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ETHANOL FUEL PRODUCTION AND USE IN KENYA FOR SUSTAINABLE DEVELOPMENT

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Abstract

This paper is based on the concept of sustainable development as defined by the Brundtland report that requires that present and future needs of especially those of the poor be met without jeopardising the environment. The objective of this study is to show in what ways ethanol production and use is more sustainable than the dependence on petroleum fuel imports. It will do this by carrying out a comparative analysis of petroleum fuels and ethanol with the aim of understanding the economic, social and environmental impacts encountered with the use of these fuels. The study used literature review, questionnaires and interview sessions, for data collection. The results were presented using tables and Causal Loop Diagrams. The findings in the study were that imported petroleum fuels are the main commercial forms of energy and that petroleum imports are responsible for trade imbalance and inflation. Secondly, the combustion of petroleum fuels leads urban air pollution, human health problems and the build up of carbon dioxide gases in the atmosphere contributing to global warming.

Ethanol fuels unlike petroleum are renewable and can be produced from locally available biomass. The production and use of ethanol in the country has the potential to generate incomes in the rural areas by boosting the agricultural sector thus bringing social economic development and environmental benefits. However its end use leads to the emission of aldehydes and the risk underground water and soil contamination. The study suggests that potential crops that could be used for ethanol production are sugarcane and sugar beet and that the ethanol processing plants be annexed to already existing sugar factories.

The overall conclusion is that depending on the government policies, implementation and management, the production and use of ethanol in Kenya has the potential to bring about economic growth, social development and environmental benefits.

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List of acronyms

ACE - Atmosphere Climate and Environment

BOSTID - Board on Science and Technology for International Development

CBS - Central Bureau of Statistics

EIA - Energy Information Administration

FAO - Food and Agriculture Organisation

IDRC - International Development Research Centre

INFORSE - International Network For Sustainable Energy

OECD- Organization for Economic Cooperation and Development

SEED - Sustainable Energy and Environment Division

UNDESA - United Nations Department of Economic and Social Affairs

UNDP- United Nations Development Programme

UNEP - United Nations Environment Programme

UNU - United Nations University

WCED - World Commission on Environment and Development

WEC - World Energy Council

1.0 INTRODUCTION

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). "It contains within it two key concepts: the concept of "needs", in particular the essential needs of the world's poor , to which overriding priority should be given; and the idea of limitations imposed by the state of technology and the social organisation on the environment's ability to meet the present and future needs" (WCED, 1987).

In order to achieve development, the Kenyan government has some set goals such as poverty alleviation through the provision of basic needs, enhanced agricultural production, employment creation and improved rural urban balance as some of the overall national development objectives (Ministry of Energy, 2004). However to realise social and economic development goals there is the need for sustainable affordable and reliable forms of energy because energy is one of the most important drivers for modern economic development (SEED-UNDP, 2000). In Kenya, the commercial energy sector is dominated by petroleum which accounts for 22% and electricity which accounts for 9% as the prime movers of the modern sector of the economy (Ministry of Energy, 2004). Petroleum fuels are thus the prime movers of the modern economy and are mainly used in the transport, commercial and industrial sectors (Ministry of Energy, 2004). Relying on petroleum fuels as the major form of commercial fuel has exposed the country to economic hardships that result from the cumulative effects of oil shocks and the adverse effects of oil importation on the domestic economy and balance of payments (Ministry of Energy, 2004). Among other factors, the economic difficulties encountered from the dependence on petroleum fuels by Kenya have been a stumbling block to the Government's efforts to alleviate poverty.

In addition to the negative impacts on economic and social growth, petroleum fuels lead to environmental degradation and human health problems. Their combustion leads to the emission of pollutants such as nitrogen oxides (NOx), sulphur dioxide (SO_2) and particulates which lead to urban air pollution and have negative effects on human health (WCED, 1987). Furthermore the combustion of fossil fuels is one of the key factors in the increase in carbon dioxide (CO_2) concentrations in the atmosphere that are contributing to global warming and the subsequent climate change (Carter 2001; SEED-UNDP, 2000). Based on the concept of sustainable development, Kenya's reliance on petroleum fuel imports as the major commercial fuel is unsustainable both in the short and long term creating the need for a shift to an alternative form of fuel. Producing and using ethanol in Kenya could be a sustainable long term solution with the potential to induce economic growth, improve living standards and reduce environment degradation.

The overall objective of this study is to show in what ways ethanol production and use is more sustainable than the dependence on petroleum fuel imports. It will do this by carrying out a comparative analysis of using ethanol and petroleum with the aim of understanding the socio economic and environmental impacts of adopting ethanol fuel in Kenya

Ethanol is a clean burning alcohol fuel that can be blended with gasoline and used in normal gasoline engines or used in its pure form in internal combustion engines designed specially for ethanol use (SEED - UNDP, 2000).Ethanol can be produced from sugar crops such as sugarcane and sugar beet, starches like corn and wheat, as well as from cellulose materials such as wood or grasses (Thomas, 2001; SEED - UNDP, 2000).

The oil crisis and low sugar prices during the 1970s motivated the Kenyan government to invest in ethanol production; in 1983 the first ethanol plant was been successfully installed as an annex to the Muhoroni sugar factory in Nyanza province (HABITAT, 1993). The ethanol produced was used as a blend for gasoline where the gasoline comprised of 10% ethanol (HABITAT, 1993; Ministry of Energy, 2004). Ten years later the ethanol plant was closed down due to management and pricing problems (Ministry of Energy, 2004). Since then Kenya has continued to rely entirely on petroleum fuel imports to run its transport sector which consumes about two thirds of all the petroleum fuels consumed in the country (Ministry of Energy, 2004).

1.1 RESEARCH QUESTIONS SCOPE AND LIMITATIONS

1.1.1 Research questions

This study addresses the following research questions

- What are the costs and benefits of Kenya's reliance on petroleum fuels?
- What are the costs and benefits of producing and using ethanol fuel in Kenya?
- What are the potential crops that could be used to produce ethanol?
- What could be suitable locations for ethanol processing plants?
- What are the barriers that could be encountered to the introduction of ethanol in Kenya
- Which of the two fuels (ethanol or petroleum) would be more sustainable for Kenya?

1.1.2 Scope

This study is concentrated on Kenya as the case study. However the analysis and conclusions are relevant for other countries that rely on petroleum fuel imports. The study compares the costs and benefits of using ethanol and petroleum fuels for transport.

1.2 METHODOLOGY

1.2.1 Data collection:

The data used in this paper was collected from:

- Literature review from books, online journals, sugar beet field trial reports and government publications.
- Questionnaires and interviews: five and three questionnaires were administered to sugar beet farmers at Nyandarua and to policy makers in the energy sector respectively. The information from the questionnaires was used for background information on sugar beet production in Kenya and ethanol and petroleum use in Kenya.
- Interview sessions: to get the status of ethanol in Kenya, eight semi-structured interviews were carried out with three people working at an oil distributing company, two people working with the news media and three gas station owners. A discussion with a plant physiologist was also carried out to get information on sugar beet and ethanol production.

1.2.2 Limitations

Time
The questionnaires for the research were to be done via the post and email. This delayed the project as about three weeks were spent waiting for the questionnaires which were important for the background information on ethanol to be sent back. None of them were sent back requiring personal travel to the field which was time-consuming.

Financial Resources:
This limited the field survey to Nairobi which is the capital city and Chuka since these two towns were easily accessible and had cheaper accommodation.

Literature:
It was difficult to get clear information on the status of ethanol in Kenya and what led to the shut down of the ethanol plant that had been put up in the 80s.

Field data:
There was sufficient data from the field due to the low response to the questionnaires however the interview sessions were successful. From the study it was observed that questionnaires may not be have been the best way to obtain data from the field especially from government offices since it appeared that all that filled in the questionnaires had been copied from the one source the end result was a collection of uniformly answered questionnaires and a report containing the same information. Consequently the study focused on the data from the books and reports given since the answers had been lifted one by word from them. Other problems included that some interviewees were unwilling to give information unless bribed this made it difficult to know which people genuinely did not know the answers or those that wanted tips in order to speak.

The sugar beet farmers' questionnaires were only used to counter check the range of figures information contained in the reports (Kiriita 2001, 2002 and 2003) as these reports contained field data from the same farmers. In addition these questionnaires were only from Central province an area that does not grow sugarcane thus for the comparisons on the production costs between sugarcane and sugar beet, the information from (Mumias sugar Company 2003 reports were used) since it had both the costs for sugarcane and for the sugar beets.

1.2.2 Data Analysis:

The data findings were analysed using;

- Comparative analysis: This was done on the impacts of petroleum and ethanol on the three spheres of sustainable development which comprise of the social, economic and environmental dimensions.

- Literature review: Where government reports, scientific journals, reports from sugar beet trial fields and case studies mainly from Brazil were used for the analysis.

- Causal Loop Diagrams (CLDs) were used for the conceptual model and the presentation of results. A CLD is a tool that is used in systems analysis approach to understand causes and effects, to describe reality through causalities between variables and how they form a dynamic circular influence (Haraldsson, 2004). It is used to observe the world through feedbacks rather than linearly and observes repeated

patterns that may be used to predict the behaviour in the problem (Haraldsson, 2004). The shortcoming of the CLD is that not all factors can be included in the diagram however several sub-systems can be created.

1.2.2.1 The Concept of Causal Loop Diagrams (CLD)

- "The arrow shows causality. A variable at the tail of the arrow causes a change to the variable at the head.
- A plus (+) sign near the arrowhead indicates that the variable at the tail and the head of the arrow change in the same direction (if the tail increases the head increases or if the tail decreases the head decreases)
- While a minus (-) sign near the arrow head indicates that the variable at the tail of the arrow and the variable at the head of the arrow change in the opposite direction (if the tail decreases the head increases)
- The letter R in the middle of the loop indicates that the loop is a reinforcing behaviour in the same direction, causing either a systematic growth or decline. It is a behaviour that is moving away from equilibrium point.
- The letter B in the middle of the loop indicates that the loop is balancing and moves the system in the direction towards equilibrium or fluctuation around equilibrium point" (Haraldsson, 2004).

