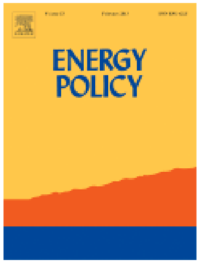

Energy Policy

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Assessing Viability of Bio-ethanol Production from Sweet Sorghum in India

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Abstract

To meet the energy requirement for transport, blending automotive fuels with ethanol has been mandated in India like several other countries across the globe. The entire blending requirement has to come from molasses (by-product of sugarcane). Ethanol produced from molasses will not be able to meet the blending targets due to cyclical nature of sugar cane production resulting in shortage of molasses and its competing uses (potable and pharmaceutical use). This has promoted research efforts to augment energy sources that are sustainable and economically viable. One such source that can be commercially exploited for ethanol production is sweet sorghum. The sugars in the stalks of sweet sorghum can be crushed to produce juice, which can be processed into ethanol for blending. An attempt is made in the paper to assess viability of ethanol production from sweet sorghum. Net Present Value (NPV) the indicator of economic viability assessment is negative and would thus be difficult for the industry to take off under the current scenario of ethanol price, feedstock price and ethanol recovery rate. Hence, an enabling environment and policy support for bio-ethanol production from sweet sorghum is crucial to meet future blending requirements.

Keywords: Bio-ethanol, Sweet Sorghum bio-ethanol, Economic viability

1. Back ground

Over the past two decades Indian economy has grown on an average at the rate of 5-6 % per annum. Energy consumption is one of the major indicators of the country's economic progress and is one of the major inputs for which use increases with economic growth and development. India ranks sixth in terms of energy demand accounting for 3.6 % of the global energy demand (Prasad et al., 2007) and this is expected to increase by 4.8% annually in the next few years (Gonsalves, 2006). The highest demand for energy in India comes from industry, followed by the transportation sector which consumed about 16.9% (36.5 m of oil equivalent) of the total energy (217 million t) in 2005-06 (TERI 2007). Currently, India's energy demand is primarily met through non-renewable energy sources such as fossil fuels (coal, natural gas and oil). Being short in domestic production, India mainly depends on crude oil imports that have risen from 57.8 million tons in 1999-2000 to 140.4 million tons in 2009-10 which accounts for about 81% of the oil consumption in the country (Ministry of Petroleum & Natural Gas, 2009). This in turn puts pressure on scarce foreign exchange resources (import bill of $75.6 billion in 2009-10). In the near future the imports are slated to rise further with no major breakthrough in domestic oil production and the rise in vehicular population that has grown at 10% per annum between 2001 to 2006[1] and is expected to continue in the near future.

In lieu of the growing concerns of energy security, environmental pollution due to high dependence on fossil fuels, globally, the focus has shifted to energy augmentation through renewable alternative sources to meet the energy demand

(GOI, 2009). To accomplish this, mandatory blending requirements of automotive fuels with ethanol have been introduced across several countries[2] and this has promoted research efforts towards energy sources that are sustainable and economically viable.

Among several alternative renewable energy sources like wind, solar, hydro and plant biomass, energy derived from plant biomass is gaining importance worldwide (Rao et al., 2007). Bioenergy derived from plant based biofuels has been the major thrust across countries to develop alternative energy sources. Bio-ethanol and biodiesel[3] are the two most common biofuels that are commercially exploited. *Palm, edible oil, Jatropha* and switch grass are some of the feedstock's that are used for production of biodiesel while sugarcane, corn, and sugar beet are common commercially exploited feedstocks for bio-ethanol. In India, molasses, a by-product from sugar production, is commonly used for alcohol and ethanol production. However, current estimates indicate that ethanol from molasses alone will not be able to meet the mandated requirement of blending.

2. Current status of demand and supply of ethanol in India

In January 2003, the Government of India launched the Ethanol Blended Petrol Programme (EBPP) promoting the use of ethanol for blending with gasoline and the use of biodiesel derived from non-edible oils for blending with diesel at 5% blending. Due to ethanol shortage during 2004-05, the blending mandate was made optional in October 2004, and resumed in October 2006 in the second phase of

EBPP with a gradual rise to 10% blending. These ad-hoc policy changes continued until December 2009, when the Government came out with a comprehensive National Policy on Biofuels formulated by the Ministry of New and Renewable Energy (MNRE), calling for blending at least 20% biofuels with diesel and petrol by 2017. Given that the mandatory blending requirements will be met in phases, the demand projections for ethanol blending are estimated at 5, 10 and 20% blending mandates (figure 1). Based on the projections [4], it is estimated that bio-ethanol requirement would be 3.46 billion liters by 2020 at the rate of 10% blending.

