

# Sugarcane as Source of Bio Fuel

## What are Bio Fuels

**B**io fuels are the solid, liquid or gas fuel consisting or derived from biomass. Bio fuels can be produced from any carbon source that can be replenished rapidly. Many different plants and plant-derived materials are used for bio fuel manufacture. Bio fuels are used globally, and the industry is expanding in Europe, Asia, and Americas. The most common use of bio fuel is in automotive transport. (<http://www.odi.uk>)

Scientists categorise bio fuels into two groups, namely first generation and second generation bio fuels. The first generation fuels made from sugar, starch, vegetable oil or animal fat using conventional technologies. The most common first generation bio fuels are vegetable oils, Bio diesel, Butanol, Bio ethanol, Bio methanol, Bio gas, and solid bio fuels such as wood, woody fibre, charcoal and dried animal excreta. The second generation bio fuels are made mainly from cellulosic biomass and non-food crops. Bio hydrogen, Bio-DME (di-methyl ether), DMF (di-methyl formamide), HTU (Hitemperature upgrading) diesel, Mixed alcohols (mixture of ethanol, propanol, butanol, pentanol, hexanol, heptanol and octanol) are some examples. Use of bio fuels for energy generation can provide a number of benefits including reduction of greenhouse gas emissions, reduction of fossil fuel use, increased national energy security, increased rural development and sustainable fuel supply for the future.

Bio fuel industries are becoming established in many developing countries. Most of these countries have extensive, unexploited biomass resources that have great potential as sources for bio fuel production. ([http://www.ethanolindia.net/ethanol\\_govt.html](http://www.ethanolindia.net/ethanol_govt.html)).

The approaches for bio fuel production vary with the country or the region. For instance, India and China are developing both Bio diesel and Bio ethanol production. Indian sugar ethanol program sets target for 5% Bio ethanol incorporation into transport fuel and India is extending plantations of *Jatropha* for Bio diesel production from seeds. China is a major Bio ethanol producer and aims to incorporate 15% Bio ethanol into transport fuels by 2010. ([http://www.ethanolindia.net/ethanol\\_govt.html](http://www.ethanolindia.net/ethanol_govt.html)).

## Ethanol as a Bio Fuel

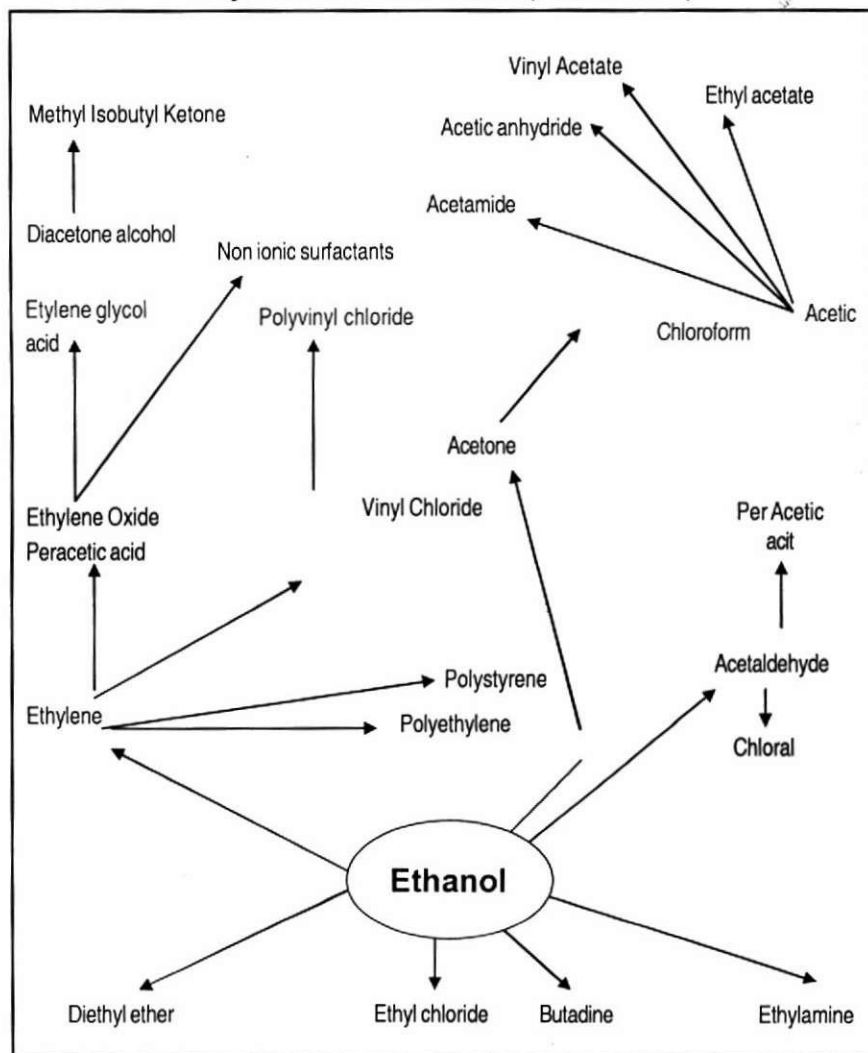
Ethyl alcohol is considered as an intoxicant and also a carcinogen. Generally, it is made by microbial fermentation of sugary materials, mainly by the yeast. Apart from used as a beverage alcohol and