2.0 BACKGROUND

In this section the social, economic and environmental impacts encountered from Kenya's dependence on petroleum fuels are presented.

2.1 An overview of Kenya's Dependence on Petroleum

The general overview of Kenya's dependence on petroleum will be presented with the aid of a CLD (Figure 1) and a graph (figure 2). CLD descriptions are further discussed in detail in the sub-sections of the paper.

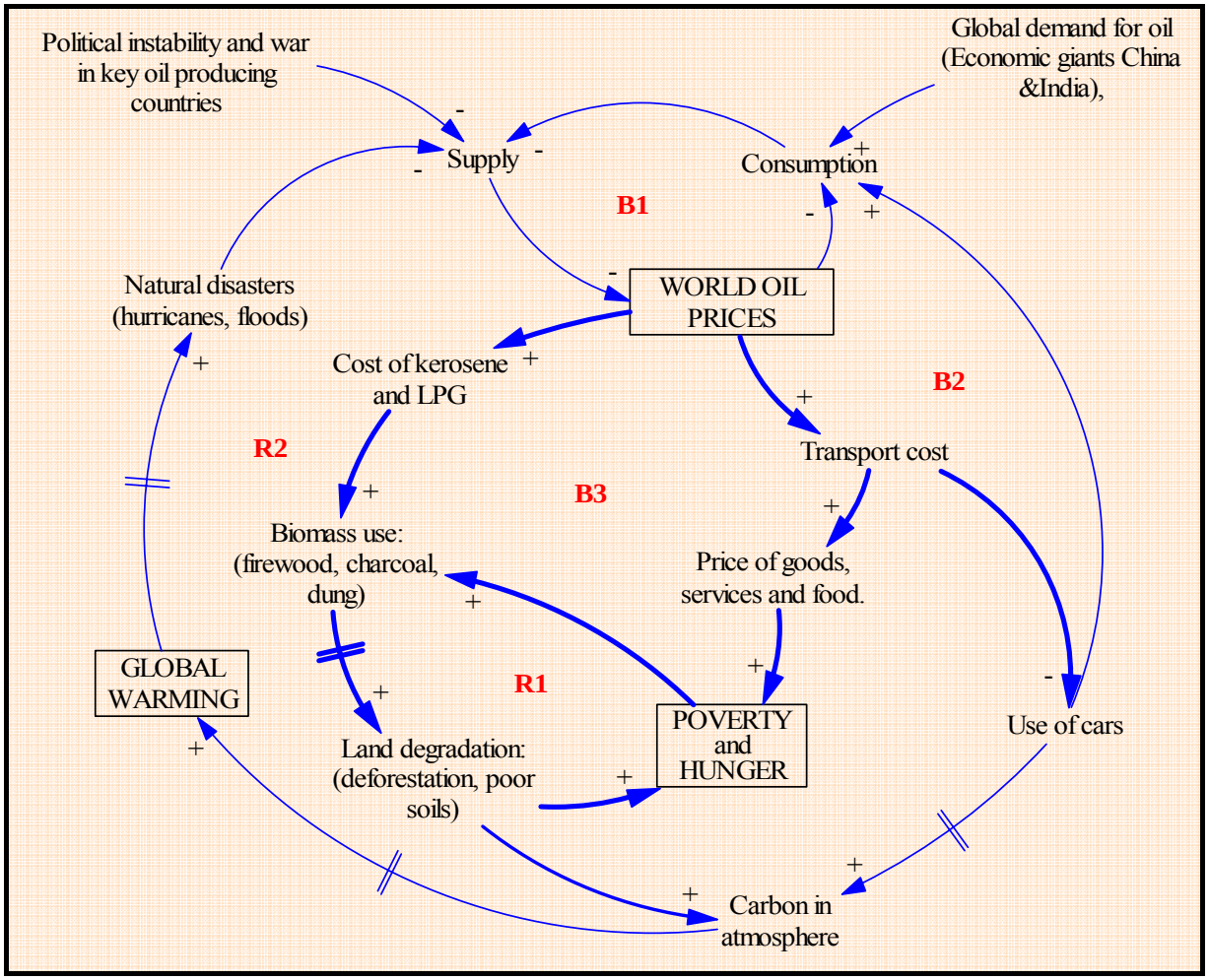

Figure 1: Dependence on petroleum fuels

Dependence on Petroleum Fuels CLD Description

By applying the concept of CLD instructions given under section 1.2.2.1, the dynamics of dependence on petroleum fuels are shown in Figure 1. The outside larger circle represents the causes and effects from a global scale while the thicker arrows on the inside of the circle represent causes and effects at the national level. On the outer circle Delay marks have been used to indicate the changes that occur after many years such as global warming while on the inner circle the delay marks have been used to indicate changes that occur within the ranges of several months to a few years like land degradation. The arrows without delay marks indicate that the changes occur fairly rapidly.

BALANCING LOOP (B1)

"WORLD OIL PRICES" shown in the upper part of the diagram are affected by "Consumption" and "Supply". A decrease in "Supply" leads to an increase in "WORLD OIL PRICES"; an increase "WORLD OIL PRICES" leads to a decrease in "Consumption"; a decrease in "Consumption"; leads to an increase in "Supply". Decreased supplies of oil could be the result war in key oil producing areas or natural disasters which reduce or cut off production leading to a higher demand than the supply which results in an increase in prices to offset the imbalance.

REINFORCING LOOP (R1)
An increase in "POVERTY and HUNGER" leads to an increase "Biomass use" as people cannot afford alternative fuels like electricity or kerosene and increase "Biomass use" leads to an increase in "Land degradation" further degradation results from as people turn to nearby forests for firewood and charcoal thus leading to deforestation and soil erosion. More land degradation comes from the use of dung and crop residues as fuel which deprive the soil of nutrients that would have been recycled back into the soil. An increase in "Land degradation" leads to an increase in "POVERTY AND HUNGER" from poor yields that result from poor soils of degraded land.

REINFORCING LOOP (R2)

An increase in "WORLD OIL PRICES" leads to an increase in "Cost of kerosene and LPG[1]" this is because Kenya depends on imports thus world oil prices lead to an increase in domestic prices of LPG and kerosene. An increase in "Cost of kerosene and LPG" leads to an increase in "Biomass use" because charcoal and firewood are usually much cheaper than kerosene and LPG. An increase in "Biomass use" leads to an increase in "Land degradation" as earlier stated and an increase in "Land degradation" leads to an increase in "Carbon dioxide in atmosphere" because deforestation practices reduce carbon sequestration through the removal of the plant cover that acts as carbon sinks. An increase in "Carbon dioxide in atmosphere" leads to an increase in "GLOBAL WARMING" because carbon dioxide is a greenhouse gas and thus contributes to the greenhouse effect. An increase in "GLOBAL WARMING" leads to an increase in "Natural disasters" through the effects of climate change that are the result of global warming. An increase in "Natural disasters" leads to a decrease in "Supply" through cutting off production in the oil producing country that is hit. And a decrease in "Supply" leads to an increase in "WORLD OIL PRICES"

BALANCING LOOP (B2)
An increase in "WORLD OIL PRICES" leads to an increase in "Transport costs" because the domestic petroleum pump prices rise when world oil prices rise necessitating the increase in fares by car owners to meet the extra cost. An increase in "Transport costs" leads to a decrease in "Use of cars" as commuters to work and school opt to walk in order to save money. A decrease in "Use of cars" leads to a decrease in "Consumption" as there will be fewer cars on the road. A decrease in "Consumption" leads to an increase in "Supply" from less cars using petroleum. An increase in supply leads to a decrease in "WORLD OIL PRICES" in order to increase consumption.

BALANCING LOOP (B3)
As earlier discussed, an increase in "WORLD OIL PRICES" leads to an increase in "Transport costs" and an increase in "Transport costs" leads to a decrease in "Use of cars" on the other hand, a decrease in "Use of cars" leads to a decrease in "Carbon in atmosphere" due to fewer carbon dioxide emissions and a decrease in "Carbon in atmosphere" after a long period of time leads to a decrease in "GLOBAL WARMING". A decrease in "GLOBAL WARMING" leads to a decrease in "Natural disasters" due to reversed climate change and a decrease in "Natural disasters" leads to an increase in "Supply" through non-interrupted production and an increase in "Supply" leads to a decrease in "WORLD OIL PRICE".

[1] LPG = Liquified Petroleum Gas

UNIDIRECTIONAL FACTORS IN THE SYSTEM:
An increase in "WORLD OIL PRICES" leads to an increase in "Transport costs"; and an increase in "Transport cost"; leads to an increase in "Price of goods, services and food" as production costs increase from increased transport costs of raw materials to factories and finished products to the market. An increase in "Price of goods, services and food" leads to an increase in "POVERTY and HUNGER" because people loose the purchasing power to meet basic needs such as food and shelter.

An increase in "Political instability and war in key oil producing countries" leads to a decrease in "Supply" through interruptions in production especially in the volatile Middle East countries that are major producers of oil in the world.

And an increase in "Global demand for oil" leads an increase in "Consumption" the increasing demand for oil puts a stress on the production quotas leading to increased oil prices.

2.1.1 ECONOMICAL IMPACTS

The economical impacts encountered from the dependence on petroleum fuels include inflation and trade imbalance discussed in this section.

Inflation

Increased oil prices lead to a rise in the price of food and goods as the cost for producing goods and services soar (Hirsch, 2005) illustrated in the CLD in figure 1. This change in prices is what is referred to as inflation which is defined as the percentage change of the Consumer Price Index (CPI) over a one year period and the CPI is defined as the measure of the weighted aggregate change in retail prices paid by consumers for a given basket of goods and services (Ministry of Finance & planning, 2002). Historically, inflation in Kenya has been mainly caused by increases in oil prices. This is because the commercial energy sector in Kenya is dominated by petroleum 22% and grid electricity 9% as the prime movers of the modern sector of the economy (Ministry of Energy, 2005). The relationship between inflation and high oil prices in Kenya can be observed in figure 2 from which it can be noted (apart from the period 1991,1993 during which inflation was due to internal and external political factors) that inflation in Kenya is to a significant extent influenced by oil prices.