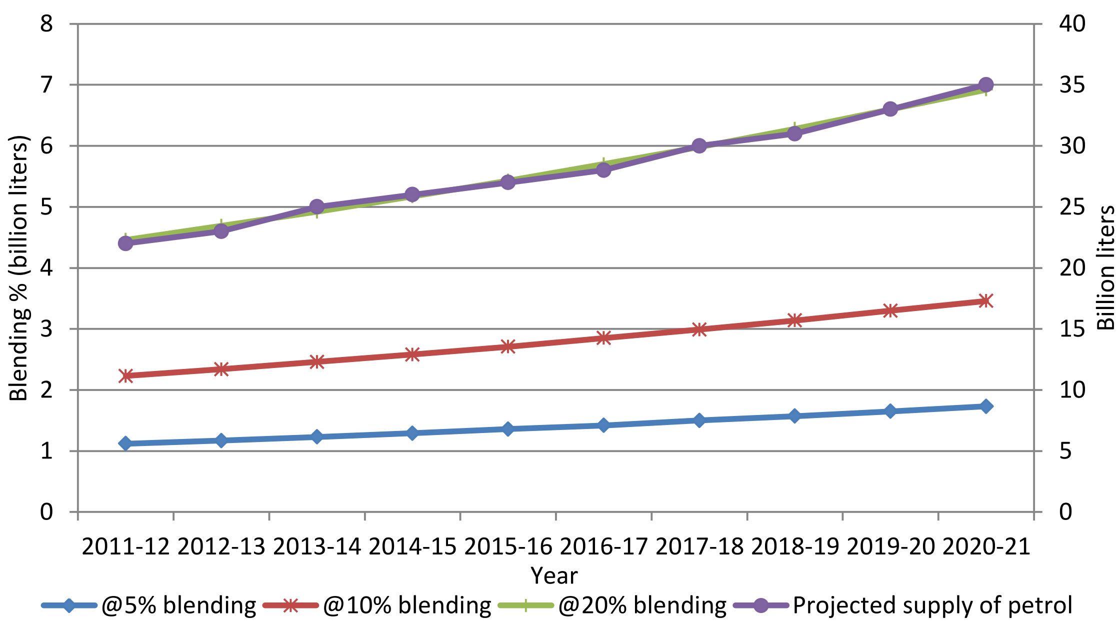

Figure1. Projected demand for petrol and ethanol for blending in India

Currently, the entire bio-ethanol requirement has to come from molasses, a by-product of sugarcane. The availability of molasses to meet blending mandates depends on cane and sugar production that are cyclical in nature. Lower molasses availability will put pressure on molasses prices and availability of molasses for ethanol production. Owing to the cyclical nature of sugarcane production in the country, the processing industry experience periodic market glut of sugarcane and molasses impacting prices. For example, the molasses prices in the last decade have fluctuated between Rs 1000 and Rs 5000 per ton (Shinoj et al., 2011). Additionally, ethanol produced has many other alternative uses such as potable alcohol, and the chemical and pharmaceutical industry. During a normal year, cane converted into sugar generates enough molasses to produce alcohol that can meet the needs of both the potable and chemical sectors (30-40% each). Another 20-30% surplus alcohol is available for conversion into ethanol for blending. However, during 2008–09 though the total ethanol supply of 2.4 million tons was sufficient to meet total demand at 1.80 million tons (potable, industrial and blending requirements), the utilization was more towards potable and industrial uses due to inability of the Oil Marketing Companies to procure the required amount of fuel ethanol bending at prevailing market prices (Shinoj et al., 2011). Import of ethanol for fuel usage is currently restricted through policy and even if made free, would cost the exchequer very dearly, as the international markets for ethanol are already very tight due to demand from other biofuel-consuming countries. Given the scenario of 10% blending requirement, the growing demand for alcohol from the potable and chemical sector (growing at 3-4% per annum) and the highest available alcohol from molasses pegged at 2.3 billion liters, there will be a shortage of alcohol for blending (Table 1). If molasses alone has to meet the entire requirement of 10% blending, an area covering approximately 10.5 million ha with 736.5 million tons of sugarcane has to be cultivated (around 20–23% in excess of what is required for meeting the corresponding sugar demand) which translates into doubling of both area and production. Presently, the country lacks both technology and infrastructure required to implement this. Further, it is not possible to increase the area under sugarcane beyond certain limit given that sugarcane is highly water intensive with a requirement of 20,000–30,000 m^3 per ha per crop. Increasing the area under sugarcane will be at the cost of diverting land from other staple food crops (Shinoj et al., 2011). Hence, ethanol production has to be augmented from alternative feedstocks. One such alternative that we are exploring in this paper is sweet sorghum which is both resource saving and sustainable (Ray, 2012).