an intoxicant, ethanol has many other uses. Pure alcohol is an ingredient in many different processes and products. Ethanol is a feed stock, and normally in its anhydrous state, it can be transformed by oxidation, dehydration or modification to produce a range of chemicals.

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**Figure 1**  
**Ethyl alcohol as a feed stock (Patarau 1979)**



**Table 1**  
**Raw materials for ethanol production**

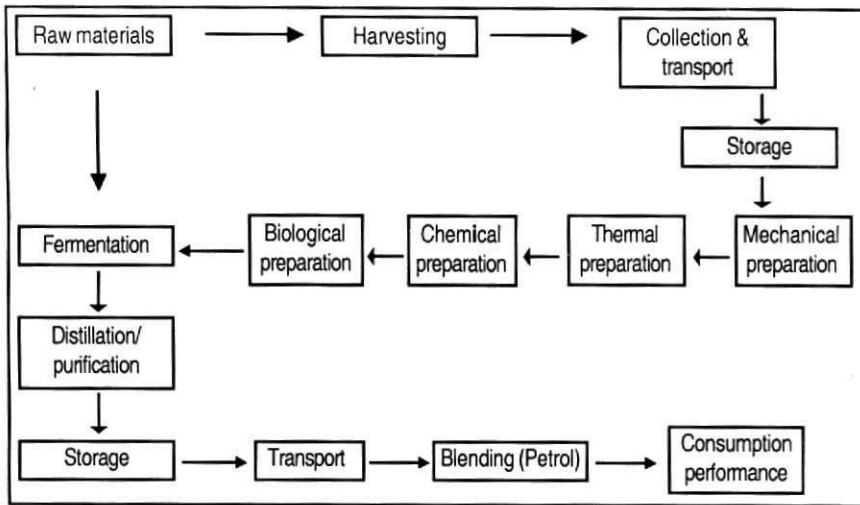
Raw material	Yd/mt/ha	Ethanol yield l/mt
Sugarcane	50-90	70-90
Sorghum	45-80	60-80
Paddy	2.5-5.0	450
Sugar Beet	1.5-5.0	90
Wheat	1.5-2.5	340
Barley	1.2-2.5	250
Maize	1.7-5.4	360
Cassava	20-65	170
Sweet potato	8-50	167

Source - Bernnet - 1981

Alcohol, with its convenient properties and universal availability, has been considered as a possible motor fuel (power alcohol) throughout the entire history of internal combustion engines. It is the most common bio fuel worldwide. This alcohol fuel is produced by fermentation of sugars derived from various carbohydrate sources including sugarcane (Table 1). However, ethanol is also produced by various chemical means such as ethylene conversion and wood distillation, etc. (Fig. 2)

