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Energy Security, Food Security and Economics of Sugarcane Bioethanol in India

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Abstract

Energy security has been an important global policy issue for more than four decades. Transport biofuels like bioethnol have been receiving increased attention in recent years as a solution to heavy dependence of imported petroleum fuels which brings destabilizing price effects on the economy and cause serious environmental problems like climate change. India's biofuel policy proposes an ambitious 20% bioethanol standard by 2017. This paper examines the economic feasibility of sugarcane bioethanol in India while considering the food security as a competing policy priority. The analyses show that 20% bioethanol standard cannot be achieved without affecting the food production in India. Moreover, cost of sugarcane bioethanol exceeds the social benefits, hence use of sugarcane bioethanol cannot be justified on economic grounds. Molasses - a by product of sugar manufacturing - can be used to produce transport fuel without compromising food production while improving the social welfare. However, use of molasses bioethanol for transport should not displace its current uses as industrial and potable alcohol to ensure positive net returns.

Keywords: bioethanol, cost benefit analysis, India

1. Introduction

Energy security has been an important global policy issue for more than four decades. Global energy markets have relied heavily on fossil fuels like oil, natural gas, and coal, which provide almost 80% of the world's supply of primary energy needs (IEA, 2007). Fossil fuels have brought with them price shocks, which destabilizes the global economy from time to time. The extensive worldwide use of fossil fuels has not only threatened energy security but has resulted in serious environmental concerns - particularly climate change. Most of the developing nations have been experiencing economic growth and consequent increase in demand for energy. One of the key challenges facing the developing world is how to meet its growing energy needs and sustain economic growth without contributing to climate change. Cleaner renewable sources of energy (such as bioethanol) believe to be part of the solution to the global energy problems.

This paper examines the economic viability of sugarcane bioethanol in India. India is an energy deficit nation having one of the lowest per capita consumption of energy. Per capita energy consumption in India was 439 kilograms of oil equivalent (kgoe) in 2003, which was much lower than that in developed countries but also than the global average of 1688 kgoe (Government of India, 2003). India's proven oil reserves are estimated to be about 775 million tons (Ministry of Petroleum and Natural Gas (MoPNG), 2009, Table 1). With limited reserves, India's domestic production was around 33.51 million tons in fiscal year (FY) 2008 (Note 1) and consumption was around 161.7 million tons (MoPNG, 2009). India does not have the ability to meet the country's growing demand for energy from its owned sources even in the short term. As a result, the country is increasingly becoming dependent on imported crude oil. India spent 3% of its gross domestic product (GDP) for oil imports during 1971-2008. It will have to spend about 6% of its GDP for oil imports during 2008-2030 (IEA, 2009).

Table 1. Proven reserves, present production and present levels of imports of coal, oil and gas in India

Type	Proven Reserves	Present Production	Present Imports
Oil (MMT)	775	33.5	128.2
Gas (BCM)	1074	32.85	8.06*
Coal (Billion Tons)	267.2	0.525	0.035

Source: MoPNG, 2009

* Million Tons of liquefied natural gas (LNG)

India has been a net importer of liquid fuels and the volume and value of these imports have steadily risen over time. The import of crude oil has risen from 57.8 million tons ($9.21 billion) in FY 1999 to approximately 140 million tons ($75.6 billion) in FY 2009, accounting for about 81% of total oil consumption in the country. Petrol and diesel consumption have been rising rapidly over the past few years. For example, diesel consumption grew at a cumulative average growth rate (CAGR) of 7.19% between FY 2004 and FY 2010. Petrol consumption grew at a CAGR of 9.18% during the same period. With the country entering a more energy intensive phase of its development, demand for liquid transportation fuels will dramatically rise in the future. Conservative estimates based on growth in the past (1998-2007) indicate that petrol consumption is likely to rise to 21.59 million tons and diesel to 87.3 million tons by FY 2017.

With global demand and energy prices likely to increase in the medium to the long term, higher oil imports could adversely affect India's balance of payments and future development. This energy outlook for India forces it to intensify its efforts to search for alternate fuel options such as biofuels. It is believed that Biofuels have potential to provide clean energy, reduce dependence on petroleum imports, and support rural development. Brazil's ethanol program is considered a success and the production of corn ethanol already has sparked a revitalization of rural communities in the U.S. Similar development may take place in many other countries across the world. At the same time, a large-scale production of biofuels could adversely impact land and water resources and food security of food importing nations (Chakravorty, Hubert, & Nostbakken, 2009; Zhang, Lohr, Escalante, & Wetzstein, 2010). To date our understanding of the associated costs, benefits, and opportunities of biofuels is incomplete. Formulation of polices to realize the full potential of biofuels require better understanding of the broad range of consequences associated with their widespread use. This paper examines the economic viability of sugarcane bioethanol in India giving special emphasis to the food security issue.

2. Literature Review

Literature on bioethanol is growing. However, most of the published work on bioethanol focuses on technical and agronomic aspects of new feedstock, feedstock conversion technologies and effect of biofuels on environment and natural resources. Here we review selected literature focusing on economic analyses of biofuels. Among the reviews of literature on biofuels, Rajagopal and Zilberman (2007) provide a comprehensive overview about environmental, economic and policy aspects of biofuels. They conclude that first generation biofuels is intensive in land, energy and chemical inputs. Their review also shows that environmental literature on biofuels discusses mainly on net carbon effect, not much on human health, soil quality, biodiversity and water depletion. They also identify the gaps in increasing economic and policy literature on biofuels. Another review by Chakravorty, Hubert and Nostbakken (2009) shows that biofuels may cause food price increase and deforestation in certain parts of the world.