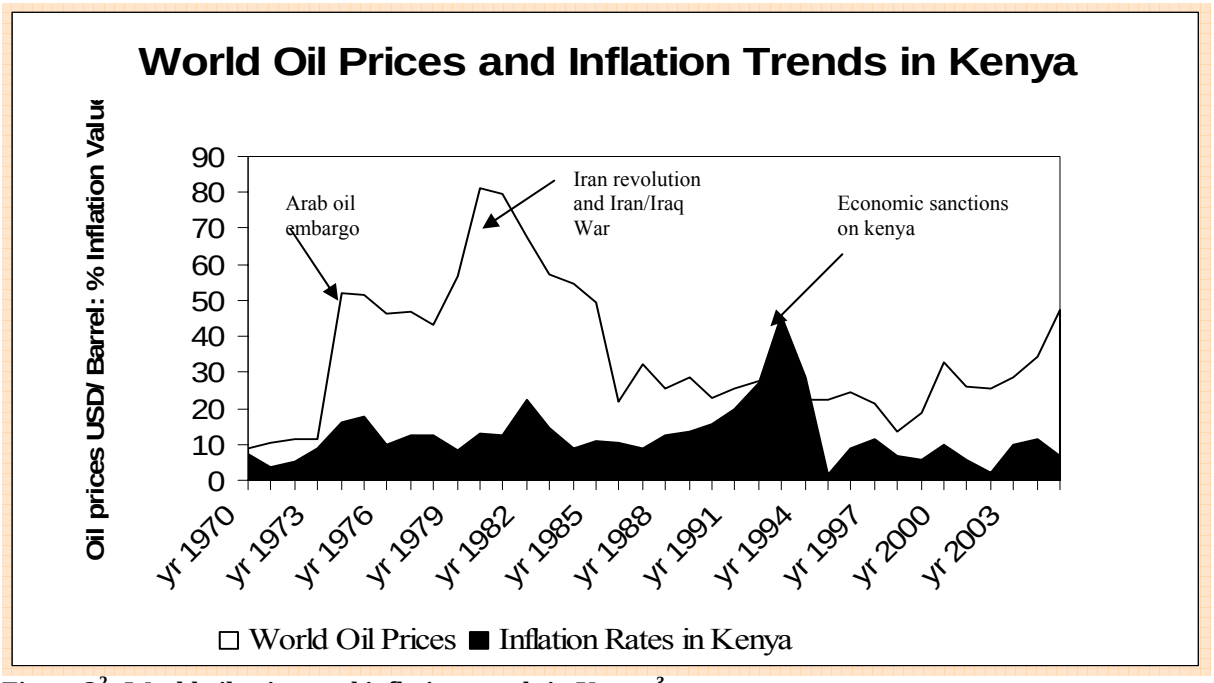

Figure 2[2]: World oil prices and inflation trends in Kenya [3]

Trade Imbalance

High oil prices leads to high import costs which reduces national income as the country is forced to spend more on oil destabilising trade balances (Hirsch, 2005) also refer to Figure 1. Trade imbalance happens when a country spends more money on imports than it gets from exports. Kenya's dependence on oil imports takes out a significant amount of export earnings with year to year fluctuations that average between 20 and 50 per cent of the import bill (INFORSE, 1997). When the prices of oil soar the country is forced to spend more money on oil imports leading to an increase in trade deficit or trade imbalance. For instance, during the period 1998/99 – 2002/03 petroleum imports averaged 2.5 Million Metric Tons per annum accounting for 25.7% of the country's total annual import bill (Ministry of Energy, 2004).

2.1.2 SOCIAL IMPACTS

Lower Living Standards

The high costs of petroleum pushes the poor down the energy ladder from using kerosene and Liquefied Petroleum Gas (LPG) to using biomass fuels such as dung, plant residues, firewood and charcoal. "Nowadays I cannot afford to buy kerosene for my children to study…" Margaret Njuki, a single mother of three is quoted as lamenting during an interview by David Mageria at the time high oil prices hit the country on the aftermath of hurricane Katrina (Mageria, 2005). Biomass fuels produce much smoke and make it uncomfortable to stay in the house during cooking hours; are inefficient and thus require longer hours to cook food and hence more time is spent in food preparation and wood gathering leaving little time for other chores (UNDESA - UNDP - WEC, 2000).

[2] NB. On the x-axis one unit represents world oil prices for the month of June in US $ and the average annual inflation rates in % for Kenya.
[3] World Oil Prices: figures from Energy Information Administration (EIA), 2005 and figures on annual inflation rates from Central Bureau of Statistics (CBS), 2005.

The high food and good prices leads to poverty and hunger (CLD on Figure 1) this is because families are forced to cut down their domestic expenditure with the poorer families having to cut down their food budget driving the poor into hunger. The high oil prices experienced after the hurricane Katrina led many into hunger in some many African countries such as Malawi were the food prices had greatly been affected by the price of oil (Mageria, 2005).

Lastly, high transport costs triggered by the oil prices (CLD on Figure 1) make travelling by car expensive especially for the students and people that have to commute daily to work; they are forced to opt to walk for long distances to school leading to fatigue, low productivity and insecurity for the people having to walk through unsafe areas. For instance when the oil prices were at 76 Kenya Shillings[4] a litre, the "matatu" owners (private public transport car owners) increased fares countrywide those operating between Nairobi and Mombasa increased their fares from 500 to 800 shillings per person, while those travelling to Kisumu and western Kenya had to pay at least 600 shillings from an average of 400 shillings citing high cost of fuel (Senelwa, 2005).

2.1.3 IMPACT ON THE ENVIRONMENT

Indoor Air Pollution

As earlier stated and in reference to Figure 1, the high cost of kerosene and LPG triggers the use of biomass fuels (firewood charcoal, dung and crop residues) for cooking. This has been reported as being the leading source of indoor concentrations of health damaging pollutants such as carbon monoxide, particulates, benzene and formaldehyde which arise from the incomplete combustion in stoves (UNDESA - UNDP - WEC, 2000); these pollutants have been linked to diseases such as lung cancer, tuberculosis, acute and chronic respiratory diseases to especially women and children that spend long hours in poorly ventilated smoke filled kitchens.

Land Degradation

When people are not able to meet their basic needs they are forced to overuse environmental resources in order to survive; the overuse of the environment leads to deeper poverty from declining yields and reduced natural capital (WCED, 1987). This makes the survival of the poor even more difficult. This vicious cycle of poverty and environmental degradation is illustrated in the CLD on Figure 1 by the reinforcing loop R1. Land degradation results from deforestation which leads to soil erosion and the use of dung and plant residues for fuel which could have been used as manure for the soils.

Global Warming

Global warming is a process that is going on as a result of the build-up of greenhouse gases that absorb the thermal radiation which is emitted by the earth's surface and act like a blanket over the surface (Houghton, 2005). Evidence from climate studies shows that the earth is getting warmer and is anticipated to increase (Carter, 2001). Studies show that during the last century, the average surface temperatures on earth rose between 0.2 and 0.6° C and was projected to further increase by between 1.4 and 1.8° C by the year 2100 (Carter, 2001). Some of the greenhouse gases responsible for global warming are carbon dioxide (CO_2) methane (CH_4) and nitrous oxide (N_2O) among which CO_2 which to date has contributed about 70% of

[4] In 2005, 1 US Dollar has been equivalent to an average of 74 Kenya Shillings.

the strengthened greenhouse effect is the most significant human induced contributor (Houghton, 2005). The main anthropogenic sources of the build up of carbon dioxide in the atmosphere are the combustion of fossil fuels (CLD on Figure 1) which contributes about 77% of the total CO_2 emissions and deforestation which contributes to 23% (UNU, 1995). Illustrated in the CLD on Figure 1, an increase in global warming leads to an increase in natural disasters such as hurricanes and flooding. The frequency of occurrence of such disasters has been linked to climate change. Of concern is that climate change from global warming could produce devastating impacts such as a rise in the sea level which is anticipated that by the year 2100 will flood many of the lowland areas (Carter, 2001). Kenya has a coastline of 536 km CIA (2005) therefore it is most likely that rising sea levels will have an impact on the ecosystems and communities living at the coastline.

Depletion of Natural Resources

Fossil fuels come from finite sources hence continued use will lead to an eventual depletion of the resource reducing the 'stock available for future generations' (WCED, 1987). Many researchers have used the Hubbert Peak Model (Figure 3), to make predictions on the approximate period of the eventual depletion of oil. A research estimated that the physical peak of conventional oil production was between 5 and 10 years (relative to 2002) after which production will decrease at approximately 3% per year to depletion (Bentley, 2002). The high prices at the peak is a result of the switch from a production for the market to one driven by supply because from the peak, there will be declining supplies and thus lower production.

