presents a great opportunity and risks for African countries to produce more biofuel crops and export them. The general structure of agronomic programme on biofuels can be schematized as follows.



7.1. Research Programme on Crops for Ethanol or Oil production

The scientific and technological challenges that must be overcome to produce these crops at competitive prices with limited impact on environment (water and nutrients) and having significant impact to rural population will require the concerted effort of governments, scientific community, engineers and society. There is a huge demand for scientists to improve crop potentialities to produce more alcohol or more oil and to improve vegetable oil transformation to help create other new products out of plants materials. Some of the main crops, which are particularly interesting for ethanol or oil production in the sub-Saharan region, are well known and a lot of research programmes have been conducted to improve their productivity. But the conducted researches were

not necessarily targeted on energy and the yields of these crops are still low and a lot of efforts are required to push the yield up.

There are needs to both optimize the use of inputs and select new varieties using biotechnology tools. Research will also be necessary to develop the non transport use of biofuels. In SSA around 80% of the energy demand is covered by traditional biomass fuels consumption (fire wood & wood charcoal) resulting in deforestation of large areas. This is strong justification to conduct researches on suitable technologies to develop stoves and lanterns using Straight Vegetable Oils or ethanol as well as to produce electricity in remote rural areas by using small diesel generator sets running with biodiesel.

The cost of biofuels (ethanol and biodiesel) is for 80% linked to the cost of the agricultural production. Processing of the crop to produce ethanol or plant oils representing only 20% of the biofuels total cost. This justifies research programmes to improve production potentiality (varieties improvement) as well as the productivity (farming techniques) of the biofuels crops.

All energy crops (as well as food and feed crops) will be affected by new agricultural practices that favour higher productivity in more competitive markets towards the raw materials and increased price of these facilities (energy, phosphorus, land, manpower, etc). In the same vein, public opinion and lobbies will require more sustainable practices (particularly northern consumers that import tropical products). Research is therefore needed in bioenergy technology development.

7.1.1. Sugarcane

For a long time, research has been extensively conducted on sugar cane. Research into breeding and selection to improve yield, sugar rate as well to optimize farming practices and techniques, is relevant for both sugar and alcohol production. Research on Sugarcane will have objectives to produce sugar, bio ethanol and electricity. This will lead to select cane varieties with higher fibre to be cultivated on poorer land for continuous production of biomass mainly during the off milling season. Wind protective species can also be investigated with the goal to use this biomass for energy generation. Sugar industries are attempting to stay competitive through restructuring plans to satisfy industry demand. Diversification into ethanol production is obviously an option. New research programmes would give priority to ethanol production from cane and molasses process. In the same vein, sugar mills are potentially large electricity producers that operate only around 6 months in a year. It will be a research interest to increase sugarcane biomass production including the use of marginal land.

7.1.2. Cassava

Cassava has one of the highest rates of CO₂ fixation and sucrose synthesis. With the objective of alcohol production in mind, research has been conducted to develop transgenic cassava with starch yields of up to 2.6 times higher than that of normal plants. So it means that specific varieties will be used for alcohol production. Farming practices and techniques are well known and adopted by most of the cassava producers. Research will be focused on improvement of varieties and improvement of the alcohol production process (saccharification and fermentation of the cassava starch). Future breeding works and selection will give priority on the identification of superior varieties, not only with high yield but with high starch content, tolerance to existing pests and diseases and other characters that will satisfy the requirements of the cassava-based industry.

7.1.3. Sweet Sorghum

Sweet sorghum which is similar to grain sorghum with sugar rich stalks has a very good potential as an alternative feed stock for ethanol production. The sorghum farming techniques are well known as sorghum is one of the most important staple foods in dry ecosystems in sub Saharan Africa. Research into sweet sorghum conducted at ICRISAT was based on twin-track strategy:

- Developing improved hybrid strategy;
- Facilitating incubation of sweet sorghum-based ethanol production technology.

The wide variability in germplasm and hybrid parents for the traits related to ethanol production, such as sugar content and high stalk yield, offers bright scope for the development of high stalk yielding sugar-rich varieties and hybrids. Promising varieties have been identified. A new research programme will aim to strengthen the development and dissemination of improved varieties as the development of Photoperiod and thermo-insensitiveness varieties to facilitate planting at different dates.

Ethanol can also be produced from lingo-cellulose biomass such as cereal crop residues. So the development of second-generation ethanol from sorghum will be facilitated with selection of brown sorghum with high biomass containing lignin, cellulose and hemicellulose.