Early literature was more optimistic about the benefits of biofuel developments. For example, Resource Systems Group (RSG, 2000) show that construction of ethanol plants results in large short term increases in employment and income in Northeast states of US. Construction of a wood to ethanol plant with capacity of 50 million gallon per year would generate between $170 million to over $200 million in income and create 4000 to 6000 jobs depending on the State and the type of plant. Ethanol plants using purchased wood, cellulose materials, and corn have substantial net positive impacts on the state economies in terms of income, jobs, and state tax revenues. Most of these positive impacts are caused by the production of the wood feedstock in these states. This study, however, does not estimate the net welfare gain to the society considering economic costs and benefits of biofuels.

APEC (2010) analyzes and compares the cost of production of various biofuels against the petroleum-based fuels they displace, factoring the impact of subsidies. This study shows that different factors such as plant and site specific synergies, economy of scale, and market availability for co-products can have a large impact on overall

production cost and hence commercial viability of a specific bio-refinery. Comparisons with calculated production costs for equivalent petroleum products indicates that U.S. corn ethanol production costs for a standardized plant have been competitive with U.S. gasoline production costs. Brazilian ethanol plants with attached co-generation facilities have consistently resulted in production costs lower than those in corresponding petroleum product. However, this low costs depend on an electricity co-product credit. Without this credit, the production cost would be on the order of US$0.46 per liter, but with the credit, costs are as low as US$0.18 per liter.

A modern cellulosic ethanol biorefinery, with capital costs and ethanol yields assumed to come from commercial plants using the best available technologies, would be cost competitive with petroleum (APEC, 2010). However, variability in cellulosic feedstock price over time cannot be estimated due to the lack of market information for such feedstock at present. More importantly, the technologies that provide reasonable ethanol yields from cellulosic material by way of enzymatic hydrolysis have yet to be proven on a commercial scale. Location of a plant and periodic market conditions affect feedstock and utility costs and consequently result in wide variability in production costs of biofuels (APEC, 2010). Plant-specific synergies such as co-generation of electricity will also greatly impact production costs. Standardized cost estimates which don't take into account these factors are unrealistic for real-world projects.

A number of published economic analyses show that bioethanol production is not welfare improving. Hahn and Cecot (2008) undertook a benefit-cost analysis on ethanol program in US. They use an Environmental Protection Agency report (EPA, 2007) on US renewable energy standards and modified some of the costs and benefits to undertake their analysis. Their findings show that the cost of increasing ethanol production to about 38 billion liters a year is likely to exceed the benefits by about three billion dollars annually. They suggest that Congress should consider repealing ethanol incentive programs, and also point out that if removing the ethanol tax credit and tariff reduces ethanol production by about fifteen billion liters, it could save roughly a billion dollars annually for the US economy.

de Gorter and Just (2010) apply cost benefit analysis to examine the efficacy of alternative biofuel policies in achieving energy, environmental and agricultural policy goals in US. They find that government mandates are superior to consumption subsidies, especially with suboptimal fuel taxes and the higher costs involved with raising tax revenues. Subsidies with mandates, however, cause adverse interaction effects; oil consumption is subsidized instead. They also show that policies that discriminate against trade, such as production subsidies and tariffs, can more than offset any benefits of a mandate.

Charles et al. (2013) evaluates the costs and benefits of European Union's biofuels industry, using quantitative and qualitative approaches. The focus of the analyses was not on regional level welfare changes but rather on costs and benefits as they impact recipient groups. Based on their findings, they question the success of EU biofuel policies in meeting the energy security, improvements in environmental performance and the generation of additional economic value. This study finds that a significant amount of public money, between Euro 5.5 and 6.9 billion (in 2011), subsidized the use of conventional biofuels and only a small portion was allocated to advance biofuels development. The study assesses the 2012 European Commission proposal to limit food-based biofuels, and finds that implementation of the Commission's proposal will significantly limit the additional costs associated with moving to a 10% market penetration of food-based biofuels. The avoided costs are significant and amount to Euros billions per year.

Larsson (2007) uses cost benefit analysis to examine economic viability of cereal based bioethanol in Sweden. This study shows that the net benefit of bioethanol depends on avoided social cost of carbon and the discount rate used for the calculation. The environment, the maintenance suppliers and the banks are large net gainers of ethanol production. There is however a considerable negative impact for the government due to the total tax exemption on bioethanol. Displacement of wheat production negatively affects the economic viability of cereal based bioethanol.

Hill, Nelson, Tilman, Polasky and Tiffany (2006) evaluate economic competitiveness of corn bioethanol and soybean biodiesel, using life-cycle accounting method. Bioethanol and biodiesel yield more energy than the energy invested in their production, and relative to the fossil fuels they displace. These biofuels also release less greenhouse gas emissions. However, neither bioethanol nor biodiesel can replace much petroleum without impacting food supplies. Biodiesel provides sufficient environmental advantages to merit subsidy. Transportation biofuels such as synfuel hydrocarbons or cellulosic bioethanol, if produced from low-input biomass grown on agriculturally marginal lands or from waste biomass, could provide much greater supplies and environmental benefits than those from food-based biofuels.