Table 1. Availability and utilization of ethanol in India

Year	Highest available alcohol from molasses (billion liters)	Ethanol utilization (billion liters)		Balance (billion liters)	Ethanol required for Blending (billion liters) @ 10%	Deficit/ Surplus
		Potable	Industry			
2010-11	2.3	0.86	0.82	0.62	1.53	-0.96
2011-12	2.3	0.89	0.84	0.57	1.64	-1.14
2012-13	2.3	0.91	0.87	0.52	1.70	-1.32
2013-14	2.3	0.94	0.90	0.46	2.02	-1.53
2014-15	2.3	0.97	0.94	0.39	2.13	-1.76
2015-16	2.3	1.00	0.97	0.33	2.23	-1.99
2016-17	2.3	1.03	1.00	0.27	2.34	-2.24

2017-18	2.3	1.06	1.04	0.2	2.46	-2.51
2018-19	2.3	1.09	1.07	0.14	2.58	-2.78
2019-20	2.3	1.12	1.11	0.07	2.71	-3.09
2020-21	2.3	1.16	1.15	-0.01	2.85	-3.42

Source: Planning Commission (2003) estimates on highest available alcohol from molasses

3. Sweet Sorghum for Ethanol Production

Sorghum [*Sorghum bicolor* (L) Moench] is considered to be one of the most important food and fodder crops in arid and semi-arid regions of the world. Globally, it occupies about 45 million hectares, with Africa and India accounting for about 80% of the global acreage (Reddy et al., 2009). Like grain sorghum, sweet sorghum, a warm-season crop, can be cultivated by smallholder farmers in rainfed areas. The crop can be grown successfully on clay, clay loam or sandy loam soils and can tolerate salinity and alkalinity to a large extent (Reddy et al., 2008, Rao et al., 2009). Cultivation practices of sweet sorghum are similar to that of grain sorghum. The only dissimilarity between grain sorghum and sweet sorghum is seen in the accumulation of sugars in the stalks of sweet sorghum that can be crushed to extract juice, which is finally processed into ethanol for blending. Besides the juice extracted for bio-ethanol, additional benefits are the grain harvested for food, and bagasse left after extraction of juice from the stalk, which is an excellent feed for livestock.

In view of the potential benefits of sweet sorghum as a feed stock for bio-ethanol production, a value chain approach model of sweet sorghum as a food-feed-fodder-fuel is being tested on a pilot basis in Andhra Pradesh to augment incomes of farmers while promoting a sustainable sweet sorghum–ethanol value chain. It is in this context, that an attempt is made in this paper to assess;

a. The financial and economic viability of ethanol production from sweet sorghum,
b. The future area requirement for sweet sorghum cultivation to meet a small proportion of mandated blending requirements if sweet sorghum is commercially exploited with policy support.

3.1 Economic Viability Assessment of Bio-ethanol Production from Sweet Sorghum

The main objective of the economic feasibility assessment is to examine whether ethanol production is profitable along the different segments of the supply chain of sweet sorghum. The economic assessment is carried out by taking a case study of a pilot project on sweet sorghum value chain for linking sweet sorghum farmers to the ethanol industry implemented under the ICRISAT- National Agricultural Innovation Project (NAIP), Indian Council of Agricultural Research (ICAR) funded project. Under this project sweet sorghum farmers were linked to a distillery established at Medak district of Andhra Pradesh in India. The farmers cultivating sweet sorghum around the distillery are directly linked for supply of sweet sorghum stalk and the distillery entered into a buy back agreement with farmers to purchase the stalks at an agreed price prior to sowing of the crop[5].

3.2 Sweet Sorghum Value Chain

A flow chart of the sweet sorghum ethanol production scenario is presented in Figure 2. After harvest, the sweet sorghum stalks are transported from the villages to the distillery for ethanol production. The sweet sorghum stalks are crushed and separated into juice and bagasse at the distillery. The juice is fermented into ethanol, which is blended into transport fuel replacing conventional gasoline. The bagasse obtained during the process of crushing is used internally as fuel in the ethanol production process. The data used for estimating cost and revenues of ethanol production from sweet sorghum is obtained from the distillery. The costs include the investments made in setting up of the distillery, procurement cost of sweet sorghum stalk, operation and maintenance costs of distillery, labor costs, chemical costs, power cost to operate the plant, marketing and other related costs. The revenues include the returns generated from selling ethanol and the returns from selling by-products (bagasse, CO_2, vinasse and effluent) derived during ethanol production.

