

## Perspective on Energy from Sugarcane

### Introduction

This report uses published data to show the likelihood of being able to feasibly utilize the energy in sugarcane. The report is based in raw sugar factory operations in Louisiana. Present raw cane sugar factories are designed to process sugarcane into sugar and they use the energy in the stalk (the fiber, bagasse) to produce energy for internal use to operate the factory. Bagasse is burnt in boilers which produce steam to provide internal heat, steam power and electrical power for the factory. The bagasse has been traditionally regarded as a byproduct that, if allowed to accumulate can create an agricultural waste problem, therefore factories have been designed with only the efficiencies needed to consume all the bagasse as a fuel to be burnt in their bagasse fired boilers. Making the factories more thermally efficient could produce a surplus of bagasse which might be used as a source of energy to produce electricity and/or ethanol for export, for sale. In addition, the sugar market within the USA, which has been traditionally shielded from the international sugar market by an import control mechanism, is feeling more pressure to accept foreign produced sugar and this has the effect of preventing the US price of raw sugar from increasing, and may even result in a sugar price decline. With the possibility of a declining sugar market there could also be sugar available from the sugarcane that might be converted into another form of energy, ethanol.

There has been talk of building so called bio-refineries which would utilize a selection of bio-mass, vegetative crop material, as feedstock for the process and produce multiple chemical and food products and energy for powering transport vehicles and industry. Often, plants which process agricultural crops have primarily targeted the most profitable product they can manufacture

and any byproduct, which happens to result from the process, is treated as a bonus to the main stream of income from the principal product. As the availability of natural resources, particularly energy, become more stressed and as concern for the environment increases, more incentives are being found for processing plants to make maximum use of every benefit that might be derived from a cultivated crop. In the case of the sugarcane crop better use of its bagasse is one possibility, but there is also the organic matter, dried leaves and green leaves, also called cane leaf matter (CLM), that are removed and left in the fields, from which useful energy might be derived if they were collected and processed. The processing of stalk and leaf matter into energy, particularly into ethanol, is receiving more research attention and it is possible that, with the efficient conversion of cellulosic material to ethanol, this could become another substantial source of income for the sugarcane industry. This report does not focus on the aspect of converting cellulose to ethanol because there are no commercially operating processing plants which achieve this and hence there is no established production cost data. Some reference to this manner of obtaining energy from sugarcane must be considered because the potential benefit for the sugar industry might be great enough to result in a substantial change to the way the sugarcane industry operates. For example, it may decide that it should incorporate into its practices, the cultivation of sugarcane varieties which contain less sugar but which yield higher stalk weight per given area of land.

### The Source Data

One document, which contains comprehensive data relating to ethanol production in the USA, is titled "The Economic Feasibility of Ethanol

Production From Sugars In The US" and it is authored by Dr. Houssein Shapouri and Dr. Michael Salassi in July 2006(1). Dr. Salassi is a Professor of Agricultural Economics at the LSU Agricultural Center and he has written many documents relating to the cost of sugar cane production. While this document focuses primarily on the production of ethanol there is a need to look further in order to chart a path which an existing raw cane processing plant might take if it were to become involved in ethanol production as a second stream to its main sugar processing stream or if it were to operate as a dual facility producing sugar at some time and ethanol at another, as the market demanded. In addition, there is a need to show what income might be derived from producing electricity for export. This document is referred to in the tables and text below as (1).

A second document titled "Production Of Ethanol From Sugarcane" is authored by U. C. Upadhiaya and was written in March 1996(2). This document describes a process whereby all the juice from the sugarcane is converted to ethanol and the bagasse is used for providing the internal energy needs of the processing plant as well as electricity for export. In addition there is a set of calculations which provide background data for this report. This document is referred to in the tables and text below as (2).

Report (1) is available from the Internet. A basic steam and product balance calculation for the Upadhiaya report is also available on the Internet at [www.iberiasugar.com](http://www.iberiasugar.com).