Gunatilake (2012) shows that biodiesel in India passes cost benefit test but only with the assumption that wastelands use for oil seed production have zero opportunity cost. As discussed above, the available limited information shows that social cost of bioethanol exceeds benefits in number of cases. More importantly, diversion of land and water resources for bioethanol can adversely affect food security. In 2007-2008, prices of many food crops doubled and the National Research Council (2011) estimates that global biofuels expansion accounted for 20-40% of this price increase. Wise (2012) assesses the cost of US bioethanol policy on countries import US agricultural products. Net-food-importing developing countries were particularly hard-hit by US biofuel policies. The six-year costs to net corn importing countries is estimated at $11.6 billion, with developing countries absorbing more than half of those costs. Wise (2012) also examines the negative impacts of US bioethanol policy on the poor in net corn exporting countries and recommends reforms to U.S. bioethanol policies. Lu & Babcock (2012) also show that US renewable fuel standards (RFS) cause less elastic demand for corn and gasoline. Thus, the RFS are also found to lead to more volatile corn and gasoline prices when supply shocks occur.

Serra, Zilberman and Gil (2011) uses time series econometric analysis on food and ethanol price and find existence of a strong link between food and energy markets in Brazil, both in terms of price levels and volatility. Zhang, Lohr, Escalante, & Wetzstein (2010) undertake a similar study and examine short-run and long-run impacts. Their results show no direct long-run price relations between fuel and agricultural commodity prices. However, sugar prices are influencing all the other agricultural commodity prices except rice in the short run. With sugar being the number one world input for bioethanol, results indicate increased bioethanol production is potentially influencing short-run agricultural commodity prices. Serra (2011) also confirms the existence of strong volatility links between oil, ethanol and sugar prices in Brazil. However, the literature on the price links between biofuels and food commodities are not conclusive. For example, Zinberman, Hochman, Rajagopal, Sexton and Timilzina (2013) argue that biofuel prices increase as both food and oil price increase, but changes in biofuel prices have limited impact on food prices.

3. Bioethanol Program and Biofuel Policy and in India

In light of rising oil prices and increased dependence on imported oil, India established a bioethanol pilot program in 2001. The program consisted of three E5 (Note 2) blending pilots in Maharashtra and Uttar Pradesh and research and development studies investigating the technical feasibility of bioethanol use (Gopinathan & Sudhakaran, 2009). The pilot projects were successful and in September 2002, the MoPNG mandated an E5 blending target for nine states and four Union Territories, effective January 1, 2003 (Government of India (GoI), 2002). The 5% target was established after consultations with key stakeholders at the state and central government levels, including the Society for Indian Automobile Manufacturers and major sugar manufacturers (Gopinathan & Sudhakaran, 2009). It was assumed that there were adequate surplus supplies of molasses and alcohol in the country to meet the initial 5% target as well as possible scaling up the target up to 10% nationwide (Gopinathan & Sudhakaran, 2009). In April 2003, India further strengthened its bioethanol program when the Planning Commission released a report on biofuels (GoI, 2003). The report analyzed various blending targets, price and feedstock availability scenarios and issued the recommendations to expand the industry to meet 5-10% blends of bioethanol.

At the time the initial policy was established, India was endowed with surplus sugar supplies. However, severe droughts in 2003 and 2004 reduced sugar supplies by over 60% from historic averages and molasses supplies by about 53%. This diminished bioethanol supplies forced India to import 447 million liters of bioethanol from Brazil in 2004 to meet the E5 blending target. Bioethanol was subject to various central and state alcohol taxes and levies, which created challenges for moving bioethanol around the country. In October 2004, India amended the E5 mandate requiring E5 blends only when adequate bioethanol supplies were available and when the domestic price of bioethanol was comparable to the import parity price of petrol.

India continued importing bioethanol to meet its blending targets and became the largest importer of Brazilian bioethanol; in 2005 India imported 411 million litres from Brazil, which accounted for approximately 9% of the global bioethanol trade. However, transporting bioethanol across states remained difficult. As a result, the majority of the imported bioethanol was used for chemical manufacturing rather than for transportation (GoI, 2006). Therefore, the government recommended a further scale-back in the bioethanol program outlined in its Integrated Energy Policy (IEP) in August 2006. Despite the IEP recommendations the MoPNG strengthened and expanded its Ethanol Blending Program (EBP) in September 2006. The EBP mandated E5 blends, effective November 1, 2006, in 20 states and four Union Territories, subject to commercial viability (MoPNG, 2007). India experienced a surplus in sugar production during the 2005-2006 season, which most likely facilitated the new policy decision. As result of the policy, 10 states had enacted their EBP by 2007.

