TECHNICAL AND ECONOMIC FEASIBILITY STUDY OF ESTABLISHING ETHANOL FUEL PLANT IN KENANA SUGAR COMPANY

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Abstract
In recent years sugar cane industry had been faced with challenges that are mainly manifested in utilization of its by-products such as bagasse and molasses, and the growing concern for the environment that makes the governments to orient its policies and efforts towards the product of fuel that is chemically extracted through fermentation and distillation.
The research paper is directed to serve the economy through feasibility study to establish ethanol fuel plant to improve the profits of the sugar industry and alleviate the environmental problems resulting from the use of fossil fuels.
The study revealed that a capital of $26,201,660 can be invested in plant that produces 200,000 liter/day of ethanol fuel; the annual gross revenue without considering taxes is estimated to be $11,133,000 with payback period of 3.67 years. The economic indicators are feasible showing that internal rate of return is 22.55%.
Keywords: feasibility study, technical, economic, ethanol fuel, sugar cane, Kenana sugar company

1. Introduction and Historical Background

Ethanol which is also known as ethyl alcohol or grain alcohol is a flammable oxygenated hydrocarbon, tasteless, colorless with a distinctive odor. At the same time, ethanol is versatile solvent. It is easily mixed with water and with most organic liquids, including non-polar liquid. In common usage, it is often referred to simply as alcohol. Its chemical formula is C_2H_5OH. It boils at 78.4 ^oC and melts at -112.3 ^oC, and has specific gravity of 0.751 at 20 ^oC.
Ethanol has been used by humans since prehistory as an intoxicating ingredient in alcoholic beverage. Dried residues of alcohol found in northern China imply the use of alcoholic beverages even among Neolithic people before 9000 years. Its isolation as a relative pure compound was first achieved by Muslim alchemists who developed the art of distillation during the Abbasid caliphate. It is the first fuel used in automobiles, it was used extensively in Germany during World War II and also in Brazil, the Philippines and USA. During postwar period, as petroleum supplies become cheap and abundant, gasoline largely replaced ethanol as automotive fuel.
Not until 1970s, when the supply of oil was restricted, did ethanol re-emerge as an alternative to or extender for petroleum – based liquid fuel. Today, many countries produce and use significant amount of ethanol. In Brazil for example one third of that country's automobiles uses pure Ethanol as fuel, the remaining two third uses mixture of gasoline and ethanol.
Ethanol attracts worldwide attention. Therefore, the future of ethanol is very bright with most countries now approving blending of fossil based fuel with bio-fuels like ethanol.
Brazil with its large cane sugar production base, over the last couple of decades, has been using ethanol as fuel supplement and gone on for further expansion in the production of ethanol. In the current context of exorbitant cost of fossil based fuel and depleting oil reserves, countries are turning to use ethanol as a supplement and alternative fuel. Hence, this is considered the right time for investment in production of ethanol.
The world is looking at ethanol as a green fuel which is environmentally clean and comparatively lower in cost when compared to fossil based fuel. Therefore, it should not be surprising that in the coming decades, ethanol will occupy center stage as a major competitor to fossil fuel.

Bio-fuels are attractive option to be part of that mix because bio-mass is a domestic, secure and abundant feedstock. In addition, fuels from bio-mass are the only renewable liquid fuel alternative to replace petroleum based transportation fuels.

Brazil is currently the world leader in flex-fuel cars with the country having embraced the concept of being independent in energy production and consumption. Brazil has preferred this technology of flex-fuel vehicles to the point that, for Brazilian the cheapest fuel choice is clearly ethanol. This is because Brazil produces ethanol very efficiently and cost effectively, the hallmarks for making ethanol production commercially viable. At the same time, ethanol is a versatile transportation fuel that offers high octane, high heat of evaporation, added to the fact that ethanol is low in toxicity, volatility and photo-chemical reactivity, resulting in reduced Ozone formation and smog compared to conventional fuel.

Ethanol can also be added to gasoline to reduce fossil fuel use, increase octane and provide oxygen to promote more complete combustion and reduce exhaust emissions of carbon monoxide and unburned hydrocarbons.

Fossil fuels or mineral fuels are fossil source fuels, that is hydrocarbon found within the top larger of the earth's crust. Fossil fuels range from volatile materials with low carbon: hydrogen nitrous like methane to liquid petroleum to nonvolatile materials composed of almost pure carbon like coal. It is generally accepted that they formed from the fossilized remains of dead plant & animals by exposure to heat and pressure in earth's crust over hundreds of millions of years.

It was estimated by the energy information administration [1], that in 2005, 86% of primary energy production in the world come from burning fossil fuels, with the remaining non fossil source being hydroelectric 6.3%, nuclear 6.0% and the other (geothermal, solar and wood 0.9%).

Fossil fuels are non-renewable resources because they take millions of years to form, and reserves are being depleted much faster than new ones are being formed.

Concern about fossil fuel supplies is one of the causes of regional and global conflicts. Production and use of fossil fuels raise environmental concerns. Therefore, a global movement towards the generation of renewable energy is therefore under way to help meet increased energy needs.

The burning of fossil fuels produces around 21.3 billion tons of carbon dioxide per year, but it is estimated that natural processes can only absorb about half of that amount, so there is a net increase of 10.65 billion tons of atmospheric carbon dioxide per year (one tone of atmospheric carbon is equivalent to 44/12 or 3.7 tons of carbon dioxide. Carbon dioxide is one of the greenhouse gases that enhances radiation forcing and contribute to global warming, causing the average surface temperature of the earth to rise in response.

Combustion of fossil fuels generates sulphuric, carbonic and nitric acids which fall on the earth as acid rains, impacting both natural areas and the built environment. Fossil fuels also contain radioactive materials, mainly uranium and thorium that are released into the atmosphere. In 2000, about 12,000 mega ton of thorium and 5,000 mega ton of uranium were released worldwide from burning coal.

In economic terms, pollution from fossil fuels is regarded as a negative externality. Taxation is considered one wary to make siesta cost explicit in order to internalize the cost of pollution. This aims to make fossil fuels more expensive, thereby reducing their use and the amount of pollution associated with them. Generally there is an arguments in favor of moving away from fossil fuels.

The mixing of ethanol with fuels can be used in the following ranges:

a) Ethanol can be mixed directly (splash blend) with unleaded gasoline in proportion that vary from 5% to 85%. Experience in Brazil & USA has shown that it is not necessary to modify combustion system of conventional engines to use blends of up to 25% ethanol (E-25). If modifications are done in the fuel system, 100% of ethanol can be used.
b) Ethanol can be blend up to 85% with diesel, although the affinity of ethanol with water makes it necessary to use a very strict dehydration of emulsion agent.
c) When mixed at 46% and 54% isobutylene, ETBE(Ethyl Tertiary Bytyl Ether) is produced which can be used as anti-knock additives, oxygenate and octane enhancer for gasoline. In

concentration of up to 10% ETBE has been adopted as substitute for MTBE (Methyl Tertiary Bytyl Ether).

d) Ethanol is currently blended typically at 10% level with gasoline in USA and Brazil employs 25% blends of ethanol in all gasoline used. Because ethanol has higher octane than gasoline, it boosts the octane of the blend. Furthermore, ethanol provides oxygen to the fuel, thereby reducing tail pipe emission of carbon monoxide (Co) and unburned hydrocarbon.

The following data in Table 1 below explains world-wide ethanol production.

Table 1 World-Wide Ethanol Production

Year	Production in billion liters
2002	32.70
2003	37.60
2004	41.30
2005	46.00
2006	50.00
2007	52.00

In USA, [2] ethanol industry is one of the most significant success stories. From a cottage industry that produced 175 million gallons in 1980, the American ethanol industry has grown substantially so that in the year 2005 it produced 1660 million liters of ethanol. USA Government has provided substantial encouragement for producing ethanol. Promising funds for additional researches in cutting edge methods.

Brazil nowadays utilizes about 190 million tons of sugar cane for alcohol production in addition to 12 million tons of molasses. In 2005/06, its market share in world sugar exports was estimated at 32%. In case of ethanol, Brazil's share is even higher which reaches up to 50%.

In European union (EU), the total output is expected to reach 2.9 billion liters from 2.6 billion liters. In Asian countries it rose slightly from 6.4 to 6.6 billion liters with higher output reported in China, India and Thailand.

Bio ethanol in Sudan is prospective, since molasses (byproduct of cane sugar production) will be the base for ethanol production. Kenana Sugar Company (KSC), the world largest integrated cane sugar manufacturing plant is a focus of ethanol production. An increase in production capacity in KSC and other factories such as Assalaya, Sinnar, Guneid, and Halfa adding to that the coming huge factory (White Nile Sugar Factory) will lead to a plant of 200,000 liters which would be considered clearly feasible.

At the same time considering the worldwide scenario in term of increase in energy consumption, it would make lot of economic and commercial sense for Kenana to go on for such a plant.

Changes and upgrading in sugar technology of Kenana Sugar factory have rendered a great saving of molasses, in addition to molasses produced in the neighboring sugar factories namely Assalaya and West Sinnar. This together with clean environment requirements became logic and reasonable for Kenana to establish an ethanol production plant to produce an amount of ethanol approaching 66 million liter per day.