The choice of raw materials for ethanol production is influenced many factors. If a crop is grown specifically for conversion to alcohol, then its yield is important. Table 1 shows approximate yields of

**Figure 2**  
Process steps of Fuel Alcohol Production



alcohol per hectare per annum for some feed stocks of alcohol production. Growing of a specific crop for power alcohol needs necessary resources and efficient organisational structure. In a power alcohol program, cost of crop cultivation and processing are important. Unlike sugarcane, for starchy crops like cassava (manioc), corn, wheat or rice and the starch must first be extracted and converted to sugar saccharification is required.

Ethanol has been used as a fuel for internal combustion engines since the beginning of this century. The changes in its use as a fuel have been determined mainly by competitive economics with hydrocarbon energy sources and to a lesser extent by availability of fossil fuel. The technology of alcohol production has been well developed. Production is done by batch fermentation, an atmospheric distillation and azeotropic distillation using benzene as entrainer or dehydration with molecular sieves or membranes. The ethanol produced by these methods is in high quality and suitable for mixing with gasoline. There are 3 different ways that ethanol can be used as a fuel in internal combustion engines; as a blend with gasoline, as an unblended ethanol and as an alcohol /water mixture. The ethanol concentration may be 5%, 10%, 20%, or 25% and the blends commonly known as "Gasohol" and the ratio of the mixture can vary with the country and the availability of alcohol. In the United States of America (USA), usually use a 10% blend, and mixtures are known and sold as E10 Gasohol. However, there are reports that Brazil is running their vehicles on unblended pure alcohol. Addition of ethanol to petrol up to 10% raises the octane rating by 3 units while blending 25% raises the octane number by 8 units. (Sharma and Goel 1997) Therefore, alcohol blends eliminate environmentally harmful lead additive to raise the Octane number of petrol. Apart from the octane enhancer, ethanol blends has many other useful characteristics as an automotive fuel (Table 2).

Although some of the positive points of alcohol were known for decades, there was little interest in its use as a fuel for many years even after the World War II. With the escalation of oil prices beginning in 1973, interest has been renewed. However, the economics are still not favourable for ethanol, but the gap has been narrowed considerably to the extent that the gasoline/ethanol mixtures are being marketed in number of countries. Ethanol-petrol mixtures in various proportions have been used from time to time in many countries, e.g., Brazil, France, Germany, South Africa and UK. In the face of rapidly rising fossil fuel prices, many countries are considering substituting a part of their petrol with alcohol manufactured from suitable agricultural crops. (McGaw and Shah 1985) Advantages of a motor fuel derived from such renewable sources are:

- i. Saving of foreign exchange
- ii. Substituting part of the motor fuel availability
- iii. Development of domestic agricultural sector.

The concept of power alcohol is therefore of

**Table 2**  
Properties of Ethanol and Petrol

Property	Ethanol	Petrol
Chemical formula	C <sub>2</sub> H <sub>5</sub> OH	C <sub>7</sub> H <sub>16</sub>
Carbon (%w/w)	52	84
Hydrogen(%w/w)	13.2	16
Oxygen (%w/w)	34.7%	00
Density	Kg/m <sup>3</sup> 789.5	702
Viscosity(Ns/m <sup>2</sup> )	12x10 <sup>-4</sup>	5.4x10 <sup>-4</sup>
Boiling point (°C)	78.32	15.7
Ignition temp.(°C)	440	425-510
Gross calorific value (KCa/Kg)	7124	11450
Net cal value (Kcal/Kg)	6401	10620
Air fuel ratio for burn (wt)	8.99	14.55
Octane value	89	70.85