The 11th Five-Year Plan (2007-2012) recommended increasing bioethanol blending mandates to 10% once E5 blends were put in place across the country (GoI, 2007). The Planning Commission recommended this increase to occur around 2010. In September 2007, the Cabinet Committee on Economic Affairs (CCEA) implemented E5 blends across the country and recommended E10 blends where feasible, effective October 2007. The E10 blending target remains in effect and will be scaled up to E20 by 2017, as proposed by the country's recently enacted National Policy on Biofuels. This comprehensive policy has provisions for variety of policy measures such as subsidies, preferential financing, fiscal incentives, research and development support, and international cooperation for promoting biofuels in India. The policy implementation will be coordinated by the Ministry of New and Renewable Energy (MNRE). The policy is not feedstock specific but maintains the government position that energy crops should not have any adverse impacts on the food sector.

4. Cost Benefit Analysis

4.1 Methods and Data

In India, bioethanol is mainly produced using molasses, which is a by-product of sugar manufacturing. Total quantity of molasses produce in India enables about 11.6% bioethanol blending. Besides, there are more lucrative alternative uses for molasses alcohol such as potable alcohol and industrial alcohol. Therefore, molasses alone is not adequate for achieving the target of 20% blending in 2017. ADB (2011) assesses the land requirement for achieving 20% blending target by using a simple natural resource accounting approach. Using an estimated 21.6 million tons of petrol consumption by 2017, it estimated that 5.76 billion liters are required to achieve the target. One ha of sugarcane yields about 4900 liters of ethanol with the assumption of sugarcane yield at about 70 tons/ha. Therefore, the area of land required to produce 5.76 billion liters bioethanol would be 1.18 million ha. Use of sugarcane from 1.18 million ha for production of bioethanol will result in a reduction of sugar production of 8.23 million t/year. Assuming this amount of raw sugar were to be imported at $350/t it would cost about Rs. 126.6 billion ($2.88 billion) /year. Given the fixed amount of arable lands which are already under cultivation, the 20% blending target cannot be met without affecting the food security (ADB, 2011).

Other feedstock crops such as tropical sugar beet (TSB) and sweet sorghum (SS) can be successfully cultivated in India. If the rainfall is sufficient, SS can be grown without irrigation during the monsoon (kharif) season. It can also be grown as a crop in the second harvest (rabi) season with limited irrigation. However, experience has shown that the combined average yield of SS for two crops is lower (about 40 tons/ha/yr) than for sugarcane, even with the additional yield of three tons of sorghum grains. The alcohol yield is also low, at about 55 liters/ton. Therefore, the land requirement would be higher than that of sugarcane for production of same volume of bioethanol. If the total amount of the bioethanol for 20% blending in 2017 is coming from SS the land requirement would be about 2.6 million ha. The SS will be grown on arable lands and diversion of 2.6 million ha of arable lands for SS production will have adverse impacts on the food sector.

TSB is a six-month crop and normally one crop can be taken per year with a yield of 65 tons/ha. Bioethanol yield from TSB is about 70 liters/ton. About 1.26 million ha of arable land is required to meet the 20% blending requirement with TSB bioethanol. The land requirements for both SS and TSB are larger than that of sugarcane but land would be available for six months a year for other crops. TSB and SS are not commercially established like sugarcane and their cost competitiveness, in comparison to sugarcane based bioethanol is not fully understood.

This study was undertaken at the request of Government of India as a policy advisory technical assistance. The data used for the analysis was taken from secondary data sources supplied by government agencies. Limited field investigations were undertaken to supplement and verify the data. When the necessity was felt, the secondary data was crosschecked and supplemented with the limited data collected from field investigations. When doubts concerning the accuracy of data arose the more conservative values were used. The economic life of project-related facilities was assumed at 25 years. If any facility's life span is expected to go beyond a 20-year period, a salvage value should be added to the economic feasibility model. However, such salvage values gave only a marginal change in the net present values (NPV). Therefore, the salvage values were not incorporated in the analysis.

First the financial viability of bioethanol production was assessed (see ADB 2011 for details). This assessment produced part of the data base for the cost benefit analysis. Financial analysis of bioethanol was carried out considering regional differences (3 regions in India -north, south, and west India) and scale of operations (1 hectare, 5 hectares, and 10 hectares and above). The regions are the predominant sugar producing areas. Across the country the economics of producing sugarcane is different because of costs and productivity differences

arising from soil and climatic conditions. The different farm sizes were considered to capture cost differences associated with the scale of operations. Sugarcane production and bioethanol production were assessed separately. The national averages were used in the cost benefit analysis. The financial analyses were undertaken for two bioethanol techniques: a) bioethanol production using molasses; b) bioethanol production using sugarcane juice. Table 2 presents the average financial costs of producing bioethanol from the two routes.

Table 2. Financial cost of bioethanol production from molasses and sugarcane

Item	Molasses Bioethanol (Rs./l)	Sugarcane Juice Bioethanol (Rs./l)
Cost of Feedstock	12.6	16.7
Steam	3.0	3.5
Electricity	1.5	3.2
Chemicals	0.3	0.5
ETP/RO operating cost	0.8	0.7
Manpower cost	0.4	0.6
Admin and overheads	0.2	0.2
Repair & Maintenance	0.2	0.2
Marketing and other expenses	1.0	1.0
Total	20.0	26.6

To attain the financial viability, most of the sugar mills in India have integrated bioethanol units. Typically, these units are set up with a capacity of 50,000-100,000 liters per day. Figure 1 presents the price structure across the value chain of producing bioethanol from two routes. With the present productivity and costs, the financial analysis shows that the price of bioethanol produced by molasses should be Rs. 27/l, to provide sufficient financial returns to each and every stakeholder across the value chain. Note that the required price estimated here is indicative and considers only the costs from the producer's side and assumes 16-18% returns. This is the common returns used in the energy sector of India in tariff determinations.