7.1.4. Cotton seeds

Cotton seed oil is a vegetable oil generally used for cooking. Cottonseed oil is a by-product of the crop, representing 15% of the commercial value of the fibres. Seeds represent 50% of the capsules weight. For a long time research programmes have been conducted to improve cotton production in terms of quality (long-staple cotton) and yield. Farming practices and techniques are well known and most of the time already adopted by producers. Selection was carried out to increase fiber quality and share, which induces small seeds. It appears that it would be possible (with the existing catalogue) to increase seed oil (seeds remaining small) content without affecting fiber quality and length. With appropriate practices and varieties it would be possible to produce in the same time fibers, biofuel and electricity (from cotton stalk).

7.1.5. *Jatropha curcas L.* & *Euphorbia tirucalli*

Jatropha has been in cultivation for a long time, but very little is known about the crop because there is less experience and because it has not been cultivated on large scale. *Jatropha* is a succulent plant that sheds its leaves during the dry season. It is, therefore, best adapted to arid and semi-arid conditions. The current distribution of *Jatropha* shows that introduction has been most successful in dryer regions of the tropics with an average rainfall ranging between 300 and 1000 mm.

The low yield revealed in several projects may have been caused by the fact that unadapted varieties had been used. Investigation into genetic diversity and yields potential is necessary. The fact that *Jatropha* is well adapted to extreme conditions does not mean that the plant does not need inputs for growing. Investigations on appropriate farming techniques are necessary to improve crop productivity.

Euphorbia tirucalli is a unique example of a plant combining permanent stems, high CO₂ uptake, important growth rate, high drought and salinity stress tolerance/resistance and high biomass production, without the necessity to use costly inputs.

Biofuel crop improvement research issues

Crop improvement

- Analysis of experiences on Jatropha & Euphorbia Tirucalli cultivation around the world. Records on systematic trials with vegetative evaluation exist in Cape Verde, Senegal, Ghana, Benin, Burkina Faso, Kenya, Tanzania, India, Costa Rica, Mexico, etc
- Collection of Jatropha & Euphorbia tirucalli germplasms from different ecosystems;
- Characterization and evaluation of the agronomic potential of varieties in terms of seed yield, oil content, quality of oil and latex (composition), growth conditions, drought resistance, plant height, etc;
- Initiation of a selection/breeding programmes with multilocation testing of promising varieties;
- Experimentation on propagation methods: generative propagation (seed, transplanting), vegetative propagation (cuttings), micro propagation, tissue culture and somatic embryogenesis from callus and adventitious shoots from different explants.

Farming techniques

- Most of the time Jatropha & Euphorbia tirucally are cultivated as hedges (live fence) along roads and paths. Research – experiments have to be conducted to define techniques of the Jatropha cultivation in more intensive orchards;
- Optimization of production/productivity through improved farming techniques (fertilization, plantation density, alley cropping or intercropping, influence of pruning on seed yields, etc).

Transformation, Utilization, Marketing

- Promote together with the private sector the creation of local/national markets for jatropha oil;
- Socioeconomic studies on how Jatropha can aid development in local communities;
- Assessment evaluation of existing small scale presses for extraction. Optimization of extraction. Development of new extraction methods.
- Methyl esterification. Oil use in adapted motor. Engine test;
- Development of (methods) technologies to eliminate toxicity in the seed cake which presently cannot be used in animal feed because of its toxic properties.
- Research on non-transport use of plant oils (latex) or biodiesel in electricity production for remote rural areas – generator sets running to plant oil or diesel) and research for development of stoves and lanterns directly using biofuels.

7.2. Research on crop diversification to produce Bio-ethanol or plant-oils

Some existing native or exotic species can present interesting properties for energy uses but have never been cultivated intensively. Investigation on this species in comparison with “industrial species” should be carried out. Research activities are necessary to identify these species and express their potential through selection.

Biofuels to be produced in SSA should preferably be obtained from locally grown crops that are well adapted to the local conditions. In sugar producing countries, bio-ethanol will be obtainable from the sugar cane. In oil exporting countries, straight vegetable oils or biodiesel can be produced from existing palm, jatropha, cotton seeds. Nevertheless other crops will be introduced and experimented to produce ethanol or plants oils.

Introduction of castor oil crop, hemp in SSA will be done. Research will be necessary on biofuels of second generation (bio-Ethanol can also be produced from "cellulosic biomass" such as trees farm wastes and grasses with much higher positive energy ratios of 2 to 3 times more energy in the ethanol produced than energy input.