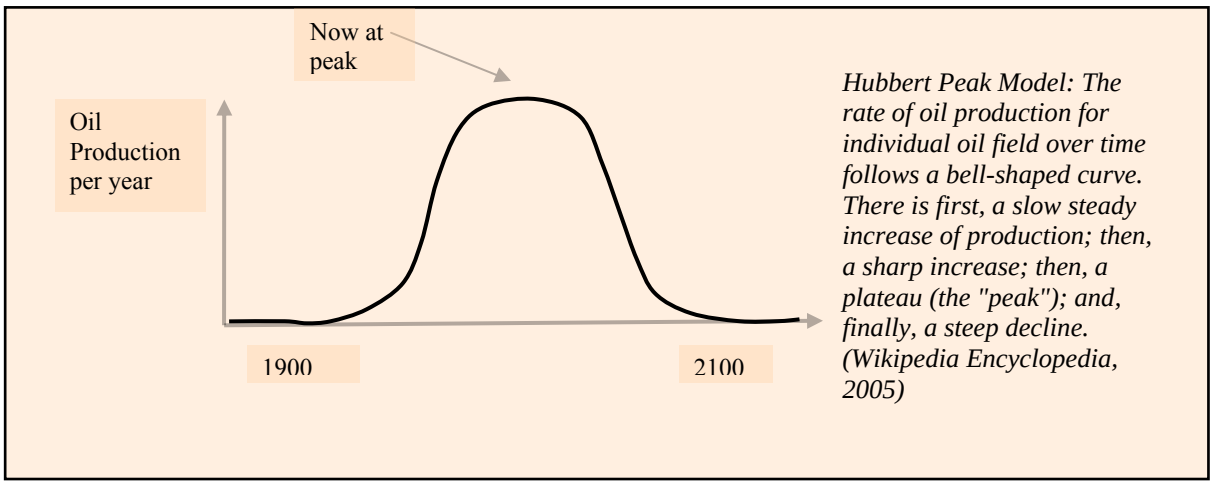

Figure 3: Oil peak model

Urban Air Pollution

The combustion of fossil fuels leads to the emission of pollutants such as oxides of nitrogen (NOx), sulphur dioxide (SO_2), particulate matter (PM), lead (PB), carbon monoxide (CO), and volatile organic compounds (VOCs). The combustion of petroleum fuels is responsible for urban air degradation especially in big cities. Of concern is that these air pollutants cause human health problems. Table 1 displays a list of some of the pollutants emitted from the combustion of fossil fuels and their impacts on human health.

Table 1: Human health problems caused by fossil fuel emissions

EMISSION	EFFECT ON HEALTH
1. Particulates	- Carcinogenic, - Lung damage (ACE, 2002)
2. Oxides of Nitrogen (NOx)	
-Nitrogen Oxide (NO)	- High concentrations causes changes to lung functions (ACE, 2002)
-Nitrogen Dioxide (NO_2)	- Shortness of breath, - Chest pains (ACE, 2002)
3.Carbon Monoxide (CO)	- Retarded growth and retarded mental development in unborn child - High doses can be life threatening (ACE, 2002).
4.LEAD (PB)	- At some concentrations in the blood can cause damage to central nervous system, kidneys and brain. - A strong link between high lead exposure and impaired intelligence in children (ACE, 2002).
5.Sulphur Dioxide (SO_2)	- causes heart disease and bronchitis, and a fall in lung function in asthmatics. -causes tightness in chest and coughing, impaired lung functioning (ACE, 2002).
6.Volatile Organic Compounds (VOCs)	
-Benzene	Carcinogenic (Gariazzo et al., 2005)
-Butadiene	Bone marrow depression and cellular immaturity (Tsai et al., 2005)

3.0 ANALYSIS

3.1 Introduction of Ethanol into the System

3.1.1 Economic and Social Benefits

"Those who are poor and hungry will always destroy their immediate environment in order to survive" (WCED, 1987). For this reason there is need for economic growth and social development in order for development to be sustainable (WCED, 1987). Ethanol production has the potential to lead to socio-economic growth.

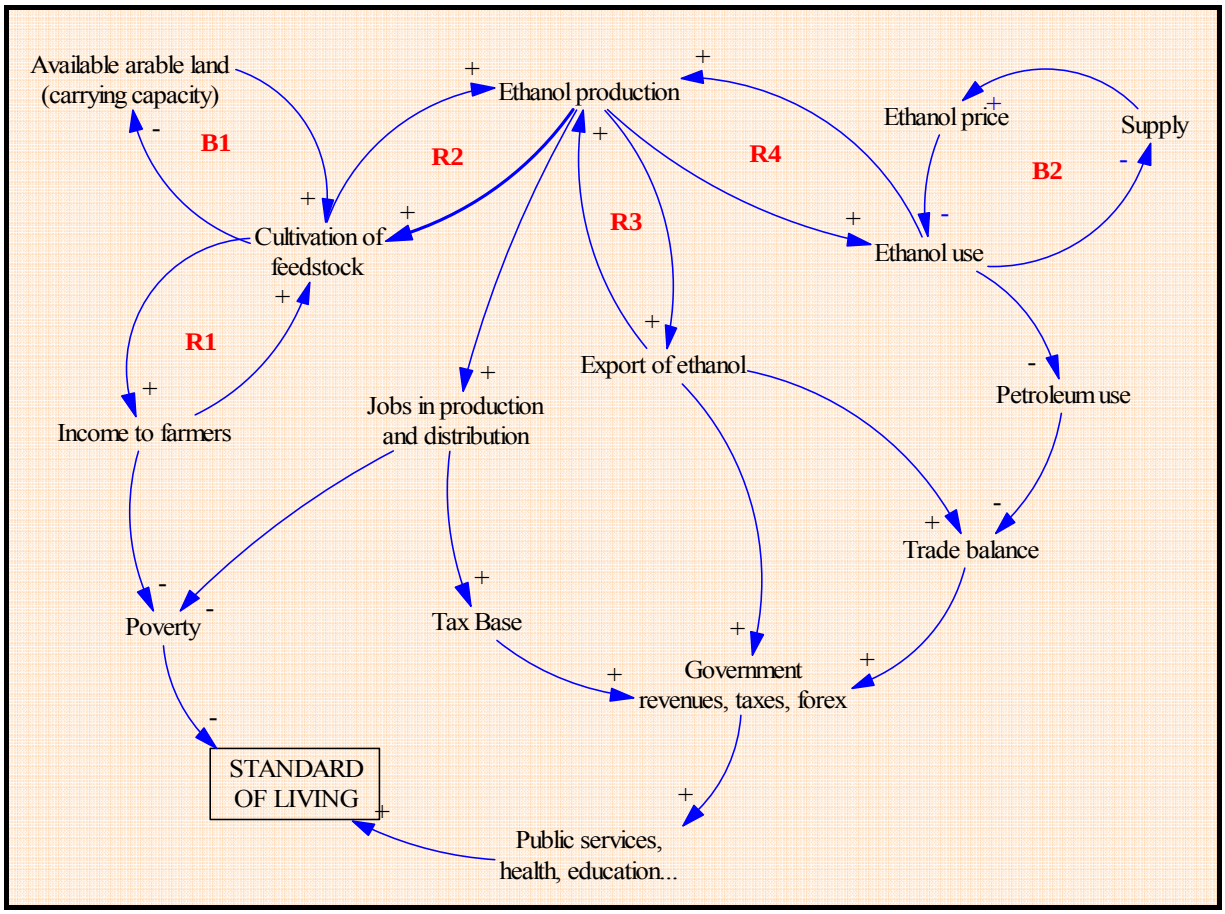

Figure 4: Economic and social benefits

Economic and Social Benefits: CLD Description

Once again the description of the CLD will be done using the instructions under section 1.2.2.1. A thicker arrow has been used between "Ethanol production" and "Cultivation of feedstock" to indicate that production drives cultivation.

REINFORCING LOOP (R1)

An increase in the "Cultivation of feedstock[5]" leads to an increase in "Income to farmers" from the sale of feedstock crops, an increase in "Income to farmers" leads to an increase in "Cultivation of feedstock" as the profits get reinvested back into cultivation.

An increase in "Income to farmers" leads to a decrease in "Poverty" and a decrease in "Poverty" leads to an increase in "STANDARD OF LIVING" decreased poverty is due to the incomes fetched from the sale of feedstock.

BALANCING LOOP B1

An increase in "Cultivation of feedstock" leads to a decrease in "Available arable land (carrying capacity)" and a decrease in "Available arable land (carrying capacity)" leads to a decrease in "Cultivation of feedstock" agricultural expansion is limited by the carrying capacity and that availability of land.

[5] In this paper, feedstock is used to refer to crops that can be used for the production of ethanol

REINFORCING LOOP (R2)
An increase in "Ethanol production" leads to an increase in "Cultivation of feedstock" and an increase in "Cultivation of feedstock" leads to an increase in "Ethanol production". The production of ethanol will provide a market to farmers who will in turn increase cultivation.

An increase in "Ethanol production" leads to an increase in "Jobs in production and distribution"; the jobs will be in the processing plants, in the transportation of ethanol and at the gas stations. An increase in "Jobs in production and distribution" leads to a decrease in "Poverty"; a decrease in "Poverty" leads to an increase in "STANDARD OF LIVING"

REINFORCING LOOP (R3)
An increase in "Ethanol production" leads to an increase in "Export of ethanol" and an increase in "Export of ethanol" leads to an increase in "Ethanol production" this is because if there is profit in the export of ethanol, production for export will be increased as a result of the reinvestment in export due to the availability of a good market.

An increase in "Export of ethanol" leads to an increase in "Government revenues" in form of export duty and trade surplus. An increase in "Government revenue" leads to an increase in "Public services (health education infrastructure)" as the Government will be in a better financial position to allocate funds to social services. An increase in "Public services (health, education infrastructure)" leads to an increase in "STANDARD OF LIVING" Improved living standard will result from better health services and education to the population if the government channels the funds to better social services.

REINFORCING LOOP (R4)
An increase in "Ethanol production" leads to an increase in "Ethanol use" and an increase in "Ethanol use" leads to an increase in "Ethanol production" as more usage will lead to more production to meet the market demand.

BALANCING LOOP (B2)
An increase in "Ethanol use" will lead to a decrease in "Supply" as the demand for ethanol increases and a decrease in "Supply" will lead to an increase in "Ethanol price" and an increase in "Ethanol price" will lead to a decrease in "Ethanol use" as the high prices will act as a disincentive.

An increase in "Ethanol use" leads to a decrease in "Petroleum use" as ethanol will replace a certain amount of petroleum that would have been used and a decrease in "Petroleum use" leads to an increase in "Trade balance" as the government cuts down on its import expenditure thus improving the balance of trade. An increase in "Trade balance" leads to an increase in "Government revenues" from the savings attained by not importing petroleum.