2. Technical Feasibility Study

A. Molasses

Molasses which is the main feed-stock to produce ethanol fuel, is a thick syrup by-product from processing of the sugar cane into sugar, molasses also refers to as sorghum syrup. The quality of molasses depends on the maturity of sugar cane, the amount of sugar extracted and the method of extraction.

Sulphureted molasses is made from young green cane and is heated with sulphur dioxide, which acts as a preservative during the sugar extraction process. Unsulphured molasses is made from mature sugar cane and does not required treatment with sulphur during extraction process. There are three grade of molasses [3]:

i- Mild or first molasses
ii- Dark or second molasses
iii- Black strap

This grade may be sulphured or unsulphured.
To make molasses, the sugar cane plant is harvested and stripped off its leaves. Its juice is extracted from the cane, usually by crushing in sugar factory mills. The juice is boiled to a certain concentration that promotes the crystallization of the sugar. The result of this first boiling and removal of sugar crystal is the first molasses, which has highest sugar content. Second molasses is created from second boiling and sugar extraction process. The third boiling of the sugar syrup gives black strap molasses, it contains significant amount of vitamins and minerals. It is a source of calcium, magnesium, potassium and iron.
Molasses is often sold as health supplement, as well as being used in the manufacturing of cattle fodder and for other industrial uses. Moreover, as per the study, molasses is fermented to produce ethanol fuel for use as an alternative fuel in motor vehicles.

B. Estimated Molasses Amount

Kenana [4], being one of the world largest cane sugar producer, produces about 140,000 tons of molasses per crop which is equivalent to 60% of the total molasses produced in Sudan. Kenana also is ideally suited for processing molasses.
In addition to neighboring sugar factories as Assalaya and Sinnar that produce an average of 60,000 tons per crop, then total molasses yields to 200,000 ton. Therefore, there is a good reason for Kenana to establish an ethanol plant of 200,000 liters per day capacity which is equivalent to 66 million liters per year working period considered 330 days, the remaining period being for repair and necessary maintenance. Therefore, it makes a reasonable economic and commercial sense to site a plant at Kenana. Kenana has a distinct edge in term of several advantage that it enjoys, which enables substantial reduced net investment and then shorter pay-back period. Table 2 shows annual production summary in Kenana Sugar Company(KSC).

Table 2 Annual Production Summary in KSC

Year	Total sugar Production (Tons)	Molasses Production (Tons)	Bagasse Production (Tons)
79/80	19,715	22,256	137,737
80/81	106,743	40,012	457,889
81/82	156,359	83,863	559,212
82/83	229,322	79,605	755,453
83/84	248,345	100,296	880,246
84/85	305,863	105,870	940,022
85/86	292,838	109,738	840,452
86/87	309,705	115,126	851,898
87/88	264,832	95,232	743,196
88/89	231,749	86,430	671,405
89/90	231,992	88,386	698,787
90/91	252,234	113,412	789,676
91/92	253,497	104,182	713,792
92/93	264,931	105,005	723,161
93/94	248,792	93,458	714,338
94/95	252,605	98,472	783,032
95/96	280,000	114,326	860,676
96/97	333,000	115,568	1,036,788
97/98	355,817	130,598	1,212,451
98/99	365,000	140,483	1,151,185
99/00	387,044	135,680	1,174,956
00/01	403,486	133,285	1,153,521
01/02	376,039	140,000	1,234,724
02/03	398,268	145,043	1,277,762
03/04	427,895	147,028	1,339,700
04/05	393,002	138,101	1,251,420
05/06	400,209	142,019	1,224,750
06/07	405,040	131,806	1,222,366
07/08	391,121	129,836	1,323,770

C. Appropriate Technology:

The decision to produce and use ethanol fuel requires addressing both direct and indirect technical and economic questions. These questions are important on scale of development ranging from individual local decision to produce on small scale to national level program.
Direct technical and economical questions in the decision to produce and use ethanol fuel includes:

- i- The cost and availability of feed stock (molasses)
- ii- By-products
- iii- End uses and marketing
- iv- Laws and regulations
- v- Production scale
- vi- Selection of plant design and equipment options

Ethanol and byproducts uses are affected by by-product transportation, distribution, storage, possible spoilage of by-product, seasonal variation in market demand or in site uses and whether the ethanol is to replace or blend with gasoline. When ethanol is to be blended [5] with gasoline, the cost and the system for distribution, blending and marketing need to be taken into account. On the other hand when ethanol is to replace gasoline, the cost of engine conversion and limitation to vehicle use are two important factors.
A principal government regulation is to make the produced ethanol unsuitable for human consumption by adding denature agent. Generally, these regulations require that ethanol be denaturized by adding chemical agents to make ethanol unfit with human consumption. The most readily available denaturant for ethanol is gasoline mixed at 1% by volume. Other regulations may govern the discharge of liquid and gases effluents and occupational safety and health.
Decisions regarding plant scale, equipment and process design depend primarily on feed stock (molasses), the availability of markets for both ethanol and its by-products and the availability of plant financing.
The complex question for which there is no absolute answer is the issue of food versus fuel; that is, whether the use of agricultural crops for ethanol fuel production will adversely affect the amount of land available for food. A large scale diversion of food crops to ethanol production could reduce food supplies and its price increase. A carefully planned and well integrated ethanol fuel industry does not necessarily result in direct competition for agricultural land and food supplies, these plans such as:

- i- Low-value crops grown on marginal land are often good alcohol stocks with poor food value.
- ii- Cultivation of low-value crops may contribute to the economy through conversion to a high volume product
- iii- Increased rural employment may increase people's economic access to high-quality food.
- iv- Ethanol might be produced for agricultural commodities that would otherwise be exported

The issue of food versus fuel emphasizes the need for careful planning, but does not mean that ethanol fuel production is an inappropriate technology.
Concerning the study, there is no crises associated with food versus fuel as the plant would have to use molasses as a feed stock, as molasses is a by-product of sugar cane processing.
Ethanol Production Basic Process: The production of ethanol from sugar based feed stock (molasses) consist of two principal process:

1- Fermentation of molasses by yeast to produce ethanol and carbon dioxide.
2- Distillation of the bear or wart to concentrate alcohol content.

Fermentation Process: A variety of commercially viable system exist to ferment the sugar (molasses), ranging from simple batch fermentation, with or without yeast recycling, to batch cascade and continuous fermentation and in some cases including sophisticated vacuum fermentation and distillation system. Traditionally, in commercial batch fermentation plants, the mash (diluted molasses) in the fermentation vessels is allowed to ferment until a concentration of 7 to 9% is reached. Yeast cannot survive at an alcohol concentration of more than about 10% and the alcohol production rate becomes progressively less as alcohol concentration in the mash or beer rises, mainly due to the death of significant quantities of the yeast.

Modern continuous fermentation plant can handle concentrations of up to 10 or 11% due to extra quantities of yeast available and the short retention times of high alcohol concentrates in the final fermentation tanks.

Once the predetermined alcohol concentration or time period has been reached, which is now called beer or mash is then pumped to distillation section, where separation of alcohol from the mash takes place by distillation or boiling in a series of steam heated columns. These columns are designed to remove most of the water from the mash (bear), concentrating the alcohol content to about 95.5% which is called neutral or industrial ethanol (alcohol).

Azeotropic distillation is a process which was commonly used in order to produce the 99% pure or anhydrous (dry) ethanol, which is required for blending with petroleum based fuels. In this process, a small amount of a lower boiling point alcohol such as benzene or even petroleum is added to the ethanol in an extra final stage of distillation, which allows the final small quantity of water to be driven off, leaving a dry alcohol of more than 99% purity.

This final azeotropic distillation or drying stage, requires relatively large quantities of steam as an energy or heating input, which increase the cost of production.

Modern practice increasingly uses molecular sieves or absorption processing to remove the last traces of water. This process utilizes a selective absorbent material such as zeolite, which absorbs water molecules but not alcohol, to remove the final vestiges of water from 96.5% or neutral ethanol. This process requires less heat or energy input in order to dry the ethanol, thereby reducing the amount of costly steam needed.

The fermentation process is sensitive to temperature and as the process produces heat, continuous cooling must be carried out to maintain the optimal temperature within the fermentation broth. Both fermentation and distillation processes require the support of a substantial cooling water system and a steam supply. continuous fermentation process, utilize specially selected and adopted so called granulating yeasts. These yeasts have a unique propensity or cling together in dumps or granules which can be easily separated from the beer (mash) in a simple settling tank. The beer is taken off from the top of the tank and the sediment or yeast sludge is recovered and reused in the continuous cycle after washing and acid treatment. A small quantity of lees or liquor from the previous fermentation is also used to provide essential nutrients for the recycled yeast going back into the first fermentation tanks.

The continuous fermentation systems have been well proven in operation in many molasses/sugar distilleries operating in tropical areas and trouble free cycles can be maintained for 90 to 120 days.