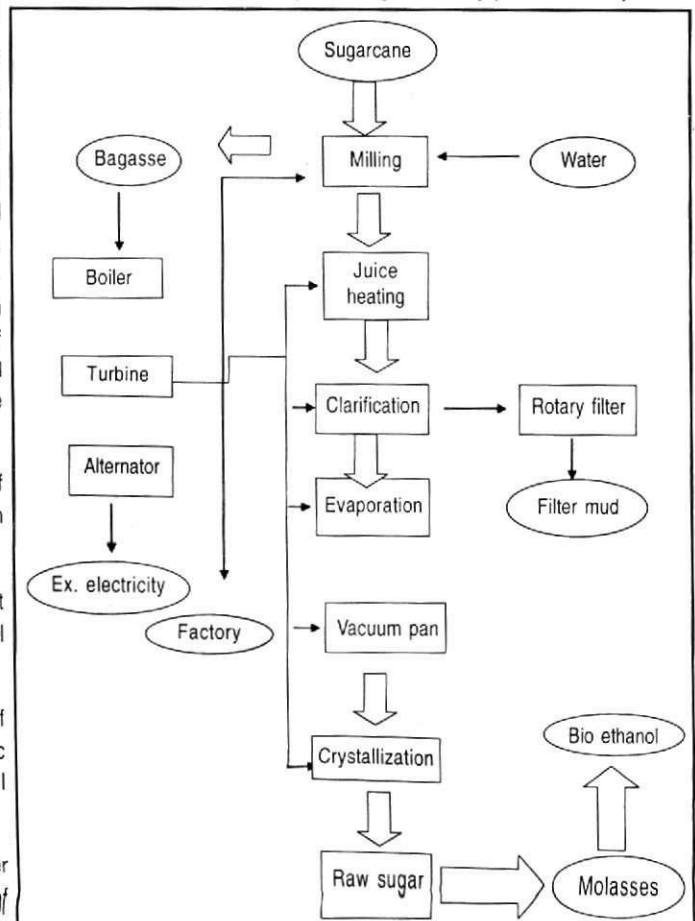
(NA) Not available, Sharma & Goel -1997.

great interest to those countries which do not have their own adequate oil reserves, but have an abundance of solar energy and water to grow the necessary feed stock like sugarcane.

### Sugarcane as a source of Bio fuel

Sugarcane (*Saccharum officinarum*) is a tall perennial grass with number of species. It is one of the most efficient photosynthesisers in the plant kingdom. It has the ability to convert about 3.8% of

**Figure 3**  
Sugar Processing in a Typical sugar Factory (Paturau 1979)



the incident solar energy into biomass. McGaw and Shah 1985) The plant needs tropical or sub tropical climate for its growth and hence it is wide spread from warm temperate to tropical regions of the world. The sugarcane plant has the capability to produce sucrose sugar during its growth period, and this sugar is extracted in a sugar factory (Fig.3). The sugar content in the plant varies with number of factors including sugarcane variety and the climatic conditions under which the plant is grown. Apart from crystallised sugar the sugarcane industry generates a number of co-products such as molasses (8%), bagasse (26%), cane tops and trash (30%), filter mud (4%) (Note: percentages are based on cane weight) and distillery vinasse (spent liquid generated during separation of alcohol from the fermented molasses) (Table 3) which can be converted to bio energy by direct or indirect means. (Paturau 1979)

Sugarcane plant can be used as source of bio fuel directly or indirectly (Fig 4). When the cane is grown for sugar production, the co-products like molasses generated by the industry can be processed to produce ethanol and the co-products such as bagasse and cane tops can be burnt for boilers and resulting high pressure steam can be used to generate electricity or else the bagasse and cane tops can be converted to fermentable sugar and used for ethanol production. Most of the sugar-producing countries processes their co-product molasses into ethanol in the factory- annexed distilleries. However, the process need very high capital investment to set up a sugar factory and the quantity of alcohol production depends on the amount of molasses produced.