Poverty Reduction

One way of meeting the needs of the poor is combating poverty through the provision of reliable income generating opportunities (UNCED, 1992). Ethanol production is an agro-based industry and thus has the potential of providing both on-farm and off farm employment opportunities especially in the rural areas and thus generating incomes. In Kenya, ethanol production would have the potential to boost the agricultural sector which plays an important role in the country's economy. Currently agriculture contributes 26% of Kenya's Gross Domestic Product (GDP) and is the source of livelihood for 80% of the people living in rural areas (Muigai, 2005). In light of this big number of rural poor, the Government recognises the

need for higher agricultural growth as critical for alleviating poverty (Government of Kenya, 2000). It further argues that agricultural growth has a growth multiplier of 1.64 thus it could catalyse growth in other sectors and is likely to have a strong indirect effect (Government of Kenya, 2000). In Brazil, it is estimated that ethanol production provides up to 700,000 direct jobs and about three to four times this number of indirect jobs (HABITAT, 1993). The presence of a large ethanol plant will attract other industries to the area just by its presence and for its fuel this will lead to the creation of additional jobs (BOSTID, 1983).

Government Revenues

The tax base in Kenya is low making it difficult for the government to effectively provide social services to the people. The Kenyan government has thus been under pressure from international funding organisations to increase its tax base so as to reduce its dependence on foreign aid (Cheeseman and Griffiths, 2005). One approach that could be used to increase the ability of Kenyans to pay taxes is to increase the tax base (Cheeseman and Griffiths, 2005). The jobs and incomes generated from ethanol production could contribute to government revenues in form of income tax from the salaries as well as in the form of value added tax (VAT) thus increasing the tax base (CLD Figure 4).

Export to Other Countries

Surplus ethanol could be exported to the world market in which there is a potential demand for instance in the European Union where some countries have adopted carbon taxes which make the use of fossil fuels expensive. By 2001 there were already eight European member states that had introduced carbon taxes (Carter, 2001). An added advantage is the geographical location of the country; unlike its landlocked neighbours, Kenya has coastline with an important port from where ethanol can be shipped to other countries. Moreover as compared to developed countries Kenya has a cheaper labour force which could lower the cost of ethanol making it competitive in the world market. Exporting ethanol will improve the balance of trade that is offset by importing petroleum (Figure 4 CLD). The export of ethanol to other countries could be favoured by free trade agreements between Kenya and other countries for instance in Africa, the East African Community (EAC) which comprises of Kenya Uganda and Tanzania and the Common Market for Eastern and Southern Africa (COMESA) of which Kenya is one of the 20 member states. Some of the COMESA agreements for instance, include: Free Trade Area (FTA) in which no tariffs are levied on goods from other member states but each state is free to apply its own laws to goods imported from outside the region; and Preferential Trade Area (PTA) where lower tariffs are applied to intra-regional trade originating from member countries than to extra-regional countries (COMESA, 2005).

Reduced Dependence on Imported fuels

From the field survey it was noted that Kenya has no economically viable sources of fossil fuels and depends on imports from Saudi Arabia, Iran, and Kuwait (questionnaire to policy makers) and that besides trade imbalance, the policy makers also recognise high and unstable prices as a major problem in the oil industry of which they asserted that little can be done to control since the oil is imported from other countries. The field survey also revealed that current and past efforts have concentrated at exploration for fossil fuel deposits in the country with no success. Therefore, the search for alternative energy sources such as ethanol could be a viable option. Producing and using ethanol in Kenya would reduce the government's high

expenditure on petroleum import. Brazil has been able to significantly reduce its foreign exchange burden from imported liquid fuels; for instance the total savings in oil imports between 1976 and 1987 are estimated at $12.48 billion whilst the total investment in the programme was only $6.97 billion (UNDP, 1994). In addition, domestic production of ethanol increases energy security in case of energy crisis; the survey (questionnaire to policy makers) revealed that the only measure that has been put in place in case of an oil crisis is 30 days stocking of petroleum fuels.

3.1 Environmental Benefits

In this section, the environmental benefits that will result from the use of ethanol will be analysed. The CLD on Figure 5 illustrates the potential environmental benefits of using ethanol.

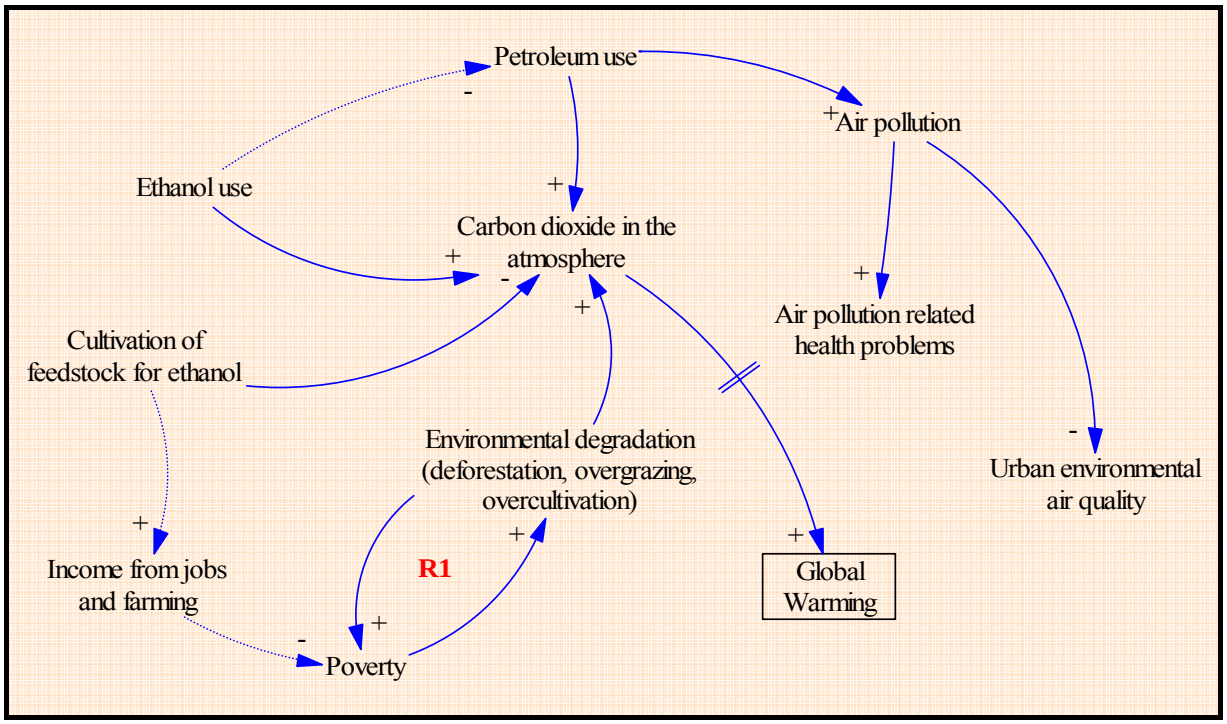

Figure 5: Environmental benefits of using ethanol

Environmental Benefits of Using Ethanol: CLD Description[6]

A decrease in "Petroleum use" leads to a decrease in "Air pollution" since ethanol has lower toxic emissions than petroleum fuels. A decrease in "Air pollution" leads to an increase in "Urban environmental quality" since there will be fewer emissions in the atmosphere. A decrease in "Air pollution" leads to a decrease in "Air pollution related health problems" that are caused by the pollutants that are emitted by petroleum fuels.

A decrease in "Petroleum use" leads to a decrease in "Carbon dioxide in the atmosphere" since the combustion of petroleum releases carbon dioxide that had been previously stored underground in oil reserves into the atmosphere. A decrease in "Carbon dioxide in the

[6] The dotted arrows discussed under economic and social benefits of figure 4

atmosphere" leads to a decrease in "Global Warming" since Carbon dioxide is one the greenhouse gases.

An increase in the "Cultivation of feedstock" leads to a decrease in "Carbon dioxide in the atmosphere" as the planted crop absorbs during photosynthesis the carbon dioxide released during combustion of ethanol since an increase in "Ethanol use" leads to an increase in "Carbon dioxide in the atmosphere" which leads to an increase in "Global Warming".

REINFORCING LOOP (R1)
A decrease in "Poverty" leads to a decrease in "Environmental degradation (deforestation overgrazing overcultivation" because people will depend less on their immediate surrounding environment for survival. On the other hand a decrease in "Environmental degradation (deforestation overgrazing overcultivation)" leads to a decrease in "Poverty" because the land will be more productive thus offer better yield.

A decrease in "Environmental degradation (deforestation overgrazing overcultivation)" leads to a decrease in "Carbon dioxide in the atmosphere" through carbon dioxide sequestration by crops and forests.

Global Warming

Ethanol like other bio-based fuels when combusted, the CO_2 remains in a closed eco-cycle as the amount of CO_2 released during combustion equals the amount plants absorb for growth UNEP (2000) during the process of photosynthesis. In light of the Kyoto protocol that has called on countries to cut down their CO_2 emissions, adopting ethanol would reduce the net build up of CO_2 by reducing the use of petroleum fuels and poverty induced deforestation practices (CLD on Figure 5 and CLD on Figure 1) thereby cutting down Kenya's contribution to global warming. The ethanol programme in Brazil is responsible for a net abatement of 9 million tonnes of carbon a year in Brazil (UNDESA - UNDP - WEC, 2000). While the results of a study from the United States indicate that in the year 2003/2004, the use of ethanol fuels in the USA reduced greenhouse gas emissions by approximately 5.7 million tons, equal to removing the annual emissions of more than 853,000 cars from the road (OCGA, 2005; WFBF, 2005)

Urban Air Pollution

Using ethanol fuel for transport will improve urban air quality (CLD on Figure 5) because when compared to gasoline fuels it produces fewer emissions and also because using ethanol reduces the amount of gasoline pollutants that would have been emitted by gasoline (WB, 1994). With as low as 10% ethanol blends lower tailpipe emissions of total hydrocarbon and carbon monoxide emissions can be observed (Niven, 2004). In addition there are lower levels of particulate matter (Mulawa et al., 1997; Niven, 2004; Poulopoulos et al., 2001) and lower nitrogen oxides (HE et al., 2003). Sulphur emissions are reduced and can be completely abated when pure ethanol is used (Moreira et al., 1997).