This study was therefore been based on a continuous fermentation system comprising three fermentation vats operating on 32-40 hours fermentation cycle. The primary vat is refilled with recycled yeast and diluted molasses every 8 hours. A typical fermentation block diagram is shown in Fig. 1.

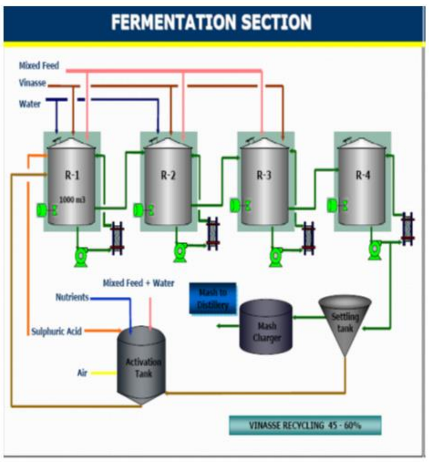

Fig. 1 Fermentation Block Diagram

Distillation Process: Distillation involves on similar number and size of columns, mash stripping, aldehydes concentration, rectification, dehydration and final solvent recovery columns. The processed distillation plant would use a combination of bubble cop and sieve type. The study has therefore also been based on providing a low energy distillation scheme in which steam is used to heat the dehydrating column and then reused to heat the dehydration vapour condensed in the mash stepping column re-boiler. A typical distillery block diagram is shown in Fig. 2.

The "beer" containing from 7% up to 10% alcohol, as well as the non-fermentable solids from the molasses and yeast cells, is pumped to continuous flow, multicolumn distillation system where ethanol is boiled off from the solids and water.

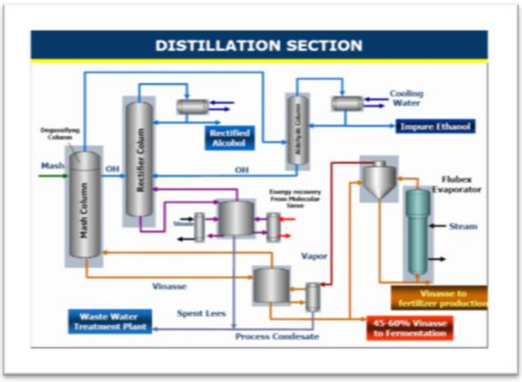

Fig. 2 Distillation Block Diagram

The ethanol leaves the top of the final column at about 96% strength, and the residual beer, called vinasse is transferred from the base of the column to the by-product processing area.

Dehydration:

In this step, a small amount of another high alcohol such as benzene was mixed with ethanol and the mixture is then redistilled to remove most of the remaining water from ethanol, leaving an almost pure 99% ethanol. This extra processing step uses more steam or energy and increases the cost of production as well as adding toxic product into the ethanol and the working environment.

Today, most ethanol plant use a molecular sieve (absorption column) to remove the last small amount of water in the ethanol by absorption. In this process, certain products such as zeolite or maize meal, which have the property of being able to selectively absorb water but not ethanol, are used in packed column, through which the ethanol is pumped. The residual water in the ethanol remains trapped in the zeolite or maize meal and 99% pure anhydrous ethanol is discharged. The columns are necessary in this process as the absorption material eventually becomes saturated and must be treated in order to drive off the water content. The ethanol stream is passed through the second packed columns whilst the first undergoes the drying process. The cycle is then repeated as the second column becomes saturated. Typical dehydration flow diagram is shown below in Fig. 3.

Denaturing:

Fuel ethanol is denatured with a small amount of (2% to 5%) of some product such as bittern, or petroleum to make it unfit for human consumption.

Co-products:

Two main co-products CO_2 and vinasse, are created during ethanol production. Carbon dioxide (CO_2) is given off in great quantities during fermentation. Many ethanol plants collect CO_2, clean it of any residual alcohol, compress it and sell it for use in carbonate beverages or as dry ice to flash freeze meat and vegetable products.

Vinasse produced is almost 15 times greater than ethanol by volume, it is high in protein and other nutrients. This effluent can be mixed into the sugar mills filter mud and sent to compositing section where a valuable nutrient rich soil conditioner and fertilizer is made. This compost can then be returned to the grower's cane fields, where it can be applied in calculated amounts with suitable supplementation by other the organic fertilizers to balance the nutrient mix required by the particular crop and soil conditions, to enhance the cane yield and sucrose potential of the following crop.

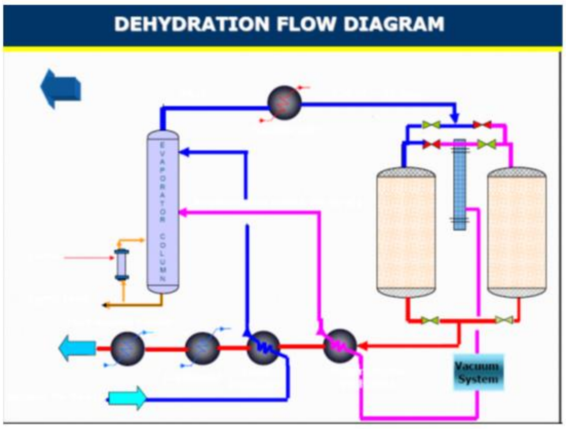

Fig. 3 Dehydration Flow Diagram

D. Trade in Ethanol:

International trade in ethanol has been small so far. Global trade in fuel ethanol [2] is estimated to have been about 3 billion liters per year over the last two years, above that of less than one billion liters in year 2000. International ethanol trade is still dominated by nonfuel ethanol used in beverage, chemical industries, etc.

It is estimated that the share of non-fuel ethanol in international trade has declined from about 75% at the beginning of the century to between 50% and 60% in the recent years, but the distinction in trade statistics is difficult given that fuel and non-fuel ethanol often share the same tariff lines as the level trade is reported.

Brazil has been the largest ethanol exporter of ethanol in recent years. In 2006, its ethanol export amounted to almost 3.5 billion liters out of 5 billion liters of ethanol traded globally. In contrast, the USA imported more than half of ethanol traded. China too has been a net exporter of ethanol over the last several years, but at significantly lower level than Brazil. Despite some exports to the USA as well as CBI countries, most of the largest destinations for Chinese are within the Asian region, particularly south Korea and Japan. European union represents the second largest import region, with a little less than 5 billion liters, its international trade in ethanol represented some 9% of global ethanol production. Table 2 below show international trade in ethanol 2006.

Table 2 International Trade in Ethanol 2006

Country	Export in Billion liters	Import in billion liters
Brazil	3.4	0
USA	0.2	2.75
China	1.0	0
EU	0.05	0.7
Others	0.25	0.35

Local and Regional Export Markets

Most of the fuel used in Sudan was formerly imported. The various petroleum marketing companies were allocated foreign exchange to import fuel in proportion to their respective market shares. Importation was through Port Sudan by rail, or road. Government issued guidelines on the range of prices within which companies could bid for supplies, based on the most recent global market spot prices. There are a few base figures in the pricing formula[6], which are mandatory. A landed price Khartoum was designated by government based on global spot oil prices and a series of input costs, associated with getting the imported product to Khartoum. The oil companies, depending on the prices they actually paid, and the routes and modes of transport they used, made gains or losses between the purchase price and the government based fixed landed cost.

Another series of costs and margins were then be added into the landed cost to arrive at a final pump sales price. The pump price is another government legislated item, requiring strict compliance, as is a fixed dealer's margin. Therefore, depending on their efficiency, the oil companies may gain or loss on the margin between landed cost and pump price. It is the landed cost figure that is of key significance of this analysis. To be competitive with gasoline, ethanol must

have a total production cost per liter that is competitive with petroleum fuel which could be equivalent of about $0.30 per liter, based on an average global spot price of $26.00 per barrel.
Since the discovery and development of Sudan's oil fields, virtually all the petroleum fuel requirements are now locally produced. The Elgeili refinery just outside Khartoum, with a production of 50,000 barrels per day is responsible for 90% of the national petroleum fuels. The gasoline that is produced and sold in Sudan is a standard fuel called "benzene". It is claimed to have an octane rating of 90. All the major oil companies have storage and distribution depots in Khartoum. Other depots locations include Wad Medani, Elgadaref and Kosti.

E. Market Prospects for Kenana Ethanol Company:

It is possible to use fuel grade ethanol neat (unblended) in motor vehicles, stationery engines, tractors, and other power machinery. However, engines must be modified to use neat alcohol effectively and efficiently. This also entails having to provide extra dedicated tanks and pumps at petrol stations and have separate tanker transport facilities. In view of fact that there will be enough ethanol produced to fill the projected desired level of use for petrol blending.
The escalating pressure on global fossil fuel supplies will almost certainly result in higher prices of these fuels. The vast sums of money and development work currently being carried out all over the world to find viable alternatives for these fossil fuels, is already being fruitful.
Ethanol can replace these imported environmentally damaging and poisonous octane enhancer, as well as acting as a fuel oxygenator, which should result in ethanol being utilized and valued in the future as a fuel enhancer and environmental protector, rather than merely a blend component or fossil fuel extender. This perception will almost certainly boost the perceived and actual value of ethanol which will help to boost the global market prices for anhydrous ethanol. There will always be a demand from the local industrial and pharmaceutical industries for high quality ethanol, which will command a premium price.

