Net Energy Analysis of Sugarcane based Ethanol

Does Sugarcane as a feedstock for Ethanol make sense in India?

Why this discussion?

- Ethanol is being promoted as an attractive **renewable fuel** for blending with gasoline.
- Ethanol in India is produced from sugarcane via a sugarcane-sugar-molasses-ethanol route.
- Sugar industry is also considering the possibility of direct conversion of sugarcane to ethanol considering the uncertainty of sugar prices.

Motivation of this paper

- Corn which is widely used for ethanol production in United States has found to have a negative energy balance by some analysts(Pimentel et al) while others (Shapouri et al)point to the contradictory and strongly advocate corn based ethanol.
- Considering the debate,we thought why not attempt a similar analysis for sugarcane based ethanol for Indian conditions
- Our understanding of Sugarcane cultivation practices in Maharastra motivated us in doing preliminary investigations .

Net Energy Value

- Net energy value can be defined as energy content of ethanol minus the fossil energy used to produce ethanol.
- Energy required for ethanol production includes energy input for sugarcane production and energy input for sugarcane conversion to ethanol.

Methodology

- Data on ethanol yield from sugarcane obtained from sugar industry sources.
- We have assumed fossil energy input for ethanol processing as nil based on our sample study of sugar industry producing sugar and ethanol because bagasse is a major fuel.

Methodology

- Parameters like crop duration, crop productivity, pump capacity and usage, fertilizer inputs and tractor use and its diesel consumption were obtained from investigation. **Interviews were conducted with ten farmers of Niphad tehsil a sugar belt in Nasik,Maharastra.**

Questions posed to farmers

- Area under sugarcane crop
- Source of irrigation-well,canal.
- Capacity of pump installed.
- Number of waterings in different seasons in the entire crop cycle
- Hours of pump operation per acre per watering.
- Fertilizer used per acre.Diesel required for farm operation.
- Productivity/acre in the last three years.

Energy input/acre for sugarcane production

- Energy (electricity) input for pumping/ irrigation.

  (Obtained from farmers responses on irrigation practices)
- Energy (diesel) required for sowing, ploughing and harvesting per acre (Obtained from farmers responses and using LCV for diesel.)
- Energy input in the form of chemical fertilizers (Obtained from data from farmers responses on fertilizer application practices. Data on energy input for fertilizer manufacturing was obtained from Klass.)

N	48.65 MJ/kg
P	13.99 MJ/kg
K	5.11 MJ/kg

Assumptions on yield of ethanol/Tonne of sugarcane to get energy input/litre

- Sugarcane industry produces about 10 litres of ethanol and 110 kg of sugar from 1000kg of sugarcane via sugarcane-sugar-molasses-ethanol route.
- According to industry sources 76 litres of ethanol can be produced from the same quantity of sugarcane if sugarcane is directly converted to ethanol. Our calculations are for direct route.
- Sugarcane productivity is 32tons/acre(80 tons/ha) from which we convert energy input/acre to energy input/litre

Bagasse surplus from Sugar factory

- Niphad Sahakari Sakar Karkana a sugar factory located in Niphad ,Nashik was surveyed.
- Crushing capacity is 4650 tons/day and bagasse generated is 1050 tons/day(about 22%)Four 22 bar (abs)boilers (efficiency 65- 70%) with steam generation rates of 30T/h each operated on an average for 20 hours and consumed all the bagasse to meet the energy requirements(electricity and shaft power) of the factory.No surplus bagasse was available .

Average scenario from case study

Parameter	Data	%	Comments
Irrigation energy	16.7 MJ/litre	71.4 %	Pumping energy. The calculations are done assuming overall (fuel to electricity) efficiency of 33%.
Fossil fuel energy input for Fertilizers	6.3 MJ/litre	26.9 %	Data on energy required for production of Fertilizers using the figures cited by Klass (1998). Fossil input will be more for less efficient Indian Fertilizer Industries.
Energy input for farm operations	0.4 MJ/litre	1.7%	Diesel required for ploughing etc
Energy input in ethanol processing	0 MJ/litre		Capital energy inputs in materials for sugar industry neglected. Energy input for ethanol processing is assumed zero because baggase is the major fuel.
Fossil energy input to ethanol	23.4 MJ/litre	100%	
Energy content available in ethanol	21.4 MJ/litre		Calorific value of anhydrous ethanol assumed is LHV 21.4 MJ/litre
Net energy value of ethanol	- 2 MJ/litre		

Findings1-
Major contribution - energy for irrigation

- Water intensive crop and grown under irrigated conditions (unlike in Brazil)
- No incentive for energy and water saving when flat rate tariff rates for Irrigation Pump Sets.