Some areas are still using leaded gasoline. In this case, ethanol can be used as a cheaper octane booster instead of tetraethyl lead (Thomas, 2001). There is a global agreement to phase out lead in gasoline due its adverse neurological effects especially in children (Thomas et al., 2001). It was noted during the field survey that in Kenya the sale of leaded gasoline was still going on. The reason could be that the oil refinery plant in Kenya has been unable to produce unleaded gasoline due to the high cost needed for upgrading it (Ministry of Energy, 2005)

Ethanol can be a potential means to phasing out lead because if neat ethanol is used, there is zero lead emissions (Thomas, 2001; WB, 1994).

Renewable resource

…"Today's needs should not comprise the ability of future generations to meet their needs" (WCED, 1987). Ethanol is derived from biomass and biomass is a renewable resource if proper farm management is practised. Ethanol is thus classified as a renewable form of energy. This makes its production and use sustainable in both the long tem and short term because its use will meet both the present and the future generations' ethanol energy and socio-economic needs. Its renewable nature is also a form of energy security as opposed to energy forms such as fossil fuels that are threatened by depletion (Figure 3).

4.0 DISCUSSION

This section is divided into two sections; section one, discusses the costs and benefits of using ethanol as opposed to petroleum and section two discusses the potential crops that could be used for ethanol production and the potential size and location of the ethanol plant. It will also discuss the barriers that could hinder the adoption of ethanol in Kenya.

SECTION 1

4.1 ETHANOL END USE

In order to mitigate air pollution that emanates from the combustion of fossil fuels, ethanol is on a global scale increasingly being used as neat ethanol, blended with gasoline and as an octane booster, as a substitute for imported oil. (Ahmed, 2001) ethanol cuts down air pollution and improves urban air quality (Figure 5). However, in addition to the good qualities of ethanol there are some negative qualities that are encountered in the production and use of ethanol. This section will discuss the impacts of using ethanol

4.1.1 Environmental Factors

NOX

The use of ethanol may actually increase NOx in the atmosphere. This can be deducted from the fact that different experiments have come up with different results in the tests that have been done to measure NOx emissions from the use of neat ethanol or ethanol blends and from the use of pure gasoline. For instance one study reports study, reports a slight lowering of NOx in ethanol blended fuels while yet another study reports an increase in NOx by 4.8% for the same; (Niven, 2004). However, Hsieh et al. (2001) concluded that NOx emission is not influenced by the presence or absence of ethanol but by how the engine operates. There is thus need for further research to find out if ethanol does cause an increase in NOx or not and if it does, how the NOx emissions can be reduced.

Aldehydes

There is a general concern that ethanol and ethanol containing fuels produce worrisome amounts of aldehydes notably acetaldehyde and formaldehyde (Hsieh et al., 2001; Poulopoulos et al., 2001, 2003; Ahmed, 2001; Niven, 2004). When ethanol is burnt is a great amount of acetaldehyde which is formed when ethanol emissions from car exhaust and from

evaporative emissions reacts with hydroxide ions is released (Grosjean, 2001). Brazil relies heavily on ethanol which it uses as an additive to gasoline and is the only country where ethanol is used countrywide as a fuel and thus its urban air is has higher levels of acetaldehyde emissions (Grosjean, 2001; Niven, 2004). Human exposure at high levels to acetaldehyde is reported to cause respiratory irritation and it is suspected that it could be carcinogenic to humans (Ahmed, 2001). In the environment, a percentage of the acetaldehyde produced undergoes photochemical reactions to produce peroxyalacetate nitrate (PAN), a compound that in some cases could lead to severe lung lesions and damage the epithelium of the upper part of the respiratory tract in humans whereas in plants, it is to some extent mutagenic and a toxin (Ahmed, 2001).

In as far as acetaldehyde emissions have negative impacts on both humans and the environment, when compared to the health and environmental damage caused by the pollutants emitted during the combustion of fossil fuels aldehyde emissions are by far less harmful (Hsieh, 2001; Niven, 2004) In addition, (Niven, 2004) argues that high levels of aldehydes for instance in brazil, are not strictly the result of exhaust pipe emissions but more from higher evaporative losses that arises from the lack of control on fuel Reid Vapour Pressure (RVP). RVP is a standard laboratory method which measures the inherent tendency to evaporate for instance at 38°C for gasoline (Emission Inventory Guidebook, 1999).
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Ground water contamination

Apart from the increase of aldehydes into the atmosphere by ethanol, it is of concern that the risk of soil and ground water contamination is higher when gasoline is blended with ethanol (Niven, 2004). This is due to its impact on other compounds and on the constituents of petroleum constituents (Niven, 2004). For instance the contact of ethanol with water leads to a reaction that causes the corrosion of steel used in underground storage tanks thereby increasing the risk of leakage to surrounding soils (Niven, 2004). Further leakage to soils comes from gas stations' underground fuel feed lines and from the use of certain materials that corrode when used to store or handle ethanol; such material includes certain metals such as aluminium and zinc and to some extent non metallic materials such as natural rubber and polyvinyl chloride which degrade depending on the percentage of ethanol (Niven, 2004). On contact with water ethanol increases the solubility of gasoline components such as benzene and toluene in water and also makes them non-biodegradable by inhibiting their biodegradation thereby increasing contamination of water and soils (Niven, 2004; Ahmed, 2001). Nevertheless since it is known that ethanol use could increase the risk of groundwater and soil contamination, it is possible to put strict measures that control the construction of storage tanks and the pipe system (Niven, 2004).

Using ethanol could lead to a decline in environmental quality thus reducing its sustainability. However with better control measures and technological improvement it has been noted, these problems could be prevented.

4.1.2 Economic Factors

Cost of Ethanol

The major economic disadvantage of ethanol is that it is expensive to produce thereby making it a more expensive fuel as compared to petroleum fuels making it to depend heavily on

government subsidies in the countries such as Brazil that produce and use it as a fuel (OECD - UNEP, 1999). But when compared to the money that the country could save by reducing the amount of oil imported, the subsidies could be justified as shifting the dollar debt caused by trade imbalance from the debt side to subsidies side (Moreira et al., 1997). Besides the ethanol prices will not be always high because with improving technologies, and economies of scale, the cost of producing ethanol will decrease (Moreira et al., 1997). In addition the rising prices of petroleum due to the increasing global demand, energy insecurity from the dependence on petroleum fuels and concerns about air quality and global warming will make ethanol competitive in the near future. Some researchers are optimistic that even if the oil prices remain low ethanol will soon be competitive when and if in addition to ethanol production electricity is generated from bagasse for use as energy in the plant and for sale to the national electricity grid (UNDP, 1997). From one perspective, it can also be argued from that if the subsidies are going to contribute to pulling a majority of the rural poor from their miserable conditions, save on health costs and act as a safety net in case of future oil crisis then the subsidies are worth having. Nevertheless, some opponents argue that subsidies increase taxes, benefit the rich farmers further impoverishing the poor (Niven, 2004).

Engine Modification

Adopting ethanol use for transport in Kenya might require that some engine modifications are done on the vehicle which could be expensive. In the USA, it is estimated that the cost of modifying a conventional car so that it can run on100% Ethanol is at about US $160 (EPAC, 2004). However the modifications are only necessary when neat ethanol is used because engines can run on gasoline-ethanol blends without the need for any engine modification; moreover the engine changes can easily be done by trained mechanics implying that the costs will not be that high (IDRC, 1994). The second option would be to manufacture some cars that are already designed to run on neat ethanol like they did in Brazil (IDRC, 1994).

4.2 ETHANOL PRODUCTION STAGE

4.2.1 Environmental Impacts

Soils

One would expect that soils would diminish after years and years of cultivating the same crop for instance sugarcane on the same piece of land year after year but in Brazil (Moreira et al., 1997) there were actually a gradual improvement in the soil quality that actually improved the yield of sugarcane for decades which they achieved by improving the sugarcane varieties, recycling of nutrients and by improving the soil preparation techniques.

Emissions

The use of ethanol emits less particulate matter into the atmosphere (Mulawa, et al. 1997) however (Niven, 2004) argues that this may not be necessarily true when a full life cycle analysis is done especially in the case where sugarcane is used to produce ethanol; he argues that burning of cane fields before harvesting causes an important amount of particulate emissions. The pre-harvest burning is practiced for pest control and to reduce harvesting costs (Moreira et al., 1997). However (Moreira et al., 1997) points out that these particular

particulate emissions from cane fields have not been reported to cause any human health problems and the only problem is that it is in form of huge amounts of smoke and thus obviously a nuisance. Nevertheless, particulates from smoke should not be difficult to control since policies can be passed prohibiting the burning of fields or provision of incentives such as providing energy markets for the residues (Moreira et al., 1997). But this could prove to be a difficult task to achieve for instance a study reveals that for instance, there is a law prohibiting the burning of cane fields in São Paulo but the law is not respected as it is difficult for farmers to change from old farming practices (Moreira et al., 1997). However, energy markets for residues in Kenya since a majority of the rural poor depend on biomass fuels which are not always easily available. From the field survey (questionnaire to policy makers) it was noted that biomass accounts for 70% of the total energy used in the country.

Biodiversity

There is speculation by a few scientists that the attempts to make ethanol cheaper could introduce unknown risks to biodiversity since it will involve expansion of agriculture and probably biogenetic engineering while proponents of ethanol argue that the threats to biodiversity are minimal (Niven, 2004). Moreover, despite the controversies surrounding bioengineering its benefits cannot be ignored because some benefits in fact better the environment and protect biodiversity both directly and indirectly; for instance pest resistant crop varieties lead to less use of pesticides which could wipe out some non target species (Carter, 2001). Also the study did not come across literature which implied that Brazil which is world's greatest producer of ethanol has lost any of its biological species due to ethanol production. However, it is now generally known that the loss of biodiversity is more threatened when people are poor and thus deplete some resources such as forests and hunting of certain animal species to extinction.

CO_2

As earlier indicated, ethanol is said to significantly reduce CO_2 emissions through its carbon recycle however this balance could be offset due to the amount of fossil fuels needed to produce ethanol and to produce and transport the fertilisers. There are two ways to deal with that: firstly, farmers could be encouraged to practice organic farming where they use compost manure from their farms instead of chemical fertilisers, or secondly, the development of seed varieties that require less fertilisers. In addition plants should be located near the markets raw materials and labour where possible to reduce long distance transportation of raw material to the processing plants and back to the market and of labour to and fro.