F. Sudanese Fuels Consumption

Historical imports of petroleum fuels in Sudan, as reported by the Ministry of Energy and the Bank of Sudan, are set out in the Table 3 below.

Table 3 Historical Petroleum Import Figures

Historical petroleum import figures (tons)		
Year	Benzene	Diesel
1996	750,000	2,333,334
1997	750,000	2,333,334
1998	775,000	2,333,334
1999	843,750	2,333,334
2000	843,750	2,166,667
2001	1,106,250	3,333,334

During the long period of civil war in Sudan, the number of motor vehicles declined drastically. By 1982 there were only slightly more than half as many vehicles in the country as in 1971. By 1991 there had been some recovery in vehicle numbers, but still only 87% as many as in 1971. Over the same period however, the population had increased by nearly 70%. As with sugar consumption the number of vehicles per capital worldwide has increased drastically over the past quarter century. The people to car ratio stood at 226:1 in 1971. In 1991 it was 429:1. Again, as the civil unrest situation return to normal, and the economy grows, the people to car ratio will undoubtedly increase rapidly. Projections of vehicle numbers based on the 9% growth rate are considered to be conservative. However, in view of the limit on potential ethanol production, a conservative estimate of Sudan's national consumption does not affect the final analysis. Table 4 below, shows Sudan's petroleum fuel consumption through the years 2001 – 2012 provided by the Sudanese Petroleum Corporation.

Table 4 Estimated Annual Petroleum Consumption Volume from Year 2001to Year 2012

Year	Benzene	Diesel
	Tons/day	Tons/day
2001	800	3400

2002	900	3500
2003	950	3600
2004	1000	3800
2005	1050	4000
2006	1100	4150
2007	1150	4320
2008	1200	4320
2009	1275	4700
2010	1350	4950
2011	1450	5200
2012	1500	5500

Table 5 below, indicates the projected future quantities of ethanol that could be made available for fuel blending from the surplus molasses produced by the four sugar mills.

Table 5 Future Quantities of Ethanol for Blending

Year	Kenana	Sinnar	Assalaya	Total (liters)
2009	33,280,000	9,308,000	9,360,000	51,948,000
2010	32,344,000	9,464,000	9,724,000	51,532,000
2011	32,864,000	12,740,000	9,932,000	55,536,000
2012	33,280,000	12,584,000	9,672,000	55,536,000

If petroleum fuel consumption exceeds the estimated growth rate, the actual blend rate could be varied to suit the available quantities of anhydrous ethanol produced. Even in the case of petroleum consumption increasing to 50% more than official estimates, there would still be sufficient fuel ethanol available from the proposed Kenana plant to allow for a 10% blend rate.

G. Product Range and Demand:

The oil crisis coupled with the fact that likely contenders to replace present internal combustion engines will operate efficiently on ethanol or possibly hydrogen derived from ethanol, confirms that there is definitely a future role of ethanol. There is considerable evidence from large scale commercial operation experience in Brazil and USA [7], to confirm that ethanol blend of up to 20% can be used without problem in normal spark ignition engines.

Up to 15%, ethanol diesel oil blends appears to give no problem in compression ignition engines provided a blend establishing agent is added. Many major oil companies are conducting ongoing researches in order to optimize blend fermentation.

Some companies already offer so called dual fuels which are ethanol blends where ethanol replaces lead based octane boosters. These lead free blends can be used in normal engines as well as modern lead free fuel engines. There are significant commercial and logistical advantage attached to these dual fuels, in that no special transport, storage or dispensing facilities are required.

An added bonus comes in the form of lower exhaust emissions from engines running on ethanol blends fuel. The use of 10% ethanol blend can reduce carbon monoxide emission by up to 75%, mainly due to the leaning out effect. Hydrocarbon are also reduced but to a slightly lesser extent as are oxides of nitrogen. The undisputed advantage of ethanol for its antiknock value alone would already appear to justify the use of blends of 10% ethanol produced from environmentally friendly renewable resources such as molasses.

Ethanol has many other uses and possible markets, industrial users, pharmaceuticals, chemicals, household heating and cooking fuels and many more.

H. Fuel Blending and Octane Enhancement

For blends up to 20%, the vapour pressure of ethanol blends increases up to 40%. This is taken by some critics as an indication that vapour lock will occur but in practice even under the hot tropical conditions prevailing in Brazil, this does not happen.

Ethanol is high in octane and oxygen content. Adding 10% ethanol to 90 octane gasoline will increase the octane value of gasoline/ethanol blend 2.5 – 3 points above the octane of the basic gasoline. For example if you add 10% ethanol to an 87 octane gasoline, you will get a 10% ethanol / 90% gasoline with octane of 89.5 – 90.

Ethanol at the same time, adds valuable oxygen to the fuel. A 10% ethanol blends creates a fuel with 3.5% oxygen. This oxygen helps the gasoline to burn more completely and more efficiently, reducing the amount of pollentron omitted from the vehicle. This factor is becoming increasingly important even in less developed countries with relatively low number of cars per square kilometer. The importance of reducing global pollution level is being accepted by virtually all nations throughout the world and there is a growing demand for more environmentally friendly fuels and also for fuels produced from renewable resources. Ethanol, scores highly on both these points [8].

I. Expected Sales estimation

Quantity of ethanol which will be produced for sales have been based on sales of anhydrous ethanol and can be estimated as follows:

Total molasses to be supplied to the plant from Kenana Sugar Company and neighboring factories yield to 200,000 ton/year

Production capacity of the plant: 200,000 lit/day

Plant working days : 330 day

Total ethanol produced = 200,000 × 330 = 66,000,000

Average ethanol price = $0.5/litre.

Total expected sales = 66,000,000 ×0.5 = $33,000,000

3. Technical Study

A. Site Selection and Location

The sugar industry in Sudan is a long standing and variable industry and has reached national production levels which exceeds 650,000 tons annually, with rehabilitation programs and the stable conditions that currently per gist, the industry can easily exceeds levels of production. Therefore, it is safe to assume that a corresponding increase in molasses production will occur which will be available as a feed stock for an ethanol fermentation plant and distillery for fuel grade ethanol production.

Factors affecting ethanol plant location at Kenana Sugar Company considering molasses as a feed stock were as follows:

1- Increasing cost of storage, handling and transport involved to overseas market.
2- Molasses is a relatively low value and bulk product.
3- Almost all other factories are sited away from Port Sudan which also increase the cost of transport far over to be transport to KSC.
4- Animal feed industry, uses a very small proportion of the potential output of molasses from the Sudanese sugar milling industry.

Another important factor, which must be considered when working with molasses, is the question of environmental contamination. This applies not only to the disposal of distillery effluent when producing ethanol but equally to the disposal of raw molasses.

Once it becomes uneconomic to sell molasses to the overseas markets, for whatever reason, producers are faced with a dilemma in what to do with the rapidly increasing quantities of molasses inevitably produced by sugar mills. Many avenues have been followed all over the world in sugar producing countries to device way and means of getting rid of this by-product. Molasses have been dumped in rivers and irrigation canals, pumped out to sea where possible, sprayed on roads or pumped into abandoned mines. All these methods rapidly lead to environmental contamination and damage and are unsustainable.

The disposal of distillery effluent or vinasse, is especially problematical due to the fact that this product has an extremely offensive odor and very high loads of organic contaminations which are extremely difficult to dispose of. Many methods have been devised to reduce or eliminate the environmentally harmful effects of this ethanol by product, which is produced of between 10 to 20 times the volume of the amount of ethanol produced. From the above, it becomes clear that several factors must be evaluated when selecting a viable and sustainable method of disposing of surplus molasses. Once the export of molasses becomes marginally or actually unprofitable, various other options must be received, often this becomes an exercise to select the least costly and least environmentally damaging method of disposal of a product which is often viewed as a waste product which will have a cost attached to its disposal, which is then treated as a production cost to the sugar mill. However, the very factors which made the export option unprofitable, can actually contribute to enhancing the viability of an ethanol for fuel production plant. Very often, the same long distance mill to port transport cost are incurred in the delivery of petroleum based fuels to the mills and estates of powering of vehicles, tractors and machinery used in growing, harvesting and transport of sugar cane and sugar from the mill. This obviously increases the delivered cost of these fuels, which makes alternative fuel substitutes more cost effective.

