

Bioethanol - A Viable Answer to India's Surging Energy Needs

Pranav Raghav Sood

Abstract—India is currently the second most populous nation in the world with over 1.2 billion people, growing annually at the rate of 1.5%. It is experiencing a surge in energy demands, expected to grow more than three to four times in 25 years. Most of the energy requirements are currently satisfied by the import of fossil fuels – coal, petroleum-based products and natural gas. Biofuels can satisfy these energy needs in an environmentally benign and cost effective manner while reducing dependence on import of fossil fuels, thus providing National Energy Security. Among various forms of bioenergy, bioethanol is one of the major options for India because of availability of feed stock crops.

This paper presents an overview on bioethanol production and technology, steps taken by the Indian government to facilitate and bring about optimal development and utilization of indigenous biomass feedstocks for production of this biofuel.

Keywords—Bioethanol, Fossil fuel, Biofuel, energy

I. INTRODUCTION

INDIA accounted for 17.5% of the world population [1] and is the fourth-largest consumer of energy after US, China, and Russia, accounting for 3.8% of global consumption [2]. The country's energy demand is expected to grow at an annual rate of 4.8 per cent over the next couple of decades and it is projected to surpass Russia to become the world's third biggest energy consumer by 2030. Growing population and rapid socio-economic development has spurred an increase in energy consumption across all major sectors of the Indian economy.

Demand for petroleum fuel constitutes 40 percent of total energy requirement in India, and is projected to be the third largest net importer of oil in the world [3,4]. There is an increasing gap in production and consumption of crude oil in India as can be seen in figure 1 below. With limited domestic energy resources most energy requirements are met through imports, estimated to be 76 percent of it's demand.

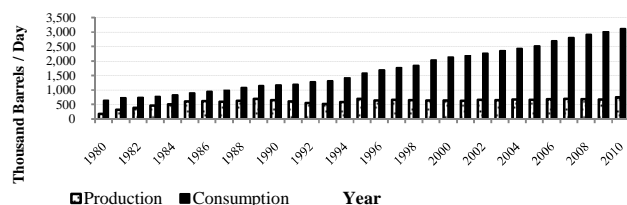


Fig. 1 India Crude Oil Production and Consumption, Source EIA

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Energy demand across the transport sector is likely to be higher [5] given double digit growth in the Indian economy, rise in domestic spending levels, and improving road infrastructures have all led to an increase in new vehicle registrations and ownership. India's on-road vehicle population [5] has increased from 49 million to more than 65 million vehicles over the last five years and is expected to grow annually by 8 to 10 percent [6].

The current growth in transport activity and the consequent increase in petroleum consumption is posing serious concerns for the environment. Looking at the fuel guzzling transportation sector, National Auto Fuel policy 2003, has a revolutionary impact on the social, economic and environmental sector of the country. Knowing that, India is the world's third [7] largest contributor to carbon emissions, the GOI transport policy is targeting EURO-III and IV norms for vehicles, which in turn would require corresponding fuel quality up gradation, by adoption of clean and green fuel. Though, policy does not recommend any particular fuel/technology for achieving the desired emission norms, it proposes liquid fuels as the main auto fuels throughout the country and the use of CNG/LPG be encouraged by higher pollution levels [8]. But both CNG and LPG are in short supply domestically and over the next decade; India's demand for natural gas and LPG will outstrip the country's ability to produce it. The government is seriously concerned about economic, environmental [9] and energy security, and is looking for use of alternate fuels to meet energy demand in a technically efficient, economically viable and environmentally sustainable manner. In biofuels, the country has a ray of hope in providing energy security.

Biofuels are environment friendly fuels and their utilization would address global concerns about containment of carbon emissions. Biofuels are derived from renewable bio-mass resources and, therefore, provide a strategic advantage to promote sustainable development and to supplement conventional energy sources in meeting the rapidly increasing requirements for transportation fuels associated with high economic growth, as well as in meeting the energy needs of India's vast rural population. Biofuels can increasingly satisfy these energy needs in an environmentally benign and costeffective manner while reducing dependence on import of fossil fuels and thereby providing a higher degree of National Energy Security. In India, biofuels are also viewed as potential means to stimulate rural development and create employment opportunities. The Indian approach to biofuels, in particular, is somewhat different to the current international approaches which could lead to conflict with food security. It is based solely on non-food feedstocks to be raised on degraded or wastelands that are not suited to agriculture, thus avoiding a possible conflict of fuel vs. food security.

