TECHNOLOGICAL ANALYSIS OF BIOFUEL – AN ALTERNATIVE TRANSPORTATION FUEL

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ABSTRACT

Fossil fuels are presently used for residential, commercial, industrial and transportation purpose and even to generate electricity. The wide-scale use of fossil fuels ranges from coal at first stage and petroleum later, and even to fire steam engines, which enabled the industrial revolution to evolve. There are a number of problems associated with fossil fuel usage. Most of which stem from the by-products created when they are burned to create energy. Biofuels-liquid fuels derived from renewable resources such as plant or animal materials – enter the market, driven by factors such as oil price hikes and the need for increased energy security. Based on this perspective, the aim of the present research work was to look at biofuel as an alternative source of energy for transportation. The technological analysis was carried out by studying the process involved in the biofuel production. The study is continued further with the comparison of quality, performance and emission intensity level of biofuel with that of conventional fuel, with respect to the transportation purpose.

Keywords: Biofuel, transportation, fuel, emission, technology

I. INTRODUCTION

Fossil fuels are presently used for residential, commercial, industrial, transportation purpose and even to generate electricity. The wide-scale use of fossil fuels ranges from coal at first stage and petroleum later, and even to fire steam engines, which enabled the Industrial Revolution to evolve. At the same time, gas in the form of natural gas or coal gas was coming into wide use. The invention of the internal combustion engine and its use in automobiles and trucks greatly increased the demand for gasoline and diesel oil, both made from fossil fuels. Other forms of transportation, like railways and aircraft also required fossil fuels. Further the major use for fossil fuels was in generating electricity and the petrochemical industry. Tar, a leftover of petroleum extraction, is used in construction of roads.

There are a number of problems associated with fossil fuels usage. Most of which stem from the by-products created when they are burned to create energy. Exhaust emissions from petrol-driven cars include, in addition to carbon dioxide and water vapour, hydrocarbons, nitrogen oxides and carbon monoxide. Volatile organic compounds are also emitted into the atmosphere through evaporation from fuel tanks, carburetors and refuelling stations. Lead has traditionally been added to petrol as an effective and economic method of boosting octane quality. However, concerns have recently arisen about the possible health effects of lead in vehicle exhaust emissions. Concerns also about atmospheric 'smog' pollution have led to the desire to remove up to 90% of the smog precursors present in engine exhaust gases by the use of catalytic converters. This in turn requires that the petrol be lead free if the catalyst is to function properly.

The rapid increase in world energy prices from 2003 to till date, combined with concerns about the environmental consequences of greenhouse gas emissions, has led to renewed interest in the development of alternatives to fossil fuels. At present, about 80% of the world's demand for transportation fuels -- road, rail, air and sea -- is met by derivatives from the fossil fuel, petroleum. Petrol, one of the major derivatives of petroleum, is used throughout the world as a motor vehicle fuel.

Other petroleum derivatives including diesel and liquid petroleum gas can be used in motor vehicles as alternatives to petrol as can compressed natural gas, which often occurs in conjunction with petroleum deposits. Some alternatives are derived from non-fossil, or partly renewable, sources such as grain or other agricultural crops. However, these need fertilizers made from fossil fuels etc. and are not, therefore, totally renewable.

II. LITERATURE REVIEW

Fuelling with respect to India's transport sector and her future dependence on imported oil was the focus of research and stressed further on biodiesel as an alternative fuel to conventional fuel for Pelkmans and Papageorgiou [1]. They also recognized that of the main problems is the competition between uses of ethanol and its feedstock. The study carried out by Gonsalves [2] showed that biofuels is in a favourable position for meeting India's energy needs, especially as the cost of petroleum is expected to continue its upward trend. In addition to providing energy security and a decreased dependence on oil imports. He also displayed that biofuels offer several significant benefits such as reduced emission of pollutants and greenhouse gases and increased employment in the agricultural sector. Rajagopal [3] worked on the theme biofuel as a transport fuel and inferred that since biodiesel is produced from renewable, domestically grown feedstock, it can reduce the use of petroleum based fuels and possibly lower the overall greenhouse gas emissions from the use of internal combustion engines. Rajagopal felt that biodiesel, due to it's biodegradable nature, and essentially no sulfur and aromatic contents, offers promise to reduce particulate and toxic emissions and it can be an attractive fuel for use in environmentally sensitive applications such as urban buses, underground mines, marine areas, and national parks. Biodiesel when mixed with diesel fuel, in small quantities, also seems to improve the fuel lubricity, extend engine life, and reduce fuel consumption. Francis et. al [4] worked on the socio-economics aspects of jatropha plantations and inferred that since the oil-rich seeds, known to thrive on eroded lands, and to require only limited amounts of water, nutrients and capital inputs. They inferred that this plant offers the option both to cultivate wastelands and to produce vegetable oil suitable for conversion to bio-diesel. Demirbas [5] worked and inferred several reasons for biofuels to be considered as relevant technologies by both developing and industrialized countries. They include energy security reasons, environmental concerns, foreign exchange savings, and socioeconomic issues related to the rural sector.