Kenana Sugar Factory

The Kenana factory was designed for a production capacity of 300,000 tons of sugar per year. The initial production achieved in 1980/81 was only 110,000 tons and only in 1984/85 was 300,000 tons of sugar made from 2,743,000 tons of cane. Since that time the factory has been expanded until in 1999 it produced 365,000 ton of sugar. Kenana has implemented a further development plan, which brought the factory production to 400,000 tons of sugar and above. It is clear that Kenana has operated previously at capacities in excess of 24,000 tons of cane per day and there should not be capacity problems in the major equipment stations, which might prevent this target being maintained. Based on the past performance and further predications for the production output from Kenana sugar factory, a fermentation plant and distillery with a nominal output of 200,000 liters per day could be sustained by this factory alone. This is based on the assumption that about 160,000 tons of final molasses would be produced from 400,000 tons of cane over an average 190 days milling period. Excluding an estimated 30,000 tons of molasses to be used for the production of yeast or used by the company's animal feed manufacturing plant and based on an estimated average yield of 260 liter of ethanol produced per ton of normal molasses, 100,000 liters per day of ethanol could be consistently produced from Kenana own molasses in a fermentation plant which could operate for 330 days per year. This study however, proposes that a 200,000 liter per day ethanol fermentation plant be installed in Kenana. This capacity has been based on the planned production outputs of surplus molasses from Kenana and nearby Assalaya, Sinnar and White Nile Sugar mills, that would ensure sufficient feed stock to be available to produce some 60 million liters of anhydrous ethanol per year. The processing of all the molasses in one large plant would allow for considerable savings in capital expenditure and running costs. Kenana being the largest sugar estate would also be in a better position to effectively utilize a large quantities of distillery effluent emanating from such a large distillery. The estimated costs of producing fuel grade ethanol from the molasses feed stock indicates that the ethanol produced, can be cost effective when sold as a blending component alone, based on sales at 10% below the current in bond landed cost (IBLC) or import parity price of locally produced petroleum fuels. The base price for petroleum based fuel used in this study was an estimated (IBLC) of $0.30 per liter for 90 octane petroleum fuels at Port Sudan. The existing sugar producing factories Kenana, Assalaya, Sinnar and New White Nile have been carefully evaluated as their capability of achieving their planned expansion of sugar and molasses production levels and also Kenana capability of supply the steam, electricity and water that the proposed distillery would require.

B. General Services and Water Supplies

Water

Water must be of potable quality, and if it is taken from open canals as in Kenana, it should be filtered and chlorinated to ensure that it does not contain coliform bacteria with total bacterial count being limited to less than 60/ml. The chloride content should be less than 25ppm (Parts per million), so Kenana ethanol plant provided with water filtration and chemical treatment plant to ensure that the above standards are maintained.

Cooling water should be available at maximum temperature of 28 – 29^{o} C at 2.0Kg/cm^{2} with total hardness of 5ppm (Parts per million) or less and total dissolved solids not exceeding 30ppm (Parts per million).

The necessary civil works and main pumping facilities required to extract the required quantity of process, cooling and emergency firefighting water have been allowed in the main plant budgets. In view of the relatively high ambient temperatures which prevail at Kenana site, the installation of adequate sized cooling towers and recirculation pumps to achieve the required temperature is essential.

Water Consumption & Disposal

Relatively large quantities of water are required for various purposes when operating an ethanol plant and distillery. Nearly 4,000 cubic meters of water would be required to operate the proposed 240,000 liter/day ethanol plant. At this rate of consumption, some 1.5 million cubic meters of water would be used once the plant was running at full capacity. The proposals which were put forward for the decontamination of the distillery influent, would allow bio-digester effluent water to be used in irrigating the sugar cane, with an addition benefit of valuable nutrients being applied which would be used for the growing crops.

C. Compressed Air for Yeast Propagation and Plant Control:

The integrated yeast propagation system, will be provided with its own dedicated air compressor system to supply the necessary filtered sterile air required for spraying into the yeast growing medium. An automatic package compressor system, with stand by unit to be included to supply the compressed air requirements of the plant process control and cleaning systems.

D. Carbon Dioxide (CO_2) Scrubbing and Recovery

The requisite blowers and scrubbers for the efficient removal of carbon dioxide (CO_2) from the fermentation vast and the removal of residual ethanol vapour from this product stream are included in the plant budget.

E. Steam and Electric Supply

Existing Kenana steam generation capacity could be drawn more cost effectively from the main boiler complex and also power station complex appears to have sufficient capacity to provide requirements for the plant throughout the year.

F. Road and Rail Access and Stock Control:

The existing roads have been incorporated in the proposed new layout and dedicated railway spur has been allowed for from the existing railway line serving the sugar stores. A combined rail/road weighbridge has been proposed at the ethanol bulk loading site which will measure and record the quantities dispatched. Molasses intake from existing Kenana bulk storage tank will be recorded via online volumetric measuring system, as will molasses transferred by pump and pipeline from existing Kenana Sugar molasses storage tanks to the fermentation plant day tank. As for the ethanol, these figures will be automatically recorded in the plants computerized operating and stock control system.

G. Laboratory and Quality Assurance Equipment

Fermentation and distillation plant requires a fully equipped laboratory in order to maintain quality control on inputs and the final products as well as effluents and waste products discharged into water way or croplands. The necessary equipment and microbiological testing facilities to effectively analyze the following:

- i- Measuring molasses
- ii- Potable water supply
- iii- Yeast contaminants
- iv- Check on pasteurization of fermenter tanks and piling.

Quality control in terms of the finished product, which will be anhydrous or fuel grade ethanol will consist of regular checks on the purity of the finished product to ensure that a minimum 99% purity is maintained. To facilitate this, at least three holding tanks will be installed, each large enough to hold one day production output. The ethanol held in these tanks will not be released or transferred to the main bulk storage tanks, until a laboratory quality assurance certificate has been issued confirming that all the product quality specifications have been met. Sample of ethanol transferred road or rail tankers will also have to be taken and submitted to the laboratory for final confirmation of specification before dispatch. In order to maintain these standards, regular and ongoing training and motivation of staff and supervisors must be carried out and laboratory sampling, equipment and analytical procedures must be checked regularly. The maintenance and strict controls on the discharge of the distillery effluent must receive as much attentions as the final product. Vinasse or distillery effluent is one of the most environmentally damaging contaminants from any production process and its uncontrolled discharge into water courses or onto croplands can rapidly destroy the natural fauna and flora and lead to permanent poisoning of the environment. BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) levels in the final effluent discharge water must be contently monitored to ensure that they don't exceed the national levels for safe discharge into canal or water courses.

H. Fire Control and Safety Consideration

Ethanol normally falls under the national customs & excise regulation and these regulations must be complied within term of storage, record keeping, sales and dispatch and payment of duties wherever applicable. Likewise national regulations regarding safety precautions and in particular fire control and firefighting facilities must be strictly complied with. While it is in common knowledge that the production of ethanol fuels escorted by a fire hazard, it has been shown through fire tests and actual fire losses that ethanol/water solutions have fire protection needs different from most flammable liquids. Ethanol unlike most petroleum, based products, is completely miscible or soluble in water so plain water is the most effective extinguishing agent for ethanol. The vapour density of ethanol is 1.6 times that of air. Ethanol vapors are invisible, and the distance they will travel is not always predictable. Testing carried out by the distilled spirits council of USA indicates that beyond 0.5 meters from the source, vapors are generally less than 25% of the allowable ethanol level and beyond 1.65 meters they are usually negligible. Liquids that contain less than 20% by volume of ethanol are not considered to be flammable liquids. The alcohol content in the fuel ethanol distilleries is usually higher than 96% (neutral spirits) as the final dried or anhydrous products in excess of 99% purity. Explosion venting is essential in any area or room where the distillation of ethanol takes place. Any vapors escaping from a distillation column may become explosive when mixed with air. however, extensive testing has shown that the vapour dissipates to safe concentration within 1 meter of the point of release. The distillation columns re-boilers, heat exchangers and condensers required for Kenana plant are all constructed within an open sided steel structure, which minimizes the risk of any dead areas where ethanol vapour could be trapped. The provision of adequate natural or mechanical ventilation and training of personnel in safe operating procedures and rapid response to fires is a pre-requisite to any distillery operation and all relevant local and international codes of practice to be followed in the design, erection and operation of the plant and equipment.

Storage

Unless the building is equipped with sprinkler protection conforming to national fire code regulations. Tanks storage of ethanol must be restricted to a maximum capacity of 5,000 liters.

Piping and Pumping Systems

The design, fabrication, assembly and inspection of piping and pumping system will be planned and carried out in accordance with recognized good engineering standards and accepted industry practices or in compliance with relevant national codes and regulations. Pumps and piping systems will be adequately sized to supply large quantities of water in the event of an emergency fire situations.

Spill Control

Provisions will be made to prevent accidental spill from endangering other facilities or adjoining property. An emergency drainage system will direct any spill together with water used for firefighting to a safe location. Bunds, curbs, scuppers, special drains or other suitable means to be installed to prevent the flow of spills throughout the building.

Fire Protection

Portable fire extinguishers and/or fire base stations will be provided in conformance with the following requirements.

- In working area and warehouses, at least one fire extinguisher will be provided at each building exit.
- At least one or more fire extinguisher on each industrial forklift, locomotive or transport vehicle.

- The fact that ethanol mixes freely with water, makes prevention and control of fires relatively easy as long as sufficient quantities of water are on hand.

An adequate fire control plan and training of all personnel in fire and safety awareness, will ensure that the distillery will provide a healthy and safe operating environment for all those concerned in the production and handling of the proposed fuel ethanol facility.