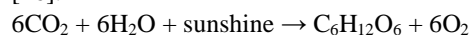
Liquid biofuels, namely bioethanol, is used to substitute petroleum-derived transportation fuels. India's biofuel strategy is focused on using non-food sources for the production of bioethanol such as sugar molasses as second generation biofuels in the near future. Advanced conversion technologies for ethanol are under development, which will allow it to be made from forest and agricultural residues. Using one-third of the surplus, biomass could yield about 19 billion liters of ethanol [5], which could displace the country's entire gasoline consumption once techno-economically viable.

II. TECHNOLOGY AND METHODOLOGY

Bioethanol is produced by fermentation from corn (maize), cassava, sugar cane, sugar beet, sweet sorghum and various lignocelluloses biomass. Hydrolytic conversion of carbohydrates (hemicelluloses and cellulose) in plants is a route to bioethanol production; this is a yeast catalyzed anaerobic conversion or digestion of sugars to alcohol [10]. The liquor containing corn, grapes juice, molasses etc. are fermented by adding yeast to it in batch fermentators for a number of hours (minimum 40 hours) when fermentation gets completed with no increase in alcohol content. The fermentation process consists of breaking of starch or cellulose chain into individual sugar molecules and then fermenting the sugar into ethanol and carbon dioxide. Fermentation of glucose/sugar to ethanol is energy efficient, about 93% of the feed energy is converted as ethanol and only a small amount is taken by fermenting organism (yeast).

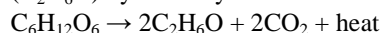
Bioethanol is a promising biofuel that can be derived from any material containing simple or complex sugars. It can be produced from sugar cane and starchy foods such as corn, wheat, and potatoes. Lignocellulose has been described as the most promising raw material. Cellulose is the most common biopolymer present in wood, organic industrial wastes and is a polysaccharide that can be converted into sugars and fermented. Thus, bioethanol from lignocellulosic materials has the potential to be a valuable substitute for, or complement to, gasoline [11]. The polysaccharides cellulose and hemicellulose in lignocellulose, are not readily available. The conversion to ethanol requires chemical pre-treatment, normally carried out in ethanol production plant, to free the carbohydrates. Lignin, which is a common constituent of plant cell walls is a complex of phenylpropanoid groups [12,13]. Lots of processes for the production of bioethanol from lignocellulosic biomass are being developed; this includes enzymatic hydrolysis and fermentation process and gassification [11]. Thermochemical methods, acid hydrolysis and enzymatic hydrolysis have been described as means of making ethanol from lignocelluloses [14]. However cheaper carbohydrate sources of bioethanol are being envisaged to reduce the cost of production and consequently energy cost [15].

Bioethanol is renewable, because it is made from glucose created in green plants by the sun, the so called photosynthesis [16]:



Sun energy transforms carbon dioxide (CO₂) into glucose (C₆H₁₂O₆). This glucose is transformed once again to ethanol

(C₂H₆O) by classic yeast fermentation:



Heat is released calling for cooling of the fermentation vessels and heat is released again when the ethanol is burned in the combustion engine:



The three equations clearly demonstrate why bioethanol is said to be CO₂-neutral. Only the CO₂ - absorbed during the photosynthesis - and no more - is released by the engine. The equations also explain why bioethanol is considered a form of solar energy. All the CO₂ and water (H₂O) absorbed by the green plants are released again. All the three processes - photosynthesis, fermentation and burning - do (all together), is in fact, to turn sun light into heat. Bioethanol is friendly to the environment. As a liquid it is a convenient form of solar energy and may replace gasoline or part of it in modern transportation. Conventional motors tolerate mixtures of as much as 10% ethanol in the petrol (E10). Newer motors are built to tolerate up to 85% ethanol (E85) and we will see more motors able to run on pure ethanol (E100) in the future [16].

III. BIOETHANOL PRODUCTION

In India molasses, a byproduct of the sugar industry is the main feedstock for ethanol. During 2002–03, the total area under sugarcane production was 4,361,000 ha [17]. During 2001–02, the total production of ethanol from molasses was 1.77 billion litres - out of which about 70 per cent was used for potable or industrial purposes, leaving a balance of 0.53 billion litres for use as fuel [18]. By 2007 the country was already the world's seventh largest ethanol producer, with an annual production of 200 million litres of ethanol [19]. There are about 320 distilleries producing ethanol for industrial, beverage, and other purposes with a total production capacity of about 3.5 billion liters per year. More than 115 distilleries have modified their facilities to produce fuel grade ethanol with a total capacity of 1.5 billion liters per year [5]. This production capacity is sufficient to meet the estimated ethanol demand of 800 million liters for a 5% blend with gasoline [20]. However, for a 10% blend, the fuel grade ethanol production capacity from molasses needs to be expanded or the industry could consider direct production of ethanol from sugarcane juice, which offers higher productivity but will require additional investments for technological modifications [21]. The direct production of ethanol from sugarcane juice requires an increase in feedstock production, which in India means developing higher yields per land unit rather than an increase in area planted with sugarcane because this crop is very water intensive and the country's irrigation water supplies are increasingly limited [5].