SECTION 2

4.3 POTENTIAL CROPS THAT CAN BE USED TO PRODUCE ETHANOL

	YIELD	ETHANOL	ETHANOL
Crop	**ton/ha/year**	**litres/ton**	**litres/ton/year**
Sugarcane	50-90	70-90	3500-8000
Sugar beet	15-50	90	1350-5500
Maize	1.7-5.4	360	600-1944
Wheat	1.5-2.1	340	510-714

Table 2: Raw materials that could be used as feedstock in ethanol production

Source: adopted and modified from (BOSTID, 1983)

The main types of biomass raw material from which ethanol can be produced include: sugar bearing materials such as sugarcane and sugar beet; starches such as maize and cassava; and celluloses such as wood and agricultural residues (Thomas et al., 2001). Kenya has the possibility of producing ethanol from maize, wheat sugarcane and sugar beet.

Maize and wheat could be used to produce ethanol: they are both grown on large scale and do quite well in the country. However, it can be speculated that since maize and wheat are produced for human food consumption diverting them from food to fuels could lead to food shortages and food insecurity. This could be in form of increased prices for the food crops if they are also used for energy. However, the reverse appears to be true; it is suggested that the cultivation of crops that can serve both as energy crops and as food crops such as in this case maize and wheat could help avoid the competition for land and other resources between energy crops and food crops (IDRC, 1994). This is because the cultivation of food crops will serve both as food and energy crops. Nevertheless the use of maize and or wheat for ethanol production in Kenya could be more expensive due to the additional costs that will be incurred by the need for an additional step (saccharification) which is required to break down starches into simple sugars; both maize and wheat are starches and will thus require this extra step (Thomas et al., 2001). Nevertheless during a (personal communication with crop physiologist) it was pointed out that depending on the market conditions there could be willingness on the side of interested parties to invest in the additional saccharification step. In addition both maize and wheat have the disadvantage of that unlike sugarcane they will not produce bagasse for cogeneration thereby more costs will be incurred in the purchase of fuel (Thomas, 2001).

From table 2, under optimum conditions, sugarcane would produce the highest quantity of ethanol per year. In addition, proponents of sugarcane argue that producing ethanol from sugarcane would, in terms of fuel, be self sustaining since energy to be used for the distillation process can be generated by cogeneration from bagasse (Thomas et al., 2001; BOSTID, 1983). However the disadvantage of the sugarcane crop for instance in Kenya is that it takes a long time (18-24 months) to mature (Mandere, 2003). This problem has in the past led to the problem of immature harvesting of sugarcane by farmers (Mandere, 2003, Odek et al., 2003).

The second alternative would be to use sugar beet for ethanol production. The strong points for sugar beet is that it has the advantage of time because as opposed to sugarcane which takes almost two years to mature, sugar beet matures in 5 to 6 months; in addition, studies have proved that sugar beet can grow in a wide variety of soils and climatic conditions giving an opportunity for different regions in the country the chance to cultivate it (Mandere, 2003). It is also less water demanding as compared to sugarcane (personal communication with crop physiologist)

The limiting factor for using sugar beet is that in Kenya sugar beet is still on trials and the only source of sugar beet now would be from the few farmers that are cultivating it in trial fields in western and central provinces of Kenya. However results from the field indicate that the sugar beets are thriving well and have a big potential in Kenya (Kiriita 2001, 2002, 2003). The latest figures on yield after a period of 6 months - the time that it takes for sugar beet to mature - from Syngenta Seeds internal field trials indicate a yield of 90 -120 tons per hectare for Sudan and 100-120 tons per hectare for Colombia (Kenneth Fredlund, Syngenta Seeds, personal communication, 2005) while in Kenya the yields are reported as being at an average of 118 tons per hectare (Mumias Sugar Company, 2003). These figures are much higher than

the yields on table 1 probably because production might have improved since 1983 when the table was made or that the figures were from other regions.

The production costs of sugarcane and sugar beet par hectare par year in Mumias in western Kenya are displayed in Figure 6. The labour costs are higher for sugar beet than sugarcane because the sowing of sugar beet seeds is time consuming as seeds requires more precision since they are much smaller than sugarcane (Mumias Sugar Company, 2003). On the other hand, canes seeds cost more than sugar beet seeds and the cost of transporting inputs such as fertilisers and seeds for sugarcane are higher mainly because the seed canes are larger than sugar beet seeds. For instance, the cost of transporting one ton of seed cane is 521 Kenyan shillings thus the cost of transporting 6.5 tons of seed canes that are required for one hectare is 3387 Kenya Shillings (Mumias Sugar Company, 2003).

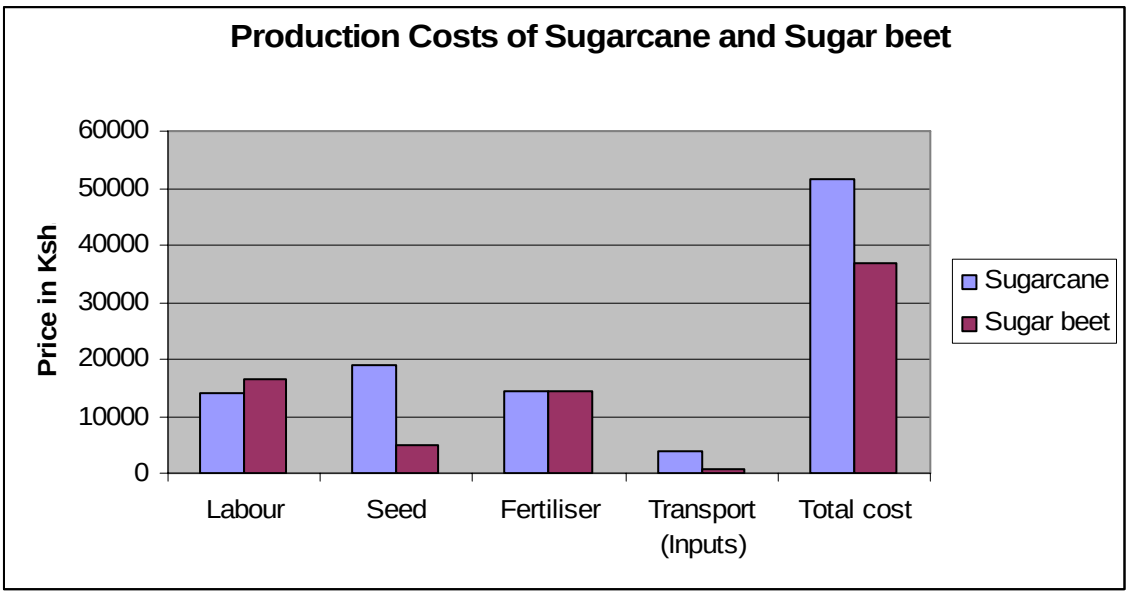

Figure 6: Production costs of sugarcane and sugar beet[7]

From the results in Figure 6, it can be concluded that the production cost for sugarcane is higher than that of sugar beet. Thus from the four crops, maize wheat sugarcane and sugar beet, sugar beet would be the optimal crop to be used to produce ethanol in Kenya seconded by sugarcane in terms of production costs. However the production of sugar beets ethanol will only be possible if large scale cultivation off after the on going trials. Nevertheless cultivating just one crop could lead to monoculture like is the case now in the cane growing areas in Kenya (Odek et al., 2003). To avoid monocultures it is hence suggested that the two crops; sugarcane and sugar beet be used for ethanol production. Crop diversification minimises risks and loses from diseases, pests and unexpected weather conditions that are usually associated with monocultures (Mandere, 2003).

Nevertheless, on ethical grounds, the cultivation of energy crops instead of food may be wrong especially in a country where problems of food insecurity are sometimes encountered. However, this paper argues that by boosting economic development there will be available funds to purchase food from other sources.

[7] The graph was made using figures from (Sugar beet field trial results of 2003 by Mumias Sugar Company,)

4.4 SIZE AND LOCATION OF THE PLANT

4.4.1 Location

Figure 7: Map of Kenya illustrating the potential sites for ethanol processing plants

Figure 7 is the map of Kenya illustrating areas where ethanol processing plants could be located; the areas marked ‘A’ ‘B’ and ‘C’ represent the potential ethanol processing plant location areas: zones ‘A’ and ‘C’ are the regions that produce sugarcane and have sugar processing factories; ‘A’ and ‘B’ are the zones which are currently under sugar beet trials; zone ‘B’ has no sugar processing plant and n sugarcane is grown in the area but it has the biggest market potential because it is close to the capital city Nairobi and as opposed to zone “C”, it is centrally placed; zone ‘C’ however, would be the optimal location to ship the surplus ethanol to the world market since it is close to the sea.

From the map on figure 7, it can be noticed that the suggestions for the location of ethanol processing plants is concentrated more to the south than the northern and north eastern parts of the country. This is because the northern and north-eastern areas are mainly arid and semis arid lands and have low population densities. The communities are also mainly nomadic

pastoralists and thus do not cultivate crops. There are also some insecurity problems from the neighbouring Somalia.

Secondly, this study proposes that ethanol distillation plants be installed as annexes to some or all of the existing sugar milling factories either to supplement or replace sugar production. This is because the sugar industry in Kenya has been and continues to undergo economic hardship due to competition from cheaper sugar in the international market resulting to companies like Miwani and Muhoroni to be placed under receivership (Odek et al., 2003). It would be possible to replace or supplement sugar production by ethanol in the existing sugar mills because as illustrated in Figure 8, sugar and ethanol processing have the same procedure apart from the two last steps (Moreira et al., 1997). It is thus proposed that sugar mills that are no longer economically viable to produce sugar could turn to ethanol and be able to make profits because for instance, a 100,000 litre per day distillery will need only 60 tons of sugarcane per hour when operating on a 24 hour basis (BOSTID, 1983). This translates to approximately 7000 hectares of land. Besides if the uneconomical sugar producing plants change to producing ethanol, the government will be able to purchase the cheaper sugar from the world market for its domestic sugar requirements and in addition improve government revenue from increased customs duty (Odek et al., 2003).