7.3. Research on Economics, Policies & Socio environmental issues

7.3.1. Economical issues

Market prices of the triple pressures of grains and agricultural feedstock, fossil fuels, and population increase are the main determinants of biofuels competitiveness. Economics of scale in production is crucial for successful implementation of any biofuel development programmes. It is also important for countries to consider the impact of a new biofuels industry on their economy, including balanced importation-exportation, job generation, rural-urban drift and support for rural communities and for local agriculture commodities. Key challenge that would hinder the viability of biofuels value chains is the availability of grains and feeds in sufficient quantities at reasonable cost to support both human population pressure and energy needs in competing with prices of fossil fuel. Price mechanisms have also to take into account the role biofuels can play in remote places.

To achieve economically sustainable production of crops for biofuels especially when using marginal land will require specific management. The rapidly increasing prices of fertilizers and other chemicals can discourage smallholder producers. Progressive incentives or reserved production quota will be studied to encourage or to maintain smallholder production.

7.3.2. Policy Options & issues

GHG balances vary from crop to crop and the choice of the crop for biofuel production is important from the point of view of the GHG mitigation agenda. Some current biofuels cause more GHG emissions than conventional fuels if full emissions costs of production taken into account. It is important to demonstrate and certify that the energy balances are positive in the next three to five years' time (Jeff Tschirley, FAO - IFAD's Governing Council, 2008). Land conversion, whether rainforest or arable land, could produce significant GHG emissions, cause soil degradation or loss of biodiversity. Land uses and competing needs of energy and food security is a therefore a key issue and effects of large-scale biofuel production on global commodity prices are significant concerns. Socio-economic and environmental implications affecting the potential for developing countries to benefit from the increased global demand for biofuel is just too obvious. Thus African countries have the option of framing national policies on:

- (i) promotion of bioenergy research for development (R4D) based on agricultural biomass, waste, and non-food crops for fuel
- (ii) promotion of food and non-food biofuel crops R4D on their own
- (iii) promotion of biofuel crops on marginal lands
- (iv) promotion of a more comprehensive and well coordinated sector-wide R4D on bio- and renewal energies.

Many SSA countries have an energy policy, but most of these policies are outdated and do not actively support the development of renewable energy. In most of the SSA countries, biofuels have not been standardized as recognized fuels or fuel blends, neither have national standard been defined. Standards have been developed in some countries (Europe, USA, Brazil...) for the addition of both bio-ethanol and bio-diesel. Research is needed on biofuels standardization and certification, to determine environmental criteria,

blending ratios, establish biofuels standards to suit local requirements recommend production modalities and consider environmental and social concerns and providing appropriate investment and consumption incentives.

Export taxes, transport charges as well as import duties in countries must be studied and defined to guarantee price competitiveness at delivery sites. The possible application on biofuels of the same fiscal tax than on petroleum fuels will probably lead to stagnation in the development of the biofuels sectors.

Agro-energy policy researches need to address these issues in a more holistic way, so as to optimize on the total net benefits on a national level. Research activities will be conducted to support national governments for adapting policies regarding food prices in case of increased related biofuels development.

7.3.3. Socio Environmental issues

There are potential conflicts between using land and water for food and biofuels. Consideration can be given to using marginal lands to grow oil-plants as *Jatropha* and *E. tirucalli*. Production of these new crops on marginal lands will require specific research for an optimum production.

Removal of crop residues, such as leaves and stalks can negatively impact on soil structure and create erosion. Strategies for managing crops residues must be researched for sustainability.

Developing life cycle studies and certification methodologies on CDM adapted criterion to the African socio economic context is of tremendous importance as methodologies that are currently developed are adapted to industrial projects. Their direct adaptation to small scale project or dedicated African project might not be feasible or advisable. It is of tremendous importance to develop African based methodology rather than adopt methodology from elsewhere. In addition sophisticated methodology might not be financially viable in some African context.

8. Conclusion:

In many developing countries, rural development and poverty reduction are critical to achieving the Millennium Development Goals. New markets through biofuel sector development can lead to a more diversified and profitable agricultural enterprises. This opportunity however presents risks and must be managed. FARA will continue to offer its policy platform to stakeholders in the bioenergy sector to discuss and fine tune biofuel policy options and development strategies at various levels of African agricultural research and development. Provided sustainability criteria are met, a biofuel market represents an opportunity for marginal and unused or abandoned land development.

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