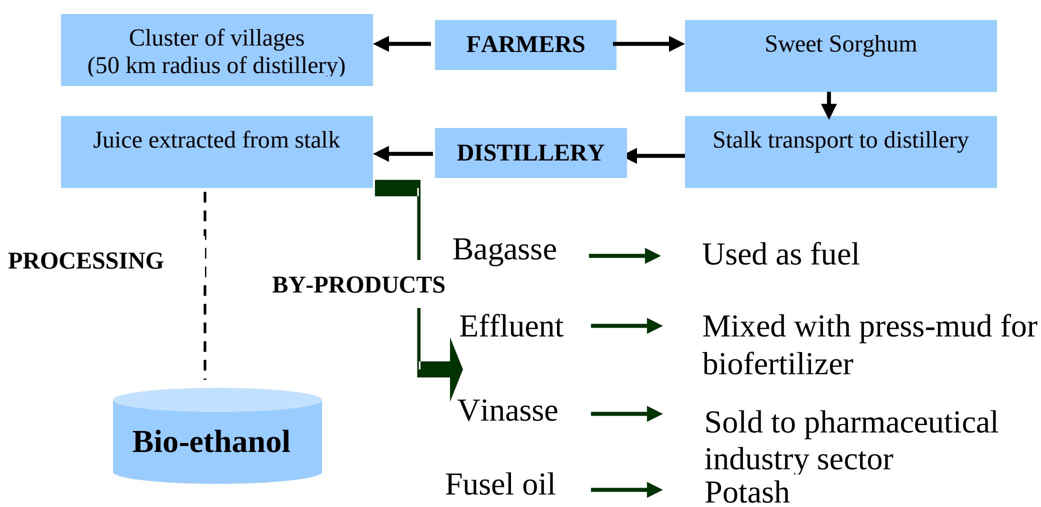

Figure 2: Sweet sorghum value chain for ethanol - Centralized Unit

4. Methodology and Data on Indicators for Economic Feasibility Assessment

The evaluation of investments on long term projects from an economic assessment perspective is through the discounted cash flow technique. The net present value (NPV) and internal rate of return (IRR) are commonly used measures to evaluate the economic performance of the project and investment risks. Accordingly, these two measures are used in our analysis.

4.1 Net Present Value (NPV)

NPV is an important financial index that plays a key role in decision making of long-term investment projects. A positive, higher NPV indicates that the net profits are higher so the investment may have favorable economic performance, or the investment is considered as economically feasible.

NPV is calculated as:

$$NPV = \sum_{n=0}^{N} (B_n - C_n)/(1+d)^{n}$$

Where $B_n = P_n \times Q_n$

B_n= Benefits or the returns from the distillery by selling ethanol and by-products

P_n is the ethanol selling price during year n,

Q_n is the annual production volume of ethanol in year n

C_n = Costs of ethanol production during year n,

d is the discount rate (the required rate of return)

n is the economic life of the investment.

4.2 Internal Rate of Return (IRR)

The IRR refers to the average earned capacity of an investment/project during its economic life. It equals the discount rate when NPV is set to zero. In general, the IRR should be greater than the discount rate for a project for economic feasibility.

IRR is calculated as:

$$IRR \Rightarrow \sum_{n=0}^{N} (B_n - C_n)/(1+d)^{\wedge n} = 0$$

B_n= Benefits or the returns from the distillery by selling ethanol

C_n = Costs of ethanol production

d is the discount rate (the required rate of return)

n is the economic life of the investment

The data on various parameters used for economic assessment of ethanol production from sweet sorghum was collected from the distillery and is presented in appendix A1. For parameters where the data was not available, assumptions were made based on expert opinion and secondary literature review for financial analysis.

The capacity of the plant is 40 kilo liters per day (KLPD) operating for 180 days. The reference year chosen is 2010 and the economic life of the project is 20 years. All economic costs and benefits (including by-products) are valued at current prices. The prevailing administered price of Rs 27/liter of ethanol announced by Government of India and conversion rate of 4.5% of ethanol per ton of sweet sorghum[6] is considered for financial and economic viability assessment. The landed cost of feedstock is Rs 1200 /ton of stalk.

5. Results and Discussion

The indicators of economic viability (Table 2) showed negative NPV of the project at a discount rate of 10% (bank rate) and benefit cost ratio of 0.89 with feedstock price at Rs 1200/ton of stalk and ethanol price of Rs 27/liter. Clearly, the cost of ethanol is highly sensitive to ethanol selling price, feedstock price and conversion rate. It would thus be difficult for the industry to takeoff under the current scenario of ethanol price, feedstock price and conversion rate.