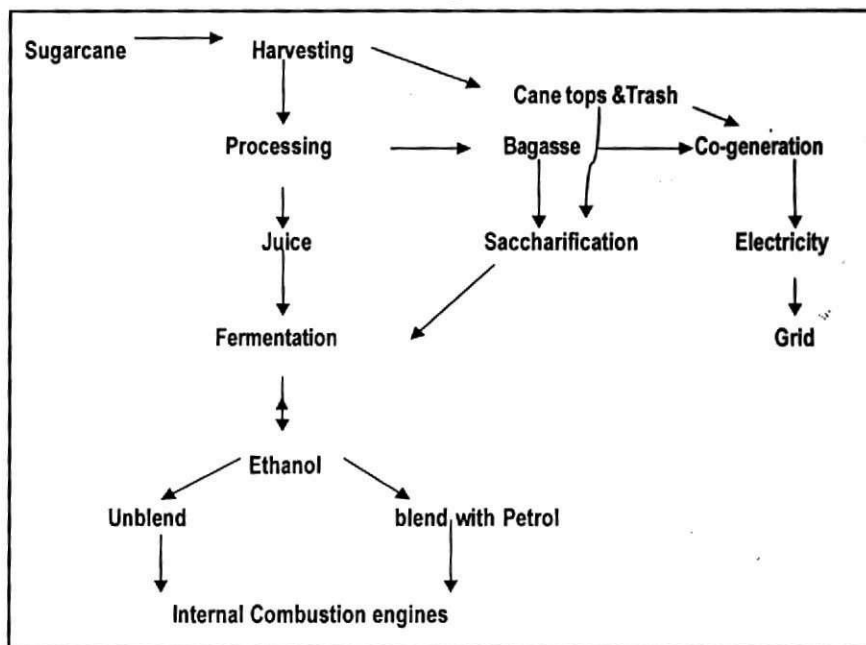
Table 3  
Properties of an Ethanol (10%)/Petrol mixture

Property	Petrol	Alcohol (10%) /Petrol mixture
Boiling point	30-225 0C	25- 2100C
Net calorific value(Kcal/kg)	10410	10026
Net calorific value (Kcal/liter)	7657	7394
Octane number	82-92	84-94
Air fuel ratio (mass)	14.5	14.0

Source: Sharma and Goel 1997

The other method is direct production of alcohol by fermentation, without extracting the sugar. In this process, whole sugarcane extract or juice is used for ethanol production. Countries like Brazil use some of their sugarcane solely for the production of ethanol to be used as an automobile fuel. However, most of the top sugarcane producers in the world such as India, China, Pakistan, Mexico, Thailand, Colombia, Australia, Indonesia, USA and also the Brazil use their production mainly for sugar production and their ethanol production mainly based on the co-product molasses. (Murtagh 1986)

Figure 4  
Direct Utilization of Sugarcane as a Bio fuel



#### Development of a National Power Alcohol Program

Sri Lanka, has faced serious economic and political problems due to recent increase in fossil oil prices in the world market. Therefore, like many other countries, it is high time for Sri Lanka to launch a power alcohol program as a substitute for fossil oil. A national power alcohol program benefits the country by reduction imports of fossil fuel and there by improving the balance of payments situation and providing opportunities for economic development in both the agricultural and industrial sectors.

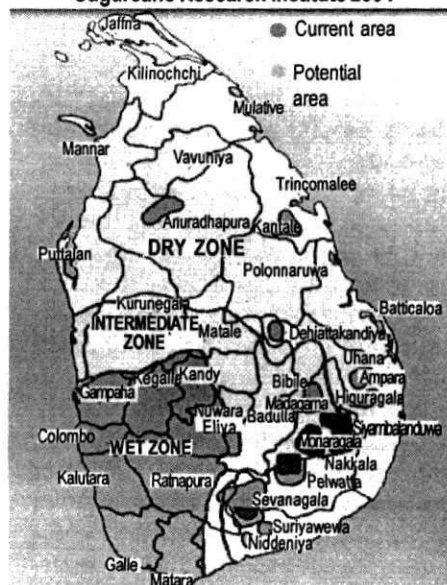
Sri Lanka started the sugar Industry as a government venture more than 50 years ago, and the farmers in the South eastern and eastern belts of the country are considered as traditional growers. Even though there are four sugar factories established with crushing capacity of about