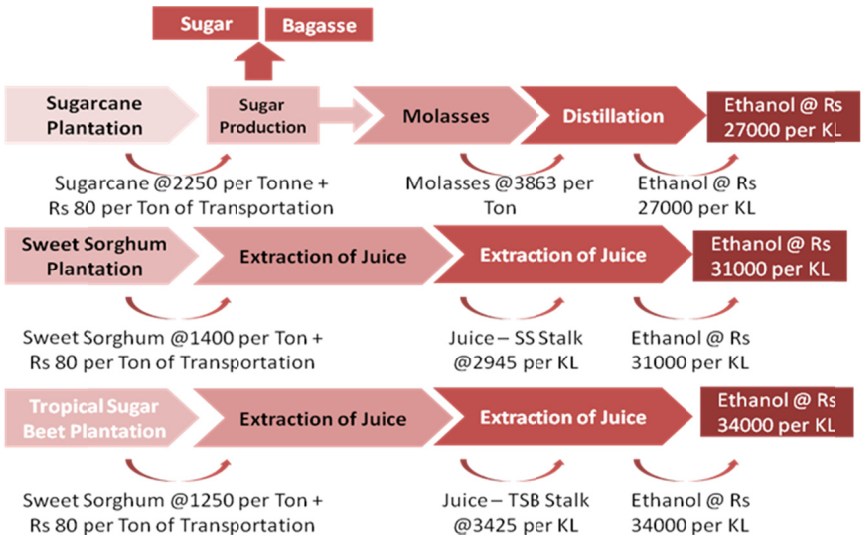

Figure 1. Price building model of *bioethanol*

The financial analysis models for bioethanol production and processing in India were aggregated and expanded to develop economic feasibility analysis models. The analysis was undertaken at the national level and the results highlight the overall welfare implications of bioethanol production and use. In aggregating the different costs and benefits along the supply chain the 20% blending target was used to define the scale of bioethanol

production in India. In other words, the national bioethanol project was defined based on the 20% blending target. A detailed analysis of various environmental implications of the bioethanol sector was not considered in the economic feasibility analysis presented in this paper mainly because of data limitations. Only the benefits of carbon emission reduction were incorporated.

All economic costs and benefits are valued at 2010 prices and are expressed in domestic currency, the Indian Rupee. Tradable commodities were valued at the border price. Non-tradable commodities were valued through shadow prices using a standard conversion factor of 0.93, and specific conversion factors: 1.0 for equipment, 1.5 for steel, 0.76 for cement, 0.82 for timber, 2.0 for skilled labor, and 0.67 for unskilled labor (ADB, 2011).

Benefits of bioethanol were estimated as the resource cost savings, equivalent to the shadow value of gasoline. Given that India's fixed arable land is already under cultivation, bioethanol cannot be produced without displacing sugar or some other crops. Therefore, the value of displaced sugar or other crop - the opportunity cost of producing bioethanol - should be properly accounted in the cost benefit analysis. In order to account for this opportunity cost, both costs and benefits were considered on an incremental basis. In the case of bioethanol production from cane juice, a better understanding is needed about the 'with' and 'without' project models. In the "without project" situation, molasses comes as a by-product of sugar production and the analysis assumes that the molasses is used for transportation bioethanol production. Let us assume that under the without project scenario:

Total cost of sugar production $= C_s$

Cost of bioethanol production $= C_{me}$

Benefits of sugar $= B_s$

Benefit of bioethanol $= B_{me}$

Net benefit without project, NB_1 $= (B_s + B_{me}) - (C_s + C_{me})$

Under the 'with' scenario sugar will not be produced and hence no molasses is produced, all the cane juice will be used for bioethanol production. Let us assume:

Total cost of bioethanol Production $= C_e$

Total benefit of bioethanol $= B_e$

Net benefit with the project NB_2 $= B_e - C_e$

Since the net benefit without the project (NB_1) is the opportunity cost of producing bioethanol from cane juice, the incremental net benefit (NB_{INC}) will be:

$$NB_{INC} = NB_2 - NB_1 = \{B_e - C_e\} - \{(B_s + B_{me}) - (C_s + C_{me})\}$$

The above incremental net benefit is the benefit of producing bioethanol from sugarcane juice. As discussed earlier, there are two possibilities for meeting the 20% target of bioethanol: i) divert existing sugar land to produce bioethanol, or ii) set aside an additional 1.18 million ha of land for sugarcane based bioethanol production. We considered only the first option because it is unlikely to allocate addition lands for sugarcane bioethanol given the land scarcity in India. The economic feasibility analysis for bioethanol considered SS, TSB feedstock in addition to sugarcane. For these crops it was assumed that alternative crops (e.g. wheat or maize) would be displaced. For example, if maize is the alternative crop for SS, benefits were assessed as the economic value of replaced gasoline minus the economic value of maize. Incremental costs are the cost differences between SS bioethanol production and maize cultivation.