Table 2. Indicators of economic viability assessment for ethanol production from sweet sorghum

Indicators	Feed stock price (Rs/ton)	Conversion rate (%)	Ethanol price (Rs/liter)
	1200	4.5	27
NPV (million rupees)		(344)	
BCR		0.89	

Source: Authors' own estimate
Note: Rs is the abbreviation for the Indian currency Rupees.

Sensitivity analysis

Sensitivity analysis was performed to derive the values of the key parameters where the project NPV becomes zero. The key parameters identified include, feedstock price, ethanol price and conversion rate. Findings from scenarios using varying values of key parameters are presented in Tables 3 and 4.

Two scenarios are developed, one based on increase in feedstock prices and the other on anticipated increase in price of ethanol as gasoline prices are also increasing. In the first scenario, at an optimistic conversion rate of 4.9% and feedstock price fixed at Rs 1200/ton of stalk, the price of ethanol should be Rs 29/liter where the project NPV becomes positive (Table 3). With the rise in cost of cultivation of sweet sorghum, if the stalk price increases to Rs 1500/ton with the conversion rates at 4.9%, the price of ethanol has to be increased to Rs 36/liter.

Table 3. Scenario 1- Sensitivity analysis with change in feedstock prices

Conversion rate (%)	Feedstock price (Rs/ton)	IRR	Expected ethanol pricing (Rs/liter)
4.9	1200	10.53	29
	1500	13.19	36

Source: Authors' own estimate

In the second scenario, since it is mandated to blend petrol with ethanol, it is anticipated that ethanol price will increase, with the increase in prices of petrol. If the ethanol prices increase to Rs 37/liter, even with a lower conversion of 3.7 % the distillery can break-even. If the feedstock price increases to Rs 1500/ton of stock with the ethanol prices remaining unchanged (Rs 27/liter) the expected ethanol conversion should be 6.7% to generate zero NPV (Table 4). Sensitivity analysis carried out has shown that even with a marginal improvement in conversion rate the NPV becomes positive.

Though indicators of economic viability are negative under the current technical parameters (crop yields and conversion rate) and policy regime (pricing), potential of sweet sorghum for ethanol production and comparative economics with other feedstocks is evaluated in view of the growing deficit of bioethanol as blending mandates are increased.

Table 4. Scenario 2-Sensitivity analysis with change in ethanol and feedstock prices

Feedstock price (Rs/ton)	Ethanol pricing (Rs/liter)					
	27		32		37	
	IRR	Expected ethanol recovery (%)	IRR	Expected ethanol recovery (%)	IRR	Expected ethanol recovery (%)
1200	8.1	5.3	13.7	4.3	9.6	3.7
1500	12.8	6.7	13.7	5.5	8.9	4.6

Source: Authors' own estimate

6. Potential benefits of sweet sorghum as feedstock for ethanol production

It is a well-known fact that sweet sorghum has the ability to adapt to drought, saline and alkaline soils and water logging conditions (Reddy et al., 2008, Rao et al., 2009). Besides, a shorter growing period of four months, it has a low water requirement as compared to sugarcane (Soltani et al., 1994). The water requirement for different biofuel feedstocks is presented in table 5[7]. Its lower cost of cultivation[8] and familiarity of farmers in cultivation of sorghum makes it much easier and willingness to grow sweet sorghum. The potential food versus fuel conflict from the diversion of crop land for its cultivation is allayed as sweet sorghum meets the multiple requirements of food, fuel and fodder. Additionally, bio-ethanol produced from sweet sorghum is more eco-friendly compared to ethanol produced from molasses.

Table 5. Comparison of some indicators between sugarcane, sweet sorghum and sugar beet as feed stocks for ethanol production

Crop	Cost of cultivation (USD ha^{-1})	Crop duration (months)	Fertilizer requirement (N:P:K kg ha^{-1})	Water requirement (m^3)	Ethanol Productivity (liters ha^{-1})	Av. stalk yield (t ha^{-1})	Per day Productivity (kg ha^{-1})
Sweet Sorghum (over two crops)	435	4	80:50:40	8000	4000 $year^{-1}$ (a)	50	416.6
Sugarcane	1079	12−16	250-400: 125:125	36000	6500 (b)	75	205.4
Sugarcane molasses	-	-	-	-	850 year(c)	-	-
Sugar beet		5-6	120:60:60	8000–10 000	6 000–6 400(d)	75-80	500-444

Source (a): Reddy et al. (2005). 50 t ha^{-1} millable stalk per crop @ 40 l t^{-1} (b) 85−90 t ha^{-1} millable cane per crop @ 75 l t^{-1} (c) 3.4 t ha-1 @ 250 l t^{-1} .
Source (d): Shinoj et al. (2011). 75–80 tons/ha of sugar beet @ 80 l/ton.