Sensitivity analysis-Water management helps

Parameter	Average scenario of irrigation	Reduction of irrigation energy by 25%	Reduction of irrigation energy by 50%
Irrigation energy	16.7 MJ/litre	12.5 MJ/litre	8.35 MJ/litre
Fossil fuel energy input for fertlizers	6.3 MJ/litre	6.3 MJ/litre	6.3 MJ/litre
Energy input for farm operations	0.4 MJ/litre	0.4 MJ/litre	0.4 MJ/litre
Energy input in ethanol processing	0 MJ/litre	0 MJ/litre	0 MJ/litre
Fossil energy input to ethanol	23.4 MJ/litre	19.2 MJ/litre	15.05 MJ/litre
Energy content available in ethanol	21.4 MJ/litre	21.4 MJ/litre	21.4 MJ/litre
Net energy value of ethanol	- 2 MJ/litre	2.2 MJ/litre	6.35 MJ/litre

Findings 2- fertiliser application takes away significant renewable content

- Irrationality on the part of users/farmers.(failure of agricultural extension service)
- With monocropping (sugarcane)soil fertility has seen to be decreasing requiring increasing dose of fertilizers .

Findings 3- Productivity Improvement is not of much help without reduction in irrigation energy .

Parameter	**Average scenario of productivity**	**Increase in productivity by 25% by increasing fertilizer use by 25%**	**Increase in productivity by 50% by increasing fertilizer use by 50%**
Cane productivity	32 Tons/acre	40 Tons /acre	48 Tons /acre
Irrigation energy	16.7 MJ/litre	13.36 MJ/litre	11.14 MJ/litre
Fossil fuel energy input for fertlizers	6.3 MJ/litre	7.87 MJ/litre	9.45 MJ/litre
Energy input for farm operations	0.4 MJ/litre	0.4 MJ/litre	0.4 MJ/litre
Energy input in ethanol processing	0 MJ/litre	0 MJ/litre	0 MJ/litre
Fossil energyiInput to ethanol	23.4 MJ/litre	21.63 MJ/litre	20.98 MJ/litre
Energy content available in ethanol	21.4 MJ/litre	21.4 MJ/litre	21.4 MJ/litre
Net energy value of ethanol	- 2 MJ/litre	-0.23 MJ/litre	0.42 MJ/litre

Concluding Remarks

- Method of sugarcane cultivation practiced by farmers –especially irrigation and fertilizer inputs is responsible for ethanol having a negative or marginally positive energy value.
- Efficient water application,increase in productivity and judicious fertilizer application can improve its Net Energy value .This can be done with proper policy environment – rationalization of energy and fertilizer prices .
- However these strategies have a limitation because sugarcane is water intensive crop.
- Hence alternative feedstock should be banked on as a long term measure.

We are planning a detailed analysis considering

- Different Agro climatic zones or at least different major sugar growing regions of India.
- Considering scenarios with
- a.surface irrigation b. groundwater irrigation
- c.rainfed regions (if any)
- Calculation with fossil energy inputs for a fertilizers from Indian Industry
- Giving energy credits to ethanol co-products.
- Considering energy balance for modern ethanol processing technologies

We also plan to calculate net employment gain

- Ethanol is a byproduct of sugar industry which has a special place in rural economy.
- Sugarcane is an important crop which gives stable returns to farmers.However it consumes precious water which otherwise could be used for alternative less water intensive crops
- For India parameter like Net rural employment gain(difference between employment produced in sugarcane-ethanol chain and employment lost if water for sugarcane is diverted to larger tracts for some other crop)can be calculated along with NEV.

- *Thanks for listening*

Brazil versus case study

	Irrigation	fertilizer	Other farm operations	Ethanol conversion	Surplus bagasse	NCV	Net energy
Case study	8.3	6.3	0.4	0	0	21.4	6.4
Brazil	0	0.8	1.54	0.6	1.9	21.4	16.6

Fertiliser application rates

	Case study kg/acre	Recommended values kg/acre	Brazil kg/acre (Macedo et al 2004)
N	150	160	25
P	110	80	15
K	60	80	40

Recommended values energy/kg of fertilizer

	Klass (1998)	Brazil (Macedo et al 2004)
N	48.65 MJ/kg	62 MJ/kg
P	13.99 MJ/kg	8.66 MJ/kg
K	5.11 MJ/kg	6.7 MJ/kg

Productivity values

	Brazil (Macedo et al)	Case study
Average	65 tons/ha	80 tons/ha (32 t/acre)
Maximum	110 tons/ha	120 tons/ha (48 t/acre)

Surplus Bagasse/tonne of cane

	Bagasse/ton	Surplus bagasse	MJ/litre
Case study	225 kg	0 kg	0
Brazil	280 kg	22 kg (8%)	1.9 MJ/litre

Average values from the survey

- Productivity 32 tons/acre or 80 tons/ha.
- Capacity of pump 7.5 HP (2 Farmers used 5 HP but their number of hours of watering were more)% loading neglected.At 85% loading balance positive.
- Number of hours pump is operated during watering 16(Farmers said that due to load shedding they operate their motors even for three days.Load shedding has ironically increased energy consumption)
- Waterings per crop cycle 42
- Typical Depth of well 80 feet (25 metres)
- Most commonly reported Fertiliser application rates and diesel consumption rates used

Caveats about our study

- Since fertilizer and irrigation practices are dependent on agro climatic conditions our sample of Nashik may or may not represent overall Indian scenario.
- Capital energy inputs not considered.
- Energy intensity of fertilizer industries in India not considered.
- Possibilities of surplus bagasse with more efficient sugarcane processing industries with cogeneration not explored