TABLE I
SUGARCANE PRODUCTION IN INDIA

Year	Area under Sugarcane (Million ha)	Yield of Cane (Million Tones per ha)
2002-03	4520	63.6
2003-04	3938	59.4
2004-05	3661	64.8
2005-06	4202	66.9
2006-07	5151	69.0
2007-08	5055	68.9
2008-09	4395	61.7

Source: Indian Sugar Mills Association [24]

A. Potential bioethanol-producing substrates

Sugarcane; India is the second largest producer of sugarcane in the world, after Brazil [22]. Total production of sugarcane in 2017 is projected at about 358 million metric tonnes (mmt) from 5.9 million ha, compared to approximately 233 mmt from 3.9 million ha in 2003 [18]. Despite the growth and substantial levels of production, India's sugarcane will probably be dedicated primarily to human consumption, and liquid biofuel production will remain limited to offsetting a relatively small percentage of domestic demand for imported fuels. The area under sugarcane has increased by a factor of 2.5 since 1950–51. In recent years, however, the area and the yield have stagnated, as shown in Table 1 [23]. At present, India has the capacity to produce about 1.3 billion liters of biofuel from molasses. However, only about one-tenth of that capacity was dedicated to fuel ethanol in 2005.

Bioethanol blending with petrol was made mandatory in 2003 in nine states and four union territories, and later extended to other parts of the country based on the availability of ethanol; but this is not implemented due to shortage of ethanol [25]. The lack of progress was initially attributed to short supply (resulting from droughts and pest attacks), and more recently, with surplus sugarcane, to taxes, mill prices and state regulations. Among other alternatives, efforts are underway to diversify the feedstock base so as to ensure improved availability. Efforts are being made to find alternative crops, such as sweet sorghum, for enhancing bioethanol production.

Sweet Sorghum; Sorghum is a potential alternative substrate to meet the growing demand of bioethanol. The stalks yield 15 to 20 per cent fermentable sugar which can be fermented and distilled to blend with petrol (gasoline). The crop can be grown in dry areas and needs less water as compared to sugarcane. Though commercial and large-scale production of sorghum has not been realized yet to its full potential, a few sugar-producing mills and corporates such as Tata Chemicals have started production. Organizations such as ICRISAT and the National Research Centre for Sorghum have developed open pollinated varieties and photo-period sensitive hybrids, enabling year-round production [26]. Ethanol production in the country is constrained because of its dependence on a single source. Promotion of alternative crops as feedstock is a potential solution to increasing bioethanol production.

Efforts to produce ethanol from other feedstock such as sugar beet, and sweet potatoes are at an experimental stage in India [21]. Additionally, various public and private institutions in India are conducting research in the area of cellulosic ethanol, which uses feedstock such as agricultural and forest residues. India has a large amount of this biomass material and is therefore a promising potential for the production of cellulosic ethanol. Using one-third of the 189 million tonnes surplus of biomass could yield approximately 19 billion liters of ethanol (assuming one tonne of lignocellulosic biomass = 300 liters of ethanol), which could displace the country's entire gasoline consumption (approximately 14 billion liters in 2008–2009) [27].

IV. BIOETHANOL CONSUMPTION

Currently bioethanol consumption is restricted to the transportation sector only. Rural India may benefit from the massive investment in developing the bioethanol value chain. Estimated potential of bioethanol production in the year 2008–09 was 1.7 billion liters. The Indian biofuel consumption market had a total revenue of \$277 million in 2010, representing a compound annual growth rate (CAGR) of 18.6 per cent for the period 2006–2010. Market consumption volumes increased with a CAGR of 9.7 per cent between 2006 and 2010, to reach a total of 2.4 million barrels in 2010 [28]. During the period March 2003 to September 2004, 0.37 billion liters of fuel ethanol was purchased by the oil industry [Ethanol India, 2005] as a part of the 5 per cent ethanol blending program. Ministry of Petroleum & Natural Gas vide its notification dated 20th September, 2006 has directed the OMCs to sell 5 per cent Ethanol-Blended Petrol (EBP) subject to commercial viability as per Bureau of Indian Standards specifications. The EBP programme was affected adversely due to shortfall in supply of ethanol by the sugar industry. Due to shortfall in sugarcane production and resultant crushing during the year 2009, the supply of alcohol was mere 15 per cent of the requirement. Efforts are being made to ensure availability of ethanol on consistent basis for the EBP programme and OMC's are in discussion with the sugar industry to firm up the status of availability at various locations [29].