The result of relative economics of ethanol production from different feedstocks in India favors ethanol conversion from molasses (Appendix A2). Sweet sorghum is the second best alternative for ethanol production. Although economics favors production of ethanol from molasses, there is the problem of sustainability due to the reasons already discussed. The direct conversion of sugarcane juice to ethanol is also not economical and additionally there exists concerns of food security due to diversion of land for cultivation. Similar concerns (food security, increase in prices and economic viability) exist for conversion of grains for ethanol production. Given the scenario, sweet sorghum serves as an excellent alternative source to augment ethanol production to meet the blending mandates.

Hence policy and enabling environment support is required to promote production of ethanol from alternate feedstocks such as sweet sorghum. If an enabling environment is in place it would be interesting to know what would be the future area required to cultivate sweet sorghum. A land requirement exercise was carried out to understand this.

7. Land requirement assessment for sweet sorghum ethanol production

To understand how the ethanol blending demand would translate into future requirements of sweet sorghum area and production, an analysis was performed to assess the land requirement for sweet sorghum cultivation by 2020 if it is commercially exploited as an alternate source of ethanol production. It is expected that a crop like sweet sorghum would only bridge the gap in ethanol requirement supply from the existing feedstock i.e., molasses. The land requirement assessment for cultivation of sweet sorghum and production is undertaken with certain assumptions, with sweet sorghum meeting the entire deficit or partially in varying proportions. Land requirement for sweet sorghum cultivation is dependent on farm productivity and ethanol recovery rate. On-farm trials have shown that farmers can harvest upto 40 ton/hectare of sweet sorghum from current levels on farmer's field at 20 ton/hectare. There is also significant scope to improve productivity on farmers' fields.

The assessment on land requirement is developed based on two scenarios. The existing scenario of 20 ton per hectare productivity with 4.5% ethanol recovery rate and the other on potential scenario of 30 ton/hectare productivity with 4.5% ethanol recovery rate. These scenarios are developed to meet 30%, 50% and 80% of the deficit under 10% mandatory blending requirement. Based on the demand for bio-ethanol and the assumptions made above, land requirement assessment for cultivation of sweet sorghum till 2020 is presented in Table 6.

Table 6. Land assessment for sweet sorghum cultivation in ethanol production

Year	Deficit @ 10% blending requirement (billion liters)	Area requirement (million hectare)					
		SC1[1]		SC2		SC3	
		Existing[2]	Potential[3]	Existing	Potential	Existing	Potential
2011-12	-1.66	0.55	0.37	0.92	0.62	1.48	0.99
2012-13	-1.83	0.61	0.41	1.02	0.68	1.63	1.09
2013-14	-2.01	0.67	0.45	1.11	0.74	1.78	1.19
2014-15	-2.19	0.73	0.49	1.22	0.81	1.95	1.30
2015-16	-2.38	0.79	0.53	1.32	0.88	2.12	1.41
2016-17	-2.58	0.86	0.57	1.43	0.96	2.29	1.53
2017-18	-2.79	0.93	0.62	1.55	1.03	2.48	1.65

2018-19	-3.01	1.00	0.67	1.67	1.11	2.67	1.78
2019-20	-3.23	1.08	0.72	1.80	1.20	2.87	1.92
2020-21	-3.47	1.16	0.77	1.93	1.29	3.08	2.06

Source: Authors' own estimate
Note: 1. SC1 refers to meeting 30% of the ethanol deficit, SC2 refers to meeting 50% of the ethanol deficit and SC3 refers to meeting 80% of the ethanol deficit.
2. Existing case is 20 ton/ha productivity and 4.5 ethanol recovery rate and
3. Potential case is 30 ton/ha productivity and 4.5 ethanol recovery rate

The estimates show that to meet the deficit at 10% blending by 2020 (3.47 billion liters), at 20 ton/hectare productivity and 4.5% ethanol recovery rate, the area required will be about 1.16 million hectares with the assumption that 30% of the deficit is met from ethanol produced from sweet sorghum. However, with the improvement in productivity to 30 ton/hectare, the requirement of land would be only 0.77 million hectare. Assuming that 80% of the deficit ethanol requirement for blending is met through sweet sorghum, a modest area of about 2.06 million hectares will be required to cultivate sweet sorghum. This would amount to about 50% of the current *kharif* (rainy season) sorghum area that is under cultivation in India. Given that grain sorghum area under rainy season sorghum in Maharashtra (state with highest area under sorghum in India) is declining at an alarming rate, cultivation of sweet sorghum in these rainfed areas will provide income for farmers provided there is an enabling environment in place to support sweet sorghum production for ethanol production.