III. OBJECTIVE

Based on this perspective, the aim of the present dissertation is to look at biofuel as an alternative source of energy for transportation. The technological analysis will be done in the present work by studying the process involved in the biofuel production.

IV. BIOFUEL

'First-generation biofuels' are biofuels made from *sugar, starch, vegetable oil, or animal fats* using conventional technology. The basic feedstocks for the production of first generation biofuels are often seeds or grains such as wheat, which yields starch that is fermented into *bioethanol*, or sunflower seeds, which are pressed to yield *vegetable oil* that, can be used in biodiesel. Second-generation biofuel production processes involves usage of a variety of non food crops. These include *waste biomass*, the stalks of wheat, corn, wood, and special-energy-or-biomass crops (e.g. Miscanthus). Second generation (2G) biofuels use biomass to liquid technology [6], including *cellulosic biofuels* from non food crops. Many second generation biofuels are under development such as *biohydrogen, biomethanol, DMF, Bio-DME, Fischer-Tropsch diesel, biohydrogen diesel, mixed alcohols and wood diesel*. The present study aims to compare the quality, performance and emission intensity level of biofuels with that of conventional fuel, with respect to transportation purpose. This comparative study will be used to estimate the economic and environmental benefit the biofuel bears to be used as an alternative transportation fuel. Europe is one of the biggest users of biofuel. Though, they do not produce their own biofuel entirely, a large part of biofuel that they need is imported. On the other hand, India has the resources to produce its own biofuel. If India uses its resources and invests in research and development, biofuel can be supplied into the Indian market for day today usage.

V. TECHNOLOGICAL ANALYSIS

Biofuels – liquid fuels derived from renewable resources such as plant or animal, materials – are entering the market, driven by factors such as oil price spikes and the need for increased energy security. Most transportation fuels are liquids, because vehicles usually require high energy density, as occurs in liquids and solids. High power density can be provided most inexpensively by an internal combustion engine; these the requirements of being both portable and clean burning. Also, liquids and gases can be pumped, which means handling is easily mechanized, and thus less laborious. Biofuels offer several significant benefits including:

Reduced emission of pollutants

Ethanol and biodiesel are both oxygenated compounds containing no sulphur. These fuels do not produce sulphur oxides, which lead to acid rain formation. Sulphur is removed from petrol and diesel by a process called hydro-desulphurisation. The hydro-desulphurisation of diesel causes a loss in lubricity, which has to be rectified by introducing an additive. Biodiesel has natural lubricity, and thus no lubricity-enhancing additive is required.

The emission of nitrogen oxides (No_x) from biofuels is slightly greater when compared to petroleum, but this problem can be ameliorated by using de-No_x catalysts which work well with biofuels due to the absence of sulphur. The table below shows how the automotive emissions using 22 per cent ethanol and 100 per cent hydrated ethanol compare with the legal limits in Brazil and India (Table 1).

One of the disadvantages in using pure ethanol is that aldehyde emissions are higher than those of gasoline, but it must be observed that these aldehyde emissions are predominantly acetaldehydes. Acetaldehydes emissions generate less adverse health effects when compared to formaldehydes emitted from gasoline engines require clean burning fuels, to keep the engine clean and minimize air pollution. The fuels that are easiest to burn cleanly are typically liquids and gases. Thus liquids (and gases that can be stored in liquid form) meet engines. The table below shows the results of the emission tests for pure biodiesel (B100) and 20 per cent biodiesel blend (B20) compared to conventional diesel (Table 2).