I. Housing

KSC, have a well-established housing and social amenities infrastructure which caters for their large work force employed on the sugar estate and in the factory and ancillary services, these existing facilities will be able to provide services and areas for housing when employees are required for the plant.

J. Manpower Establishment

In setting out the manpower requirements for ethanol fuel plant and its ancillary operations, full details of each job description and the range of qualification and experience are required for all posts. On the other hand when calculating the overall manpower required for the ethanol plant, that the ancillary services and structures will not need to be duplicated. These services such as clinics, main mechanical and electrical workshop, major construction and building services, power generation etc. are all fully catered for within the existing sugar milling operation.

In Kenana a highly skilled manpower both local and expatriates are available to give full support to the ethanol plant during the commissioning and operation stage. Kenana today has a management contract for erection and commissioning of the White Nile Project which almost of equal size to that of Kenana. Adding to the above, Kenana through its intermediary KETs (Kenana Engineering & Tech. Service) has undertaken several jobs in Nigeria. The most recent being the successful rehabilitation and commissioning of the Savannah plant. Kenana over the years has undertaken highly specialized erection and installation jobs for factory up-rating, the most one being the complete erection and commissioning of animal feed plant.

K. specifications

Water

(a) Potable water

For fermentation: 2000 – 2500m^3/day

Depending upon F.S (Fermented Sugar) content in molasses.

(b) Cooling water circulation

Rate at : 30^{o}C max and 2.5 kg/cm^2

For fermentation : 800 – 1000 m^3/hr

For distillation : 650 – 750 m^3/hr

For dehydration : 330 – 350 m^3/hr

(c) Cooling water makeup.

For fermentation : 400 – 500 m^3/day

For distillation: 1000-1200 m^3/day

For dehydration : 300-350 m^3/day

All above quantities are indicative and will depend on site conditions such as humidity and wind speed.

Electric Supply

Volt : 440 V

Phase : 3 phase

Wire : 4 wire

Hertz : 50 Hertz

For fermentation installed: 500 Kw

For fermentation operating: 400 Kw

For distillation installed: 300 Kw

For distillation operating: 200 Kw

Steam Requirements

The required steam is to be dry saturated and de-superheated.

For stripping column : 3.0 Kg/cm^2 (gauge)
For other columns : 1.5 Kg/cm^2 (gauge)
For dehydration absorber
Columns : 5.0 Kg/cm^2 (gauge)
For distillation steam usage : Minimal for pasteurization only
For distillation steam usage
At 2.55 Kg/litre : 25600 Kg/hr
Total estimated hourly
System usage : 26.5 Ton/hr
Total boiler capacity required : 30.0 Ton/hr

These steam consumption figures are based on the presumption that only anhydrous fuel grade ethanol will be produced and the final drying will be carried using molecular sieve (absorption) dehydration.

Compressed Air Requirements

Compressed air necessary for control instrumentation and pre-fermentation operation must be dry and free from impurities.

- For instrumentation : at 7 Kg/cm^2, abs.
- For pre-fermentation : at 0.6 Kg/cm^2 (gauge)
  0.02 NM^3/Litre ethanol

Total estimated hourly usage : 250.0 NM^3/hr
Total installed compressor
Capacity : 5.0 NM^3/min

Chemicals & Nutrients Requirements

Listed below are average specifications and consumption for chemicals and nutrients necessary for an efficient fermentation process.

- Ammonia sulphates : 1.5 Gr/Lit – 350 – 400 Kg/day
- Sulphuric Acid : 7.91 Gr/Lit – 1800 – 2000 Kg/day
- Magnesium sulphates : 0.50 Gr/Lit – 120 – 150 Kg/day
- Di-ammonium phosphate: 1.68 Gr/Lit – 400 – 450 Kg/day
- Zinc sulphates : 0.70 Gr/Lit – 175 – 200 Kg/day

The actual consumption of the various nutrients will vary from day to day, depending on the actual composition of the feed stock (molasses) and fermentation parameters. The actual chemical and nutrient requirements will be determined on an operational basis as molasses from different sources or even different lands at Kenana will have slightly characteristics and requirements. The makeup of chemical and nutrient mixture will be monitored and adjusted almost by laboratory and fermentation personnel.

L. Materials Compatibility Information

Most materials used in retail gasoline dispensing system are totally compatible with gasoline/ethanol blends. Equipment used to dispense denatured ethanol (e.g. terminal meters) should be designed to withstand the solvent action of ethanol. The following discusses each major equipment category.

Tanks

The mild steel used in finished product terminal tank is compatible with both ethanol and gasoline/ethanol blends. Both steel tanks and fiber glass tanks designed/or gasoline storage are compatible with gasoline/ethanol blends containing up to 10% volume ethanol. Higher blend concentrations (above 10% volume of ethanol) may require a tank constructed of special chemical resin. Tanks for storing denatured fuel grade ethanol should have a fixed roof with an internal floater. They should be equipped with 16 ounce pressure/one ounce vacuum vent (16/1 P/V). which confirms that the storage tank can tolerate this pressure before the rent is installed.

Pumps and Piping

For denatured ethanol, the preferred materials for seals are carbon and ceramic. Teflon impregnated packing materials are recommended for packing construction. For pipes carrying neat ethanol, Teflon tape is best sealant. For retail facilities dispensing gasoline/ethanol blends, alcohol based pipe sealant should be avoided. Suitable sealant include.

- Scotch brand pipe sealant with Teflon No 4178
- Loctite pipe sealant with Teflon No 592
- Permatex scales pipes No 804

Meters

Meters for neat ethanol should have internal O-rings and seals designed to withstand ethanol's solvent action. Gasoline meters have been used for gasoline/ethanol blends with no accelerated wear or leakage problems. When first converting to an ethanol program it is advisable to recalibrate meters after 10-14 days to ensure that the change of product has not caused any meters to over dispense.

Filters, Hoses and Nozzles

Filters and screen used at both the terminal and retail facility are compatible with gasoline/ethanol blends. A 10 micron filter is recommended for the retail dispenser. A #40 mesh screen in the transfer line is recommended for terminal operation. Filter life will be similar to that when using gasoline.

Manufacturers of hoses for retail dispensers have indicated that these hoses are suitable for gasoline/ethanol blends containing up 10% volume ethanol. These blends have been dispensed through numerous brands of hoses over the past twenty five years.

Gasoline/ethanol blend have been dispensed through all major brands of nozzles for many years without problem as with hose manufacturers, the nozzle manufacturers have indicated that their products are suitable for use with gasoline/ethanol blends containing up to 10% volumes of ethanol.

4. Economic Study

A. Cost/economics

It is difficult to provide general information about ethanol fuel economics because production cost and product value depend on the followings:

1- Plant location
2- Feed stock
3- Production scale
4- End use

Ethanol production includes both capital and operating costs. Two important factors in capital costs for small batch plants are starch hydrolysis systems and boiler capacity. In large plants, the followings units are more relatively significant such as:

1- Engineering
2- Distillation system
3- Process control

Generally, capital costs for alcohol plants range from $0.5 to $1.0 per litre of annual production capacity. The greatest operating cost in ethanol production, regardless of scale is a feed stock. For ethanol fuel production to be profitable, an economical supply of feed stock is essential and that what was happen in Kenana, as ethanol plant is located near the sugar factory feed stock (molasses). There is another indirect costs that are important in evaluating ethanol production cost which are:

1- Marketing
2- Plant utilities
3- Transportation of feed stock
4- Products

Ethanol market value depends on end use. The market value of ethanol as a replacement fuel would be measured relative to gasoline prices. The market value of ethanol when blended with gasoline may be higher than gasoline because of the increased octane value of ethanol/gasoline blends. To be competitive with gasoline, ethanol must have a total production cost per litre that is competitive with in band landed cost (IBLC) of petroleum fuels which would be equivalent of about $0.30 per litre on an average global spot price of $26.00 per barrel.

By-product market value is measured against the local price of animal feed. The value is typically determined by comparing the protein content of feed. Other factors, aside from ethanol production costs and the market value of ethanol may also be significant to the economic analysis. Displacement of imported petroleum with domestically produced renewable fuel may improve balance of payment deficits and may be economically advantageous despite relatively higher ethanol costs. Probable opportunities for such plants are:

1- Rural employment
2- Alternative markets
3- Energy independence

These opportunities may provide significant economic advantages in addition to direct accounting of plant profitability.

B. Economic Overview

Foreign exchange is administered by the bank of Sudan with assistance of the authorized banks and specialized banks acting as exchange houses. All exporters and importers are required to register with the Ministry of trade. The main import commodities include automotive component, building materials, agricultural fertilizers, food ingredients, medicines and various petroleum products.