4.2 Economic Feasibility of Molasses Bioethanol

As discussed above, 20% bioethanol blend target would require production of 5.76 billion liters of bioethanol per year by 2017. The cost benefit analysis assumes that this amount of bioethanol will be produced by 2017 with a gradual increase from 2010. The total quantity of molasses produced in India in 2007 is about 11.3 million tons ADB (2011). At the average rate of growth of 4.5% per annum, the total molasses quantity will be 17.6 million tons by 2017 and the use of the full amount will make it possible to blend little over 50% the blending requirement. The analysis assumes that half of the 20% bioethanol blending standard will be achieved by production of 2.88 billion liters of bioethanol from molasses. The molasses bioethanol conversion rate used in the analysis is 220 liters of bioethanol from 1 ton of molasses.

Bioethanol is used for three purposes in India: transport fuel, industrial use, and as potable alcohol. There is limited information on the quantity of alcohol used for industrial use or human consumption. According to Indian Chemical Council (ICC) about 70% of the bioethanol produced in India is used for industrial uses and as

potable alcohol (ICC, 2010). Given this meeting half of the targeted blending requirement with molasses ethanol cannot be accomplished without displacing industrial and potable alcohol. Assuming that other uses of alcohol will remain constant, it was estimated that about 20% of the industrial and potable alcohol will be displaced if half of the 20% ethanol standard is met with molasses alcohol. Therefore molasses bioethanol has an opportunity cost when used for transportation, despite being a by-product of sugar production.

The total gross benefit of bioethanol is estimated as resource cost savings because every liter of bioethanol displaces 0.67 liters of petrol on energy parity basis. The market price of petrol as of March 2010 was Rs. 47.43/liter. This includes Rs. 14.78 of excise duty and educational levy. On top of these taxes another value-added tax is levied on petrol at the supply point. The value-added taxes vary from state to state. In the present calculation, the Rs. 7.90 (20%) rate applied in Delhi was used. Altogether the total tax will be about Rs. 22.68/liter. Once all these taxes are added to the refinery gate price, if oil companies incur a loss the government pay the balance to the companies. This payment is known as under recovery. As of March 2010 under recovery was Rs. 4.18/liter. Deducting the taxes from the market price and adding the subsidy (under recovery) the shadow price was estimated to be Rs. 28.84/liter. These calculations provide the shadow price coefficient of 0.6, which was used in estimating the benefit of bioethanol.

The benefit of bioethanol is directly linked to market price of oil, and oil prices have been fluctuating heavily in recent times. Oil price increases in the future may make bioethanol economically viable even if it is not viable at present. To understand the economic viability under high petrol price scenario we undertook sensitivity analysis. We use 15%, 25% and 40% increase of petrol prices in the analysis. At the time this study was undertaken market price of oil was $80/barrel. Given that the base case price is already on the high side, assumed increases in petrol price reasonably represent potential oil prices increases in the future.

Table 3 provides a summary of the results of cost benefit analysis. Note that since the net benefit stream is positive for all the years, economic internal rate of return (EIRR) estimation was not possible and the economic feasibility assessment is based on the net present value (NPV). The base case provides an NPV of Rs. 25,229 million at the Government of India's official social discount rate of 12%. This indicates molasses based bioethanol production generates social benefits in excess of costs, and hence improves social welfare. The base case result is stable against the changes in the discount rate.

Table 3. Results of the economic analysis of molasses based bioethanol

Scenario	NPV (Rs. Million)		
	10% discount rate	12% discount rate	15% discount rate
Base Case	29 612.4	25 228.9	20 375.3
Base Case + Opportunity cost of industrial/potable bioethanol	-77 390.5	-65 934.5	-53 249.8
Base Case + CDM benefits	32 348.0	27 360.5	21 872.8
Cost increase by 20%	-52 216.0	-44 486.6	-35 928.1
Gasoline price increase by 15%	95 425.6	81 299.9	65 659.2
Gasoline price increase by 25%	139 301.1	118 680.5	95 848.5
Gasoline price increase by 40%	205 114.3	174 751.5	141 132.4

Avoided carbon emissions are estimated to be 6.56 million tons equivalent (tCO_2e) per annum at the 20% blending of bioethanol. This estimate is based on an estimate made by Ministry of Science and Technology (Government of India, 2010). According to this study, the net energy balance per 1000 liters of bioethanol from molasses is 19.11 gigajoule (GJ) and the net energy ratio is 4.57. Avoided carbon emissions per 1000 liters of bioethanol produced from molasses is 1.14 tCO_2e. If all the potential CO_2 reductions are carried forward for clean development mechanism (CDM) registration at an estimated rate of $5 per tCO_2e, the projected revenue is about Rs. 1,476 million per annum. However, eligibility for this benefit depends on the mandatory blending requirement. If 20% blending standard is made mandatory, only the carbon reduction over and above the 20% requirement will be eligible for CDM benefits. Therefore, realization of this benefit is unlikely. Despite this

uncertainty, we incorporated the CDM benefits in sensitivity analysis and the results show that adding the CDM benefit increases the NPV.