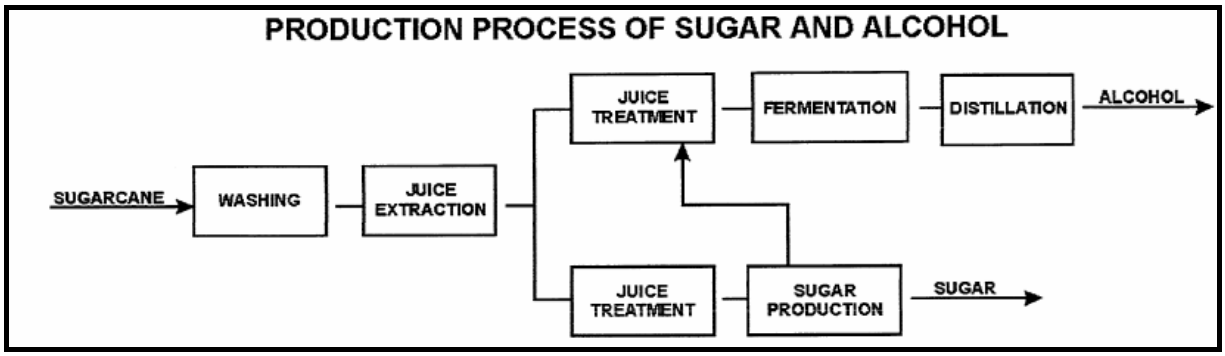

Figure 8: Production process of sugar and alcohol

Source: Moreira et al. (1997)

4.4.2 Size of plant

Large scale plants are more energy-efficient and more cost-effective in terms of litres of alcohol per unit of investment than small scale plants (BOSTID, 1983), nonetheless, this study suggests that ethanol processing plants be several small scale plants as opposed to few large scale ones. First because small scale plants would be in normal circumstances cheaper to install than large scale ones; consequently it will be easier to take loans for small scale projects as high interest rates make large loans uneconomic (BOSTID, 1983). On the other hand, it is pointed out that large scale plants are more energy-efficient and more cost-effective in terms of litres of alcohol per unit of investment than small scale plants (BOSTID, 1983).

4.5 WHAT ARE THE BARRIERS THAT COULD BE ENCOUNTERED IN THE INTRODUCTION OF ETHANOL IN KENYA

4.5.1 Policy

One of the barriers that could be encountered in reintroducing ethanol would be the policy framework. From the field survey and from the energy policy paper "Sessional paper on Energy" prepared by the Ministry of Energy, that very little attention has been directed to the potentials of renewable fuels and alcohol fuels such as ethanol get even lesser attention which features briefly in the long term policies. All efforts seem to be directed to petroleum fuels and exploration for possible domestic reserves of fossil fuels even though the results have been negative ever since the 1950s.

In addition there was a general lack of awareness of ethanol fuels and their potential both among the general public and the policy makers in the energy sector; questionnaires were filled with "I don't know" on the section on ethanol while others claimed that ethanol fuels were not a form of energy. It would thus be difficult for ethanol to be introduced in the country if the people working in the energy sector do not know what ethanol is or what potentials can be derived from it.

The study suggests that there be increased awareness among the policy makers and the general public on the potential social, economic and environmental benefits of ethanol production and use in the country. Such awareness campaigns could be initiated by non governmental organisations operating in country especially those that deal with development and energy matters.

Secondly, the study suggests that the Sessional paper on energy be revised with the aim of shifting focus away from the dependence on petroleum fuels to the adoption of cleaner and renewable forms of fuel under which ethanol falls.

4.5.2 Financial

Putting up ethanol plants could be expensive to the government and may therefore require external funding. However the possibilities of getting funding from the global environment facility (GEF) which is programme that provides funding to help less developed countries to implement measures to protect the environment, should be exploited. Secondly private investors and companies could be encouraged to invest in ethanol production through the provision of soft loans and incentives such as tax reduction.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the study it was observed that structured questionnaires may not be have been the best way to obtain data from the field especially from government offices and that in-depth interviews were more successful. However the study concludes that currently Kenya depends on imported petroleum to run its commercial sector and is thus is a prime mover of the modern economy in Kenya. Nevertheless, the dependence on imported petroleum causes trade imbalance and inflation during periods of high oil prices which have a stagnating effect on the social development and economic growth of the country. In addition to the negative impacts of petroleum fuels on socio-economic growth, use of petroleum, emits CO_2 that a gas that

contributes to global warming. Petroleum further releases CO, NOx and SO_2 which cause human health problems. Further petroleum oil reserves are non-renewable and hence can be depleted in the long-term.

Ethanol is not currently being produced in Kenya, but its adoption can generate both on farm and off farm jobs. In addition, unlike petroleum it is a cleaner energy form; it emits lower CO, NOx, SO_2 and lead. It also does not lead to the net increase of CO_2 in the atmosphere. However the use of ethanol fuel releases high amounts of aldehydes and can cause groundwater and soil contamination. Since ethanol is produced from biomass crops that can be produced locally, it can reduce trade imbalance as well as provide a reliable renewable source of energy in the long term.

Thus when compared to petroleum fuel imports, the social, economic and environmental benefits of ethanol are much more for ethanol than for petroleum while the negative impacts on the social economic and environmental dimensions, petroleum fuels have much more negative impacts than ethanol.

Thus the study concluded that the production and use of ethanol fuel in Kenya is more has the potential to be more sustainable than the reliance on fossil fuels. However the sustainability of ethanol production will largely be influenced by government policies and farm management practices.

5.2 Recommendations

The paper makes the following recommendations:

- The study recommends that to start of the ethanol production and use in the country, the government should give some form of incentives and subsidies either for instance as tax reduction for ethanol or additional taxes for gasoline so that ethanol it can compete with gasoline. Also tax reductions could be offered to the people that purchase cars that run on ethanol.
- Secondly, soft loans should be provided to private investors willing to invest in ethanol production.
- The study also recommends that the introduction of ethanol blended with gasoline be first and gradually shift to neat ethanol as production becomes stable.
- The government should carry out more research on the potentials of ethanol production and also on ethanol management technologies to reduce negative environmental risks for instance groundwater and soil contamination.
- Reforms in the agricultural sector need to be done in order to give farmers better support especially in times of crop failure or bad market prices.
- There is need for the continued fight against HIV/AIDS which continues to affect a big percentage of the youth and working age people in the country this reduces labour force in the farms which end up being run by very old people that have far less energy to work.
- Finally there is need for the continued corruption fight which is a major stumbling block to the development of many projects.

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Appendix 1

Questionnaire to policy makers

POLICY MAKERS / ENERGY SECTOR EMPLOYEES

SECTION ONE:

BACKGROUND OF ENERGY IN KENYA

1. In the table 1 below please fill in the kinds of energy sources are used by the following groups of **users**: large scale industries, small scale industries, domestic/ households, and by agriculture.

Instructions

*In the 6th column, **(comment on cost)** please give on a scale of 1 to 5 where **1** is cheap☺ and **5**, is very expensive☹, your comment on the cost.*

*On the seventh column **(availability of the energy source)** give on the scale of 1, to 5, where **1** is readily available☺ and **5** is very unreliable ☹your comment on the availability.*

Table 1

User	**Energy source**	**Activit(y)ies**	**Quantity per month**	**Cost per unit**	**Comment on cost**	**Availability of energy source**

1.1. Do you experience any problems with these energy sources?

- Yes
- No

2.1. If yes fill in table 2 below

Table 2

Energy source	Problem	How these problems are being addressed **now**	How could they be **otherwise** solved or addressed

3. Would you say that the energy sources in the country are enough to meet the current energy needs of the country sufficiently?

- Yes
- No

3.1. If no, by what percentage should it be increased?

……
……

3.2. What measures are in place to increase the energy supply in the country?

……
……

4. What challenges face the energy sector in Kenya today?

……
……..

Renewable energy

5. What is the government's policy on renewable energy sources?

……
……6

.1. Is this policy being implemented?

- Yes
- No

6.1.2. If yes, which forms of renewable energy are currently used in the country?

Renewable energy	Percentage in use in 2005	Percentage in use in 1990	Reason for increase or decrease in use

Fossil fuels

1. Does the country import fossil fuels?
- Yes
- No

1.2. If yes, from which countries?

Country	Fossil fuel	Uses	Quantity imported in 1990	Quantity imported in 2005	Cost per litre 1990	Cost per litre 2005

1.3. What has been the trend in the cost of fossil fuels over the past 15 years?
……
……

1.4. What has been the trend in the use of fossil fuels over the past 15 years?
……
……

2. is there a plan in place that will be used in case of an oil crisis?

- Yes
- No

2.1. If yes, what?
……
……
……

3. Is there a carbon dioxide air pollution problem in the country?

- Yes
- No

3.1. If yes, what?
……
……
3.1.1 What efforts are made by the government to solve the problem?
……
……

4. Has the government been influenced in any way by the Kyoto protocol?

- Yes
- No

4.1. If yes in what way?
……
……

SECTION 2

ETHANOL

1. Are there any crops being used to produce ethanol in Kenya today?
- Yes
- No

1.1. If yes, what crops?
……
……

2. What technologies are used to produce ethanol?
……
……

2.1. What are the estimates on the inputs and final ethanol produced by the different technologies?

Technology	Energy use (joules)	Labour (high, average, low)	Crop input (kg)	Ethanol produced (litres)	Cost of ethanol produced /litre

……
……

2.2. What are the shortcomings of the above technologies?
……
2.3. What are the strong points of using the above technologies?
……
……
3. From what other sources can ethanol be generated in Kenya?
……...
4. Is ethanol imported into the country?

- Yes □
- No □

4.1. If yes, from which countries?

Country imported from	Quantity imported	Cost per litre

5. What is the ***current*** government policy on ethanol?
……
……
……

6. Does the government have any ***future*** plans for ethanol?

- Yes □
- No □

6.1. If yes what?
……..
……..