7,500 tonnes of cane per day, only Pelwatte and Sevanagala sugar factories which have the crushing capacity of about 4,700 tonnes of cane per day are in operation today. There are about 18,000 ha under sugarcane cultivation under these two factories. All these sugar factories are equipped with alcohol distilleries to produce ethyl alcohol from the co-product- molasses.

Even though, the present sugarcane cultivation is limited to some areas of Monaragala district, feasibility studies have shown that there are number of potential areas, Kantale (2,500ha),

Hingurana (5,000ha), Monaragala (8,000) (Siyabalanduwa (5,000ha), Nakkala (3,000ha)), Bibile (20,000 ha). Mahaweli System C (1,000ha), Walawe left bank (3,500ha), and Badulla district. (Sugarcane Research Institute 2004) Some parts of the Anuradhapura, and unproductive lands in the coconut triangle, has also identified as potential areas (Fig.5). Therefore, there are about 48,000 ha of potential areas have been identified. Assuming the development of all the potential areas, one can expect a boost in the production of sugar, alcohol and electricity. With the expansion of the industry, it is estimated that 30 million litres of molasses-based alcohol and about 625,000 tonnes of bagasse can be produced. This alcohol and bagasse can easily be used in a bio-fuel program.

Figure 5  
Sugarcane Research Institute 2004



With the ever increasing fossil fuel prices in the world market, it is strongly felt the necessity of an alternative to fossil fuel to substitute present fuel consumption. The local petrol consumption in the year 2007 was about 700,000.000 million litres, (Central Bank ) and a planned power alcohol program would help to cut down the petrol consumption at least by 10% by introducing 10% alcohol- blended petrol without any modifications to the exiting automobile engines. For a 10% substitution, the estimated alcohol requirement is about 70 million litres of dehydrated alcohol. If the total power alcohol requirement is to be met by sugarcane alone, the estimated acreage for the production is about 28,000 ha at the rate of 2,500 litres/ha (Minimum yield). Present sugarcane-based annual ethanol production in the country is about 11 million litres and over 90% of the local production is used as potable alcohol. However, the annual domestic requirement is about 40 million litres.(Per.com, Dept of Excise and Sri Lankan sugar companies) Therefore, if Sri Lanka wants to implement a power alcohol program by blending with petrol, the total annual requirement will be over 100 million litres. Therefore, there will be a big domestic market for alcohol in the country.

However, alcohol in Sri Lanka appears to be an expensive fuel with a total cost typically approaching about Rs. 90/litre. Without government taxes. With the government taxes, the price may go even above Rs 200/litre. Therefore, a strong policy decision on taxation is needed if a national alcohol program to be set up.