As a part of the sensitivity analysis, the potential opportunity cost was deducted from the benefits. Opportunity cost of displaced industrial and potable alcohol was estimated at Rs. 25 per liter, which was the market of price of bioethanol in industrial use. The results show negative NPV indicating molasses bioethanol is economically feasible only if incremental production (over and above industrial and potable alcohol) is used as a transport fuel. If any of the other current uses are displaced, the use of molasses based bioethanol as a transport fuel is not economically justifiable. Switching value analysis shows that 6% of the industrial or potable bioethanol displacement is sufficient to make negative NPV. Oil prices should increase by about 20% to off-set the negative impact of opportunity cost of industrial and potable alcohol. The clear message is that India should use only the excess bioethanol for transportation. Diverting industrial or potable alcohol for transportation will not benefit the country.

A 20% increase in cost will make molasses based bioethanol economically unfeasible, the bioethanol industry is quite sensitive to cost escalations. The major cost in the bioethanol industry is the cost of molasses. Cyclical fluctuations in sugar production make the fluctuations in price of molasses and using excess bioethanol for transportation in sugar surplus years can provide better benefits. The benefit of bioethanol also depends on the price of oil. As shown in the Table 3, the NPV increases as the price of oil goes up. The molasses based bioethanol industry will provide higher net benefits than those indicated by the base case, if oil prices increase in the future.

4.3 Economic Feasibility of Sugarcane Juice Bioethanol

In the above model it was assumed that molasses based bioethanol will provide half of the bioethanol for 20% blending requirements. In the overall (national) model the other half is assumed to come from sugarcane juice. Here, sugarcane juice is assumed to be directly used for bioethanol production without going through the sugar production process.

In the sugarcane juice based model, bioethanol production reaches 2.88 billion liters (half the 20% blending requirement) in 2017 with a gradual increase from 2013. One ton of sugarcane produces 100 kg of sugar and 45 kg of molasses, which contains about 25 kg of fermentable sugar. One kg of fermentable sugar produces about 0.56 liters of bioethanol. Therefore, the total quantity of bioethanol from one ton of cane is about 70 liters. Ten tons of sugarcane produce one ton of sugar. Therefore, one ton of sugar will be displaced by production of 700 liters of bioethanol. These parameters were used in the sugarcane based bioethanol model. In addition, the cost of production of sugar was estimated to be Rs. 23,723 per ton and the market value was estimated to be Rs. 30,000 per ton.

In the without project model the total quantity of bioethanol produced from molasses is used for industrial and potable alcohol purposes and its value was estimated at Rs. 25/liter. Table 4 shows the results of the 'without' project model. This model result NPV of Rs. 137,654 million at the 12% discount rate indicating sugar production together with bioethanol for industrial and other purposes is economically viable. Sugar production shows cyclical fluctuations and prices drop in excess production years. The net benefits under the without project scenario are quite stable to price drops and cost escalations. An unlikely price drop by abour 23% (Rs. 23,000 per ton of sugar) makes sugar plus bioethanol production economically infeasible. Overall, the results show that the without project scenario is economically quite attractive.

Table 4. Results of the economic analysis for sugarcane based bioethanol - without project scenario

Scenario	NPV (Rs. Million)		
	10% discount rate	12% discount rate	15% discount rate
Base Case	202 324.9	166 126.6	126 601.4
Sugar price decrease by 20%	58 268.1	47 843.3	36 460.3
Total cost increase by 20%	43 709.9	35 889.7	27 350.8
Bioethanol price decrease by 20%	185 518.3	152 326.8	116 085.0

Results of the cost benefit analysis of sugarcane juice beased bioethanol are given in Table 5. As is evident from the table the net benefits (NB_2) of sugarcane based bioethanol are negative. This is because the shadow value of bioethanol at current prices is lower than the cost of production. This clearly demonstrates that the use of sugarcane for bioethanol production is not economically feasible. Once the opportunity cost of sugarcane based bioethanol - displaced sugar and molasses based bioethanol- is incorporated into the model the negative benefits (NB_{INC}) or the economic losses become larger. The economic feasibility of sugarcane based bioethanol should be determined based on the last column of the Table 5. The negative values indicate it is not worthwhile to convert sugarcane juice to bioethanol.

The results clearly show converting sugarcane juice to bioethanol is not socially desirable. Adding CDM benefits or a decline in the sugar and industrial bioethanol price do not change the basic conclusion. An increase in petrol price by about 25% makes the conversion of sugarcane to bioethanol feasible but once the opportunity costs are added, NPV remains negative. This situation does not change even if petrol prices increase by 40%. Therefore, converting sugarcane to bioethanol will not be economically feasible even in the future with higher oil prices. Cyclical drop in sugar cane prices will only have a marginal impact on the economic feasibility of cane juice based bioethanol. About 40% drop in the sugar prices is required to make sugarcane juice based bioethanol economically viable. Even in surplus years, that type of a drop is highly unlikely.