C. Cost Advantages of Establishing Ethanol Fuel Plant in Kenana

The cost advantages are very visible and the plant could set-up with the most minimum expenditure when compared to the cost of setting-up a complete plant with all the attendant facilities. This will enable the plant to maximize its profits and achieve early pay-back and break-even points as the cost per unit will be substantial less when compared to the cost of a new plant which will also require all attending utilities and facilities. This would also mean a shortest gestation period enabling the plant to come on stream within the shortest possible time. However, the saving that could result on establishing ethanol fuel plant in Kenana can be summarized in the following points:

1- Saving in cost of steam boiler
2- Saving in cost of power generation
3- Saving in erection cost (existed supporting equipment, workshops and manpower)
4- Saving in cost of water supply.
5- Saving in cost of storage molasses tanks.

D. Processing Costs per Gallon of Ethanol

Processing molasses, raw and refined sugar into ethanol requires a simple process. Unlike the conversion of corn into ethanol which requires cooking and adding enzymes to convert starch to glucose, the processing of molasses, raw and refined sugar only requires yeast to ferment sugar to alcohol and removing water. The energy requirement for this process is much less; about half of the energy used in the production of ethanol from corn [9].

Table 6 below presents estimates of USA ethanol production costs using molasses, raw and refined sugar as a feed stock.

Table 6 USA Ethanol Production Costs

	Feed stock		
	Molasses	Raw sugar	Refined sugar
Feed stock required (ton/gallon)	0.0144	0.0074	0.0071
Feed stock price ($/ton)	63.00	422.00	5.09.00
Feed stock cost ($/gallon)	0.91	3.12	3.61
Ethanol operating cost ($/gallon)	0.36	0.36	0.36
Total cost	1.27	3.48	3.97

Total ethanol production costs were estimated to be $1.27 per gallon using molasses compared with $3.48 per gallon using raw sugar and $3.97 per gallon using refined beet sugar. Estimated costs for these three feed stocks exclude any transportation costs of moving the feed stocks from a supply location to an ethanol facility. Production of ethanol from molasses would appear to be relatively cost competitive in comparison with corn based ethanol in USA as shown in Table 7 below. Ethanol can be produced from either sugar cane molasses or sugar beet molasses. Other studies have shown that molasses based ethanol production is economically feasible in the USA.

Table 7 Molasses Cost Competitive with Corn

Cost Item	Corn Wet milling	Corn dry milling	Sugar cane	Sugar beet	Molasses	Raw Sugar	Refined sugar
Feed stock costs	0.40	0.53	1.48	1.58	0.91	3.12	3.61
Processing Costs	0.63	0.52	0.92	0.77	0.36	0.36	0.36
Total cost	1.03	1.05	2.4	2.35	1.27	3.48	3.97

E. Capital Expenditure Costs

Although capital expenditure costs for any type of processing facility are dependent upon the circumstances involved with constructing a particular facility in a given location. Capital expenditure data from existing ethanol facilities may provide a reasonable range of what the expected capital costs would be for new USA facilities utilizing sugar crops as a feed stock.

Economics of scale have been shown to exist in construction costs of ethanol plants in USA. However, average capital costs of plants of a given size at a particular location is still highly variable due to costs associated with unique circumstances such as utility access and environmental compliance. Capital costs across plants surveyed were varied significantly from $1.05 to $3.00 per gallon of ethanol. Data from Louisiana suggests that a 32 million gallon per year ethanol plant, utilizing molasses as a feed stock could be built for $41 million or $ 1.28 per gallon of annual capacity. Recent data from Brazil indicates that 45 million gallon per year could be built for $60 million or $1.32 per gallon of capacity.

F. Equipment Required

Before going into financial projection, the equipment necessary for both fermentation and distillation are set out in the Tables 8 and 9 below.

Table 8 Fermentation equipment

No	Description	quantity
1	Fermentation vats	4
2	No (17 & No (2) yeast propag. Vats	2
3	Fermentation tanks	3
4	Molasses pumps	4
5	Fermenter transfer pump	4
6	Circulating pump	4
7	Carbon dioxide blower	4
8	Pipe work (carbon steel, stainless steel and valves)	As required

Table 9 Distillation equipment

No	Description	Quantity
1	Mash distilling, rectifying columns	2
2	Absorption column	2
3	Pre-heater, mash and final condenser	3
4	Re-boiler mash column	1
5	Mash/stillage heat exchanger	1
6	Product cooler	1
7	Stillage, mash feed and product transfer pumps	3
8	Distiller and rectifier reflux pump	2
9	Dehydration feed, condensate and ethanol transfer pump	3
10	Pipe work (carbon steel, stainless steel and valves	As required

G. Financial Projections

Basic Assumptions and Parameters

1- Initial capital expenditure for the Kenana ethanol plant is estimated at $26,201,660 for the plant and equipment required to build a fermentation distillery with an output to 240,000 litre of anhydrous ethanol per day is shown in Table 10 below. Pre-commission interest and establishment costs have been capitalized to $5,000,000 and added to these figures to give an overall project cost of $31,201,660.

Table 10 Capital expenditure

Description	Year 1 and 2 disbursements
1- Land & infrastructure development	1,970,187
2- Building & civil works	1,301,164
3- Feed stock intake, storage and handing	0,100,558
4- Fermentation section – supply	4,082,902
5- Distillation section – supply	2,790,593
6- Plant utilities & Ancillary services	3,793,065
7- Laboratory W/shops, offices, etc.	0,638,818
8- Ethanol storage & dispatch	0.823,742
9- Effluent disposal system	5,236,385
10- Erection & commissioning cost	2,075,448
11- Shipping & transport	0,472,324
12- Project management & tech fees	2,916,472
Total	**$ 26,201,660**

2- The first year of operation has assumed an annual ethanol production and sales of just under 56 million litters (200,000 liters per day) from Kenana, Sinnar and Assalaya mills surplus molasses, with output increasing over years two and the three, in line with the estimated intake of surplus molasses that will be produced from the White Nile sugar mill which will push the output up to 200,000 liter per day.
3- It was not allowed for the intake of any molasses from the Guneid or New Halfa mills, but this option could be considered in the first two or three years of operation in order to make up the short fall in production until the White Nile mill achieves its projected output.
4- The ethanol price has been based on the price on Sudan of 90 octane benzene in band landed cost (IBLC).
5- Excise rebates will not be applicable and thus have not been taken into account.
6- Ethanol distribution cost have assumed bulk supply to Khartoum refinery by road/ rail transport at 50/50 ratios in 32 to 38 ton capacity tankers.
7- The study has been based on use of maximum available quantities of surplus 'C' molasses as feed stock to the ethanol plant at a price of $19.45. 'C' molasses to be drawn from Kenana, Assalaya and Sinnar up to a maximum of ± 200,000 tons per annum at full planned capacity of 60Ml/year.

Operating Costs

When ethanol is produced in conjunction with sugar factory operations, there are four main items of operating costs attributable to the fermentation and distillery operations. These are:

1- Labor cost.
2- Chemicals cost.
3- Maintenance and repair cost.
4- Cost of operating an environmentally acceptable system for the disposal of the large quantities of toxic effluents produced by the fermentation process.
5- The labor force required for the continuous operation of the plant, has been estimated at a total of 149 full time staff and workers with total annual estimated cost of $837,095.00 including overheads, medical and social services costs.

The personnel requirements and cost are set out in Table 11 below.

Table 11 Personnel requirements cost

Job title	Quantity	Salary/month In dollar	Annual (x13)	Total
1/ Senior management				
General manager	1	500.00	6,500	6,500.00
Production manager	1	425.00	5,525	5,525.00
2/ Middle management				
Section manager	5	350.00	4,550.00	22,750.00
Tech. manager	5	250.00	3,250.00	16,525.00

3/ Supervision				
Section supervision	10	220.00	2,860.00	28,860.00
Assist supervisor	10	200.00	2,600.00	26,000.00
4/ Semi skilled				
Senor tech./clerk	4	180.00	2,340.00	9,360.00
Mid-level tech./clerk	54	175.00	2,275.00	122,850.00
Plant operator	2	170.00	2,210.00	4,420.00
5/ unskilled				
General labor	57	150.00	1,950.00	11,150.00
Total	149	Total		253,665.00
		Overheads, medical and social services costs		583,430.00
		Total annual operating Cost		$837,095.00

- Chemicals used in the ethanol production process, represents an insignificant cost on a per liter basis and was found to be $3.6/kiloliter ethanol.
- Repairs and replacement requires are also low, applying mainly to pumps, valves and gauges.