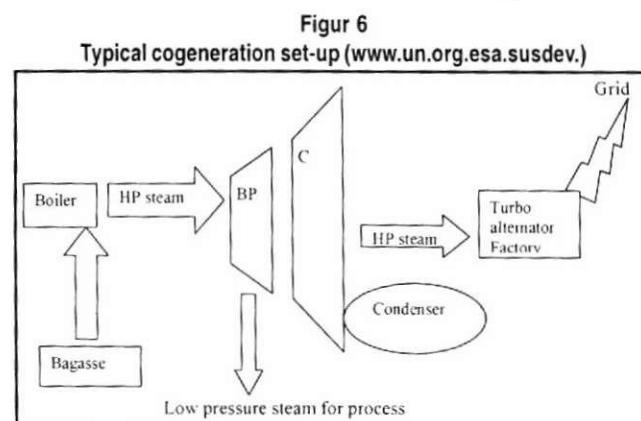
### Energy Balance

In the context of energy crisis, the energy balance is also important, and for alcohol production the process should show a net energy gain. One of the most important factors in energy balance is the amount of energy required to operate the alcohol production unit. In terms of energy balance, sugarcane shows a significant advantage. Sugarcane provides both the fermentable sugar and the bagasse fuel simultaneously. Sugarcane provides about 22-30% bagasse which is more than actually required to process cane juice into sugar or alcohol. Apart from sugarcane, Sri Lanka has variety of other resources (Table 1) available for fermentation and production of alcohol at different market prices. During off seasons, some alternative feed stocks such as cassava starch and other under-utilised crops or surplus products or co-products of agro- industries would be used instead of molasses or cane juice. Utilising those products, the cost for feed stocks can be reduced. However, this needs some modifications to the normal molasses distillery. The saccharification facility, for an example, will greatly increase the flexibility of the plant to accept any fermentable feed stock. However, evaluation of the economics of these raw materials is important prior to incorporate those in a national alcohol program.

### Cogeneration of Electricity in Sugar Factories

The production of electricity and useful thermal energy simultaneously from a common fuel source is known as cogeneration. The rejected heat from industrial processes can be used to power an electric generator. Surplus heat from an electric generator can be used for industrial processes, or for heating purposes. Cogeneration by burning of bagasse and cane tops for steam generation and the utilisation of the steam in the production process and for power generation is a common practice in sugar factories all over the world.(Fig 6)

Most of the factories are equipped with boilers and turbo-alternators for this purpose. Bagasse, a fibrous residue leaving the last mill tandem, is mostly used in sugar factories for cogeneration. Production of bagasse in a sugar factory varies from 22-30% of milled cane weight. The amount depends on the percentage fibre in cane, cleanness of cane, and the harvesting practices.



The calorific value of bagasse varies with its moisture content. With 0% moisture, the gross calorific value is about 19,250 kJ/kg (kilo joules/kilogram of bagasse) and with 48% moisture, it is about 9,950 kJ/kg. The net calorific value at 48% moisture is about 7,985 kJ/kg. Percentage of cellulose, or the fibre, residual sucrose, extraneous matter and the low bulk density of cane also influence the calorific value of bagasse. The calorific value of bagasse has direct relationship with the heat generation when it is used as a fuel for the generation of electricity. When a sugar factory is in operation, theoretically, every tonne of cane crushed will produce about 50 kwh of surplus electricity. With the expansion of sugarcane cultivation for sugar production one can expect about 2.5 million tonnes of cane crushed in a year and about 120 million kwh of surplus electricity (Patarau, 1989). However, if the factory is energy efficient, the surplus bagasse quantity will be about 50% of the total bagasse produced (Patarau, 2003). Therefore, this excess bagasse could also be used in the cogeneration process and the expected power generation is much higher. If the entire sugarcane production is crushed and used for ethanol production, resulting ethanol and the bagasse could be used as Bio fuels much more efficiently.

### Factors to be considered in a National Bio Fuel Program

In a national bio fuel program, the primary resources to be evaluated are land, labour and capital cost. Also special attention should be given to under-utilised agricultural produce and manufacturing capabilities available. In such a bio fuel program, the special areas to be considered are: (1) Sugarcane estate and infrastructure development cost including cogeneration set up; (2) Cane harvesting and transportation costs; (3) Purchase prices of other fermentable raw materials; (4) Storage facilities and factory/distillery capital and operating costs; (5) Alcohol storage, distribution and blending costs and cost of power transmission (6) Prices of petrol and electricity, and government duties and taxes on them.

### Conclusion

Taking all the above facts, one can say that the sugarcane is a wonderful grass not second to petroleum when considering its potentials as bio fuel, and many other useful products that can be made out of it. Therefore, Sri Lanka should have a strong national policy to exploit the potentials of Botanicals like sugarcane and to utilise the natural resources like solar energy and the under-utilised lands for the well being of the man kind.

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