Table 5. Results of the economic analysis of sugarcane juice based bioethanol

Scenario	NPV (Rs. Million)	
	Without Opportunity Cost, NB_2 (12% discount rate)	With Opportunity Cost, NB_{INC} (12% discount rate)
Base Case	-687 48.4	-234 8745.0
Base Case + CDM benefits	-65 211.5	-231 338.1
Sugar and Industrial bioethanol price decrease by 20%	-	-201 649.7
Sugar price decrease by 40%	-	1691.6
Gasoline price increase by 15%	-26 310.1	-192 436.7
Gasoline price increase by 25%	1982.0	-164 144.5
Gasoline price increase by 40%	44 420.3	-121 706.3

The results clearly show that the economic costs of sugarcane based bioethanol exceed the social benefits; hence there is no justification for expanding bioethanol production using sugarcane juice. Gunatilake and Roland-Holst (2013) also show using a general equilibrium model that 20% sugarcane bioethanol standard does not improve macroeconomic indicators of the Indian economy. Therefore, there is no justification for a promotional program or any government support for sugarcane juice based bioethanol production in India. In contrast to these results, the molasses based bioethanol is economically attractive provided that only excess bioethanol is used for transportation. Molasses based bioethanol does not have adverse effect on food sector too. If sugar production increases at around 4.5% per annum, there will be some excess molasses for producing bioethanol for transportation. However, potable alcohol and industrial alcohol demands are also increasing. Therefore, how much excess alcohol is available for blending is uncertain.

4.4 Economic Feasibility of Alternative Feedstock

This section assesses the economic feasibility of two alternate bioethanol feedstocks: TSB and SS. Today, there is no SS or TSB production on a commercial scale in India. However, research trials have been undertaken by agencies including the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The two basic financial models were built upon data from those trials, was used for economic analysis with the necessary modifications. Sweet sorghum can be cultivated under harsh conditions, but still it will have to compete with rain-fed food or feed crops such as corn or millet. Tropical sugar beet generally requires more water and other soil nutrients to produce an economically attractive yield. Therefore, the opportunity cost of TSB would be higher than SS because it replaces more profitable crops like legumes, onions or high value vegetables. We have assumed a positive opportunity cost for both crops in undertaking cost benefit analysis. The results are given in Tables 6 and 7.

Table 6. Results of the economic analysis of sweet sorghum based bioethanol

Scenario	NPV (Rs. Million)	
	Without Opportunity Cost, NB_2 (12% discount rate)	With Opportunity Cost, NB_{INC} (12% discount rate)
Base Case	4487.7	-40 027.6
Base Case + CDM benefits	6619.3	-37 895.9
Opportunity cost decrease by 20%	N/A	-31 124.5
Gasoline price increase by 15%	195 216.1	150 700.8
Gasoline price increase by 25%	212 191.4	167 676.2
Gasoline price increase by 40%	237 654.3	193 139.1

In the base case, without the opportunity costs, the NPV is positive. When we include the CDM benefits, the NPV is even more attractive. However, when the opportunity costs are included with the base case, the NPV becomes negative. Note that economic decisions should be made on the results of the model with the opportunity cost. The results basically show bioethanol based on SS is not economically feasible at current oil prices. However, when gasoline prices increase, in all cases the NPV becomes positive. Gasoline prices must increase by at least 15% for SS to become a part of India's biofuel industry with justifiable economic benefits. Regardless of oil prices, SS for fuel is competing with food crops; hence promotion of SS for fuel may conflict with the government policy of not compromising food security for promoting energy crops.

Just as in the case of SS, opportunity costs cause the NPV to become negative in the case of TSB. However, increases in gasoline prices likewise cause TSB to become economically viable. Just as with SS, gasoline prices must increase by at least 15% for TSB to become a part of India's biofuel industry with adequate economic benefits. Even at higher prices, TSB still competes for the agricultural resources, despite being economically attractive.

Table 7. Results of the economic analysis of tropical sugar beet based bioethanol

Scenario	NPV (Rs. Million)	
	Without Opportunity Cost, NB_2 (12% discount rate)	With Opportunity Cost, NB_{INC} (12% discount rate)
Base Case	2991.8	-24 402.2
Base Case + CDM benefits	5123.4	-22 270.6
Opportunity cost decrease by 20%	N/A	-18 923.4
Gasoline price increase by 15%	130 144.0	102 750.1
Gasoline price increase by 25%	141 460.9	114 066.9
Gasoline price increase by 40%	158 436.2	131 042.2

5. Conclusions

The economic analysis in this paper was conducted from the perspective of the nation and it focuses on the potential welfare change due to interventions on bioethanol. The analysis was conducted separately for molasses and sugarcane juice based bioethanol because molasses ethanol does not compete for agricultural resources. Results show molasses based bioethanol is economically feasible. However, if industrial and potable bioethanol are displaced, the costs exceed the benefits. Therefore, the drive to blend bioethanol should not result in displacing the current use of alcohol for potable and industrial purposes. In contrast, cost of sugarcane juice based bioethanol exceeds the social benefits, even without considering the opportunity cost of sugar. Once the opportunity cost of displaced sugar is added, the already negative net returns becomes larger, making sugarcane juice based bioethanol economically even more unattractive. Higher oil prices (even up to up to 40% increase) cannot make sugarcane juice based bioethanol economically attractive; hence, sugarcane based bioethanol will

not be beneficial to India. Tropical Sugar Beet and Sweet Sorghum are economically viable only with higher oil prices. Large scale production of these energy crop also will undermine food production in India.

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Notes

Note 1. Fiscal year 2008 refer to April 01, 2008 to March 30, 2009.

Note 2. E5 refers to 5% blending of ethanol.