8. Conclusions

The economic and financial viability analysis has shown that viability of ethanol production from sweet sorghum depends on the ethanol and feedstock pricing, besides conversion rate to ethanol. A marginal improvement in recovery rate to 4.9% from the current level of 4.5% and ethanol price to Rs 29/liter (current price Rs 27/liter) and keeping feedstock price fixed at Rs 1200/ton of stalk, ethanol production from sweet sorghum becomes attractive. With the rise in cost of cultivation of sweet sorghum, if the stalk price increases to Rs 1500/ton with ethanol recovery rate at 4.9%, the price of ethanol has to be increased to Rs 36/liter.

The distillery did not realize potential benefits owing to few shortcomings. One of the major shortcomings was the need for extensive co-ordination and planning in the supply chain management. Delay in crushing stalks beyond 24 hours of harvest causing low recovery of ethanol per ton of stalk. Additionally, the distillery faced some teething problem in terms of functioning of crushers, boilers and other equipment. A 40 KLPD ethanol distillery requires continuous supply of feedstock from large area and hence mobilizing farmers to cultivate sweet sorghum and sourcing the raw material becomes difficult. Field observations have shown that considerable scope exists for increasing the efficiency both at crop production and processing stages. Hence, with improvement in crop and processing technology for ethanol production, the overall profitability of sweet sorghum cultivation and processing can be increased.

The estimates on the demand side of ethanol blending show deficits from the current level of supply, and that demand will outstrip supply. With the highest available alcohol from molasses at 2.3 billion liters coupled with the inability to increase area under sugarcane and adverse impacts on food production, the future supply of bioethanol has to be augmented through alternative feedstocks. The potential food versus fuel conflict from the diversion of crop land for cultivation of sweet sorghum does not arise as sweet sorghum meets the multiple requirements of food, fuel and fodder for small-holder farmers. Land requirement assessment for sweet sorghum cultivation has shown that area required for cultivation will be a modest 1.16 million hectares with the assumption that 30% of the mandated 10% blending deficit is met from sweet sorghum (at 20 ton/hectare productivity with 4.5% ethanol recovery rate). Given that grain sorghum area under rainy season in Maharashtra has declined in the last decade, cultivation of sweet sorghum in these rainfed areas will provide income for farmers provided there is enabling environment in place to support ethanol production from sweet sorghum. The relative economics augurs well in the agro-ecological regions of Maharashtra and Andhra Pradesh where sorghum is predominantly cultivated. Since ethanol production is from the stalks, the harvested grain from sweet sorghum adds to the food basket. As such, land for food will not be diverted for ethanol production.

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Footnotes:

[1] Authors own estimate based on Road Transport Year Book 2006-07, MoRTH, Government of India (2006).

[2] The mandatory blending requirements across different countries are- 3% in United States; 25% in Brazil;5.75% in European Union;10% in China and Indonesia; 5% each in Canada, United Kingdom, Australia and India.

[3] For the details of future prospects of Biodiesel production in India see Biswas et al. (2010).

[4] Authors' own estimates based on crude utilization available from Hand Book of Statistics on Indian Economy, RBI (2011).

Assumptions made for projecting demand for petrol and ethanol blending area. Growth rate of 8% per annum is assumed for crude oil supply which is average of 2000-01 to 2009-10.The share of petrol in total crude is 9% for 2007-08, 14% for 2009-10 and 13% for rest of the years. based on the report of the working group on petroleum and natural gas sector for the XI plan (2007-2012) and the conversion of metric ton to liters is based on the conversion rate of 1 metric ton of crude=7.33 barrels and a barrel is equal to 0.159 kiloliters

[5] Data on cost of cultivation collected over a period of 3 years by ICRISAT across various locations under the project "value chain model for bio-ethanol production" funded by NAIP, ICAR, Government of India, shows that the yield of sweet sorghum stalk has varied between 14 to 18 ton per hectare with feedstock priced at Rs.700-1000 ($ 15- $ 22) per ton of stalk. On an average, the cost of cultivation has varied between Rs.9476 ($211) to 11,765 ($261) per hectare excluding family labor.