Reduced emission of the greenhouse gas

The net CO_2 emission of burning a biofuel like ethanol is zero since the CO_2 emitted on combustion is equal to that absorbed from the atmosphere by photosynthesis during the growth of the plant (sugarcane) used to manufacture ethanol. This is illustrated by the following equations:

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 \text{ (plant sugar) } + 6O_2$$
(photosynthesis)

Table 1. Comparison of Emissions from 22% ethanol (E22) and 100% hydrated ethanol (E100) with legal limits

Parameter	E22	E100	Legal Limits, Brazil	Legal Limits, India (Euro III/ Bharat III)
Carbon Monoxide (g/km)	0.76	0.65	2.00	2.3
Unburned Hydrocarbons (g/km)	0.13	0.15	0.3	02
NO_x(g/km)	0.45	0.35	0.6	0.5
Aldehydes (g/km)	0.004	0.02	0.03	
Evaporatives (g/test)	0.86	1.6		
Particulate Matter (g/km)	0.08	0.02		
Sulphur Dioxide (g/km)	0.064	0		

Table 2. Comparison of Emissions from pure biodiesel (B100) and 20% biodiesel blend (B20) to that of conventional diesel

Emissions	B100 (100% Biodiesel)	B20 (20% Biodiesel)
Regulated Emissions		
Total Unburned Hydrocarbons	– 93%	– 30%
CarbonMonoxide	– 50%	– 20%
Particulate Matter	– 30%	– 22%
NO_x	13%	2%
Unregulated Emissions		
Polycyclic Aromatic Hydrocarbons(PAH)	– 80%	– 13%
NPAH (Nitrated PAH)	– 90%	– 50%
Lifecycle Emissions		
Carbon Dioxide (LCA)	– 90%	
Sulphur Dioxide (LCA)	– 100%	

$C_6H_{12}O_6 + 3H_2O \longrightarrow 3C_2H_5OH$ (ethanol) $+ 3O_2$ (hydrolysis and fermentation)

$3C_2H_5OH + 9O_2 \longrightarrow 6CO_2 + 9H_2O$ (combustion of ethanol)

Life cycle analysis, from well to wheels, shows that ethanol has the lowest CO_2 emission among the major transportation fuels (Figure 1).

Life cycle analysis, from well to wheels, shows that ethanol has the lowest CO_2 emission among the major transportation fuels as shown in the table below.

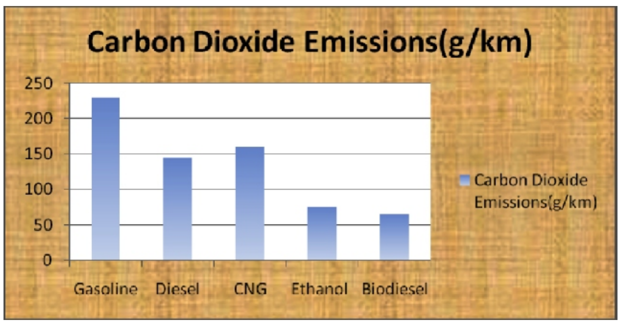

Fig. 1. Carbon dioxide emission, life cycle analysis

Energy security and decreased dependence on oil imports

India ranks sixth in the world in terms of energy demand, accounting for 3.5 per cent of the world commercial energy demand in 2001. But at 479 kg of oil equivalent, the per capita energy consumption is still very low, and the energy demand is expected to grow at the rate of 4.8 per cent per annum. India's domestic production of crude oil currently satisfies only about 25 per cent of this consumption. Dependence on imported fuels leaves many countries vulnerable to possible disruptions in supplies which may result in physical hardships and economic burdens. The volatility of oil prices poses great risks for the world's economic and political stability, with unusually dramatic effects on energy-importing developing nations. Renewable energy, including biofuels, can help diversify energy supply and increase energy security.