Fermentation & Distillery Operating Inputs and Costs:

The necessary operation inputs are:

1- Feed stock (molasses)
2- Water supply (potable, cooling & make up)
3- Steam consumption
4- Electric consumption
5- Chemicals
6- Yeast

Table 12 below Illustrates the daily input quantities required and relative costs per kiloliter of ethanol

Table 12 Daily Input Quantities Required and Relative Costs per kiloliter of Ethanol

No	Description	Daily	Unit cost $	Cost/kiloliter of ethanol
1	Molasses	714.3 tons	$19.62/ton	$75.32
2	Water usage & consumption			
	A- Potable water for molasses dilation	2,543 m^3	0.08	$ 1.93
	B- Fermentation cooling water	18,000 m^3	-	-
	C- Distillation cooling water	20,400 m^3	-	-
	D- Make up water for cooling tower losses	1,200 m^3	0.04	$0.42
3	Steam consumption			
	a- Steam cons. Per kiloliter of ethanol	960,000 kg/hr	0.0007	$6.69
	b- Steam required or sterilization & pasteurization	48,000 kg/hr	0.0007	$0.33
4	Electrical consumption Estimated elect. Cons. For both fermentation & distillation per kiloliter of ethanol made	137 kwh	0.04	$ 5.21
5	Cost of operating effluent digester including CO2 produced and methane produced from vinasse			$3.41
6	Biogas valve as fuel oil replacement boiler fuel	102,778,971 M joule/m^3		$4.27
7	Plant maintenance & repair at 0.4% of capital expenditure			$1.31
8	Chemical & nutrients This include:			
	a- Sulphuric acid	390 kg	0.13	$2.11
	b- Di-ammonium phosphate	54kg	0.21	$0.47

	c- Ammonium sulphates d- Micro nutrients e- Antifoaming agent f- Formaldehyde 40%	81kg 1kg 55 kg 4 kg	0.22 0.05 0.08 0.37	\$0.74 \$0.05 \$0.077 \$0.06
9	Yeast	As required from in house propagation		0
	Total cost/kiloliters ethanol			\$3.60

From the table, total cost/kiloliters ethanol = 27.17 without molasses cost

For 200,000 litre production capacity per day

Total input cost/day = $\frac{\$27.17}{1000\ \text{litre}}$ x 200,000 = \$ 5,434/day

Annual inputs cost = \$ 20498 x 330/day = \$1,793,200

Annual Operating Costs Summary:

- Annual estimated manpower cost = \$0,837,095.00
- Annual estimated inputs cost = \$1,793,200.00
- Assuming annual assets cost = \$0,200,000.00

Total annual operating cost = \$2,830,295.00

Taxation, Excise and Levies

It has been assumed that the company would qualify for a 10-year tax exemption. Excise duties would not apply to Kenana Ethanol Companies because the fuel grade ethanol would be supplied in bond directly to the refinery or petrol distributors, who would then become responsible for the payment of the relevant excise duties in the normal course of their business. No special levies are currently payable on the production of ethanol in Sudan.

H. Financial Evaluation

Project Viability

When considering the Sudanese economy as a whole, it would appear to be a large potential synergy in the implementation of a national ethanol blending strategy. The production of fuel grade ethanol from renewable resources such as molasses is an established, well proven and cost effective technology. The increasing attention which is being focused on environmental conservation and a growing awareness by all oil producers and consumers, that fossil based leaded petroleum fuels are not only the environmentally damaging but that these resources will soon be depleted, increases the need to replace or supplement these dwindling resources with more environmentally friendly fuel made from renewable feed stock.

Annual Revenue:

The total ethanol fuel production is expected to yield 66,000,000 liters and the total expected sales yields to \$33,000,000. Therefore, the sales revenue can be calculated as follows:

Production cost of ethanol = \$0.3/litre

Total cost of ethanol produced = 66,000,000 × 0.3 = \$19,800,000

If sales expenses is taken as 5% without tax, then

Sales expenses without tax = \$1,690,000

Annual sales revenue without tax = 33,000,000 – 1,690,000 = \$31,131,000

Annual revenue = annual sales revenue – cost of ethanol produce

= \$31,131,000 – 19,800,000 = \$11,133,000

Cash Flow

Cash flow is essentially the movement of money into and out the company [10].

Based on revenues and expenses estimations, a ten year estimated cash flow is shown in Table 13 below.

Table 13 Cash flow (Before interest & taxation)

Capital expenditure	Prep. period	Operating production period					
	Year 1 & 2	Year3	Year4	Year 5	CONTINUED	CONTINUED	Year 10
Equip, civil, housing & Infrastructure	- 26,201,660						

Direct & indirect Prepared cost	- 03,369,082						
Finance raising fees, etc.	- 01,630,918						
Project cost	- 31,201,660						
Cash flow out	- 31,201,660	-2,830 295	-2,830 295	-2,830 295	-2,830 295	-2,830 295	-2,830 295
Cash flow in		11,133,000	11,133,000	11,133,000	11,133,000	11,133,000	11,133,000
Net cash flow		8,500,700	8,500,700	8,500,700	8,500,700	8,500,700	8,500,700

Estimated net cash flow can be derived using the following formula:

Net annual cash flow = annual revenue (cash flow in) - Annual expenses (cash flow out) = $11,133,000 - $2,830,295.00 = 8,500,700.

It is assumed based on market price that input costs, production capacity and other relative factors stability, cash flow to be maintained constant.

Internal Rate of Return (IRR)

IRR is a discount rate that generates zero net present value for a series of future cash flows. It has been calculated from the net cash flow projections for Kenana ethanol plant before interest and taxation. It is determined by the following formula:

$$CF_o + \frac{CF_i}{(1+r)} + \frac{CF_2}{(1+r)^2} + \frac{CF_3}{(1-r)^3} + \text{------} + \frac{CF_n}{(1+r)^n}$$

Where: CF = cash flow generated in specific period, n = latest period, r = IRR

It is based on 10 years of operation, using the above formula and by trial and error, IRR at 10% average sales price = 22.55%.

This IRR shows a healthy positive return. This return is achieved after sugar factories have received payment of their surplus molasses at standard price of 19.46 per ton.

When payment of molasses is taken into account and bearing in mind that the rate of return should improve annually as more productive years are added to the pool of base figures, effectively diluting the negative return received during first 2 to 3 years of operation.

Payback Period

The payback period is a method which involves the determination of the length of time required to recover the initial investment based on project cash flow, using formula [11] :

$$\sum_{t=1}^{t=m} R_t \geq C_0$$

Where C_0 ≡ initial cost of investment, t ≡ period in (year) , m≡ payback period.

For m = 1 & 2 : nothing received (prep. Period)

For m = 3 : 8500,700 < 31,201,660

For m = 4 : 17001,400 < 31,201,660

For m = 5 : 25,503,100 < 31,201,660

For m = 6 : 34,003.800 > 31,201,660

Exact Payback period = investment required/ net annual cash flow =

$$31{,}201{,}660 \div 8{,}150{,}700 = 3.67\ years$$

I. Project implementation

Kenana ethanol plant implementation now is under construction by Kenana itself in contract with Tech. serve Company which undertake the design, procurement, expediting, logistic and delivery arrangement. The erection which is now running by Kenana is supposed to be completed by April 2009.

J. In commissioning & Plant handover

Commissioning will be carried out under the supervision of Tech. serve company and Kenana ethanol project managers and will also form part of the initial training program for all relevant operating and maintenance personnel.

5. **Conclusion**

Ethanol production, based on the projected surplus molasses output of Sudanese sugar estates, provide sufficient economic incentive for Kenana Sugar Company to install and operate fermentation distillery plant. Even when basing the sales price of anhydrous ethanol delivered to Khartoum at 10% less than the in bond landed cost of petrol, the cost of producing and delivering the ethanol provides a margin that will ensure a profit for Kenana Sugar Company Limited.

With the simple splash blending system required, the existing petrol distribution will have no large capital investment costs. The ethanol will simply be pumped at the required rate into their existing storage tanks along with unblended petrol. The restricted availability of ethanol will preclude excessive quantities of ethanol being mixed into the final blend.

This kind of investment, would make more profitable and productive use of the surplus molasses emanating from Sudanese sugar industry, the disposal of which could potentially become environmental problem as the existing sugar estates expand their production and possible near estates add to the overall production figures. The very long and consequently expensive transport chain required to move a relatively low value high bulk product such as molasses from the far flung sugar producing region to Port Sudan, makes the export of this molasses a loss containment exercise rather than adding any extra value to the sugar millers balance sheet.

The implementation of the proposed fuel blending program would allow Sudan to earn extra foreign exchange by releasing more locally refined petroleum fuel for export in the profitable world market. No extra capital investment, funding or subsidies are required on the part of government in order to accomplish this. The national economy, the people of Sudan and the sugar companies will all gain from the implementation of such a program.

Issues of environmental damage or pollution are becoming increasingly serious even in countries such as Sudan, where environmental pollution has not reached anywhere near the critical proportions it has in many developed countries. Despite resistance from some major powers, there is little doubt that international environmental protection protocols such as “Kyoto protocol” currently being promoted globally, will be accepted and implemented by most responsible nations. Countries, which have already instituted environmentally friendly programs such as ethanol blends/lead free fuels and are encouraging the development of renewable energy resources will have a clear moral and financial advantage over other noncompliant countries.

Ethanol as a component of petroleum fuel blends can never meet the demand (full blend program) and will increasingly fall behind percentage wise unless additional sugar or new technology or experimental technologies to convert cellulose wastes such as bagasse in order to satisfy 15% blend of the total motor fuel estimated to be consumed in the coming future.

Several countries have already implemented similar programs. Methods and results of these policies are available for other countries to follow or adapt to suit their own circumstances and requirements.

All the major motor vehicles manufacturers support the blending of ethanol into petroleum fuels at the currently accepted level of between 5% and 20% and maintain the full warranties applying to their engines when run on gasohol.

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