[6] A range was provided by the distillery on the recovery of ethanol which varies between 4 to 4.8 %. For economic feasibility assessment an average recovery of 4.5% is considered for our analysis.

[7] A policy paper of International Water Management Institute (IWMI, 2008) shows that in India, where sugarcane depends heavily on irrigation it take 3,500 liters of water to produce a liter of ethanol which is the highest compared to Brazil, USA and Northern China. The policy paper highlights that sweet sorghum requires only one-seventh as much water as sugarcane.

[8] The economic competitiveness of sweet sorghum worked out from on-farm data for three years by the authors across locations of Maharashtra and Andhra Pradesh has shown that sweet sorghum is competitive with dryland crops such as sorghum and maize. The benefit cost ratio for sweet sorghum was 1.55 while it was 1.30 and 1.37 respectively for maize-pigeon pea intercrop and sorghum-pigeon pea intercrop.

Appendix:

A1. Details of the indicators used in financial feasibility assessment[a]

Assumption	Indicators
Capital expenditure (million Rs)	50
Operating days	180
Distillery capacity (kiloliters per day)	40
Sweet Sorghum feedstock requirement (tons /kiloliter)	22.3
Feedstock stock price (per ton of stalk at the gate)	1200
Requirement of bagasse as fuel (tons per kiloliter)	5
Cost of bagasse (Rs/ton)	1000
Labour cost (Rs/kiloliter per day)	400
Cost of power (Rs/kiloliter)	2500
Chemical cost (Rs/kiloliter)	1000
Operation and maintenance cost (Rs/annum)	30000
General costs (Rs for entire life of project)	3000000
Marketing and other expenses (Rs/kiloliter)	1000
General inflation (%)	3
Output (Main product and by-products)	
Recovery of ethanol per ton of stalk (liters)	45
Output of ethanol (kiloliters per day)	40
Selling price of ethanol (Rs/liter)	27

Escalation in price of ethanol	1.5%[b]
Recovery of CO_2 (tons /40 KLPD)	20
Selling price of CO_2 (Rs/ton)	10000
Additional recovery of bagasse (tons/ 40 KLPD)	150

Note: a The interest on working capital is taken as 13% and debt to equity ratio as 60:40. The investment made is for 25 years. The term loan interest assumed is 6% as loans provided are classified as priority sector lending. A depreciation rate of 5% is assumed on the capital expenditure and repayment of 10 years.
b Though the demand for alcohol from potable and alcohol are growing at 4% per annum, the escalation in prices alcohol assumed is on a conservative basis.

A2. Relative economics of ethanol production from different feedstocks in India

Parameter	Sweet sorghum	Sugarcane molasses	Sugarcane juice	Grains (Pearl millet & broken rice)
Cost of raw material (Rs t^{-1})	700[a]	3000-5000[b]	1200[c]	8000[c]
Cost of processing (Rs t^{-1})	384	1890	490	2800
Total cost of ethanol production (Rs t^{-1})	1084	4890-6890	1690	10800
Output of ethanol (liters)	45	270	70	400
Value of ethanol (Rs t^{-1})	1215	7290	1890	10800
Net Returns (Rs t^{-1})	131	2400 - 400	200	0
Cost of feedstock (Rs liter^{-1})	15.5	11.1-18.5	17.1	20.0
Ethanol (Rs liter^{-1})[d]	24.0	18.1-25.5	24.1	27
Profit for ethanol (Rs liter^{-1})	2.9	8.8 - 1.4	2.85	0

Note: The information on the parameters is collected from Rusni distilleries for sweet sorghum, Nizam Deccan Sugars Pvt. Ltd. for molasses and AGRO Bio-tech, Ajitgarh, Rajasthan for grains.
The value of by-products is not considered in the analysis.

a. Even when the feedstock is priced at Rs. 800, it becomes profitable to produce ethanol from sweet sorghum without accounting for capital costs. However, the cost of feedstock has varied in the range of Rs.700-1200/ton.
b. The molasses prices have ranged between Rs 3000 to 5000/ton during the last few years and hence the profitability of molasses ethanol production is highly sensitive to fluctuating molasses prices.
c. The data on all the other feedstock costs is for the year 2009. The prices of feedstock (sugarcane and grains) have increased in the recent years.
d. A Study from USDA (2006) shows that the average ethanol production from sugarcane in Brazil was the lowest at USD 0.214/liter compared to ethanol production from corn in United State of America at USD 0.27/liter and from sugar beets in EU at USD 0.76/liter. Comparable figures for molasses as a feedstock in India are USD 0.57-0.60/liter and sweet sorghum at USD 0.55/liter excluding capital costs during 2010.