V. INITIATIVES BY THE GOVERNMENT

Keeping in mind these possibilities, government of India has initiated various policies to give an effect to the early implementation of the biofuels program. The Ministry of Petroleum and Natural Gas (MoPNG) issued a notification in September 2002 for mandatory blending of 5 per cent ethanol in nine major sugar-producing states and four union territories from 2003 [9]. In 2003, the Report of the Committee on Development of Biofuel [18], under the auspices of the Planning Commission, recommended a phase-wise implementation programme to blend biofuels with petrol and diesel. However, due to a supply shortage from 2004 to 2005, the ethanol-blending mandate was made optional in October 2004, but it resumed in twenty states in October 2006. In October 2007, the Government of India made it mandatory to blend 5 per cent ethanol in petrol across the country, with the exception of J&K, the Northeast and island territories [30]. In 2008, the Government of India announced its National Biofuel Policy, mandating a phase-wise implementation of the programme of ethanol blending in petrol in various states. The blending level of bio-ethanol at 5 per cent with petrol was made mandatory from October 2008, leading to a target of 20 per cent blending of bio-ethanol by 2017. This was taken up by the oil marketing companies (OMCs) in twenty states and four union territories [9]. The new biofuel policy was approved by the Union Cabinet in December 2009 [5].

In view of the multiplicity of departments and agencies, it was felt imperative to provide a high-level co-ordination and policy guidance/review of biofuel development, promotion and utilisation. For this purpose, the policy proposed to set up a National Biofuel Co-ordination Committee (NBCC), headed by the Prime Minister. Ministers from the concerned ministries were proposed to be members of this Committee. The role and active participation of the states was considered crucial in the planning and implementation of the biofuel programme. The policy also proposed that the minimum purchase price (MPP) for bio-ethanol should be based on the actual cost of production and import price of bio-ethanol. The price of ethanol would be determined by the Biofuel Steering Committee and decided by the NBCC and, in the event of diesel or petrol prices falling below the MPP for bio-diesel and bio-ethanol, the government would duly compensate OMCs. Biofuel imports would be permitted to the extent necessary and decided by the NBCC under the policy. Additionally, it was mentioned that bio-ethanol already enjoys a concessional excise duty of 16 per cent. Duties and taxes would be levied on imports to ensure that indigenously produced biofuels are not more expensive than imported biofuels.

The objective of the National Biofuel Policy has been to encourage domestic production of ethanol and further the Ethanol Blending Programme (EBP) in the country. The Indian approach to bio-fuels is based on non-food feedstock to deliberately avoid a possible conflict between food and fuel. However, the implementation of the 5 per cent EBP throughout the country has in reality remained pending due to problems such as ethanol shortages, the variable taxation structure of state governments and certain regulatory restrictions.

VI. CONCLUSION

The global debate over diversion of food crops for biofuel production is largely inapplicable to Indian biofuel programme, as the country gives considerable emphasis on using only non-edible feed stocks for bioenergy production. However, there is widespread concern over the long-term sustainability, economic viability and commercial feasibility of the programme in its present shape. The review reinforces that ethanol production focused over sugarcane molasses as a primary feed stock is neither economically viable nor sustainable with the available technologies. It also raises strong apprehension over the overall readiness of the various stakeholders involved in the bioethanol supply chain. It is therefore, imperative to prioritize the various options available so that the efforts are not only directed towards making it sustainable and economically viable, but also pro-poor and resource saving. If promoted, sweet sorghum based ethanol may prove a better option, which would be pro-poor in marginal and rain-fed areas and so is the case with tropical sugar beet. Development of a self-reliant community to manage the natural system is one of the important elements of sustainable development. Here lays the importance of biofuels as a domestic and renewable energy supply.

Bioethanol can be foreseen as future fuel in the transport sector. But commercialization of these fuels on a large scale needs tremendous technological innovation supported by proper policy approaches. Government of India is very keen to give it a head start for all the biofuel programs. A concerted effort from both the government and private parties towards a coherent technological and policy initiative will lead India to meet its energy requirements substantially through biofuels materializing the vision of development and thereby creating a revolutionary changes.

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