Increased employment

At the beginning of the new millennium, 260 million people in India did not have access to a consumption basket which defines the poverty line. India is home to 22 per cent of the world's poor. A programme that generates employment is therefore particularly welcome. The biofuels sector has the potential to serve as a source of substantial employment. The investment in the ethanol industry per job created is $ 11,000, which is significantly less than the $ 220,000 per job in the petroleum field. In India, the sugar industry, which is the backbone of ethanol production, is the biggest agro-industry in the country. The sugar industry is the source of the livelihood of 45 million farmers and their dependants, comprising 7.5 per cent of the rural population. Another half a million people are employed as skilled or semi-skilled labourers in sugarcane cultivation.

Increase in nutrients to soil, decrease in soil erosion and land degradation

In ethanol production from sugarcane, the by-products like vinasse (solid residue left after distillation) and filter cake contain valuable nutrients. Using these organic fertilizers instead of chemical fertilizers reduces the need for chemicals, which could be hazardous and avoids pollution of ground water and rivers.

Improved social well-being

A large part of India's population, mostly in rural areas, does not have access to energy services. The enhanced use of biofuels in rural areas is closely linked to poverty reduction

Good fuel properties

Ethanol has a research octane number of 120, much higher than that of petrol, which is between 87 and 98. Thus, ethanol blending increases the octane number without having to add a carcinogenic substance like benzene or a health-risk posing chemical like methyl tertiary butyl ether (MTBE). The energy content of ethanol is only 26.9 MJ/kg compared to 44.0 MJ/kg for petrol. This would suggest that the fuel economy (km/litre) of a petrol-powered engine would be 38.9 per cent higher than that of an ethanol-powered engine. In actuality, this difference is 30 per cent since ethanol engines can run more efficiently (at a higher compression ratio) because of the higher octane rating. For a 10 per cent ethanol blend the fuel economy advantage of a petrol engine is only 3 per cent. The flammability limit of ethanol (19 per cent in air) is higher than that of petrol (7.6 per cent), and likewise the auto-ignition temperature of ethanol is higher than that of petrol (366 versus 300°C). Thus, ethanol is safer than petrol due to the lower likelihood of catching fire. Ethanol's higher latent heat of vaporization and greater propensity to absorb moisture may lead to engine starting and corrosion problems, respectively, but none of these problems have manifested in the millions of hours of running automobile engines in Brazil. Biodiesel has good fuel properties, comparable to or even better than petroleum diesel. It has 10 per cent built-in oxygen content that helps it to burn fully. Its cetane number (an indication of its fuel burning efficiency) is 52 for biodiesel from Jatropha oil, higher than the 42 to 48 cetane number of most petroleum diesels. The esters of the long-chain fatty acids of biodiesel are excellent lubricants for the fuel injection system. It has a higher flash point than diesel, making it a safer fuel.

VI. CONCLUSION

In the context of high oil prices, fuel ethanol production from molasses and sugar cane is a real alternative for sugar cane producing countries like India. There is also need to look at less demanding starch crops such as cassava in suitable areas. High oil prices could mean that, in the long term, fuel ethanol demand could increase in India. In India, most of the consolidated alcohol industry is still geared for industrial and potable purposes. The government needs to reform restrictive policies to loosen constraints on ethanol production. For instance, the ban on cross-state movement of molasses should be removed. Ethanol distilleries should be allowed to use sugarcane juice instead of just molasses for ethanol manufacture. When sugar prices are depressed, this would permit sugarcane farmers to divert some of the sugarcane to ethanol production, thus bringing extra income to the farmers. Also the wide fluctuations in the price of molasses, which is the main determining factor in the cost of ethanol, should be brought under control. In order to protect itself from the volatilities of molasses prices, the alcohol-based industry is demanding that futures trading be allowed for the commodity. This would take away the spikes in the prices, as well as smooth the price graph to more realistic levels. India is now the world's largest sugar consumer, and this has put added pressure on the ethanol industry. Thus, when sugar production dropped to 15 million tons in 2003-2004, only 196 million litres of the required 363 million litres of ethanol could be produced, causing a temporary derailment of the 5 per cent petrol blending programme. Alternate feedstock crops are needed. As agricultural research has amply demonstrated, sweet sorghum and tropical sugar beet could be grown as cost-effective feedstock crops instead of sugarcane.

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