### Comparing The Data

In order to make the connection between the recoverable energy and food value in sugarcane and income which might be derived as a result of selling these commodities it is necessary

to set out the basic starting data and the data which relates to the price and government incentives for producing

energy and food in this way. The following is a comparison of the data taken from the reports:

Parameter	Source	Comments	Metric		Imperial	
			Units	Value	Units	Value
Sucrose yield (as sugar) from sugarcane	(1), pg 46	---	tonne/tonne	0.1175	lb/ston	235
Sucrose yield (as molasses) from sugarcane	(1), pg 46	---	tonne/tonne	0.0208	lb/ston	41.6
Sucrose yield from sugarcane	---	---	tonne/tonne	0.1382	lb/ston	276.6
Yield of ethanol from sucrose stoichiometric (theoretical)	(1), pg 17 (per Dr. P Rein)	---	L/kg	0.680	US gal/ston	163
Maximum obtainable yield under ideal conditions	(1), pg 17 & (2)	Experiments by Louis Pasteur	%	94.5	%	94.5
Maximum obtainable yield under ideal conditions	(1), pg 17	$163 \times 0.945 = 154$	L/kg	0.642	US gal/ston	154
Yield of ethanol from sucrose in laboratory conditions	(1), pg 17	---	L/kg	0.621	US gal/ton	149
Yield of ethanol from sucrose in practical conditions	(1), pg 17	$149 \times 0.945$	L/kg	0.588	US gal/ton	141
Yield of ethanol % theoretical yield	(1), pg 17	$141 \times 100 / 163$	%	12	%	86.5
Pol (sucrose) % cane	(2)	---	%	12	%	12
Sucrose yield from sugarcane	(2)	$12 \times 2000 / 100$	tonne/tonne	265	lb/ston	240

Note: this is 15% lower than the sucrose yield assumed in report (1). In order to obtain the sucrose yield shown in the report (1) would require a pol % cane value of 13.8%

Yield of ethanol from total fermentable sugars (TFS)	(2)	---	L/kg	0.620	US gal/lb	0.0738
Yield of ethanol from total fermentable sugars (TFS)	(2)	$0.738 \times 2000$	L/kg	0.620	US gal/ston	148
Fermentable sugar and yield loss in process	(2)	---	%	27	%	27
Yield of ethanol from sucrose in practice	(2)	$148 \times (1-27/100)$	L/kg	0.450	US gal/ston	108
Yield of ethanol % theoretical yield	(2)	$108 \times 100 / 163$	%	66.3	%	66.3
Yield of ethanol if sucrose yield is increased by 15% to a pol % cane value of 13.8%	---	$108 \times 1.15$	L/kg	0.517	US gal/ston	124
Yield of ethanol % theoretical yield if sucrose yield is increased by 15% to a pol % cane value of 13.8%	---	$66.3 \times 1.15$	%	76	%	76

Note: this ethanol yield, adjusted for higher pol % cane, in the calculation in report (2) is still about 13% lower than suggested in report (1). The only way that the number in report (2) could be increased is if the losses of 27% were reduced. Is it practical to think that these losses can be reduced?

The cane quality entering the process must be established. Cane with low fiber and high sucrose will yield high sugar and high ethanol from juice but will not provide large quantities of surplus bagasse for electrical power generation. Furthermore if cellulosic conversion to ethanol is considered, the amount of surplus bagasse will impact the amount

of ethanol which might be derived from this process. Report (1) provides limited details about the quality of the sugarcane expected to be processed. For future discussion in this document the pol % cane value will be considered to be that which will yield ethanol from sugarcane at 141 US gal per ston sucrose. This pol % cane value is likely

to be high when compared with more normal Louisiana values of about 12%.

If the existing practice of recovering sugar from sugarcane in Louisiana is followed, the amount of sugar that might be recovered per unit of cane is about 210 lbs per ston and there would also be about 5.5 US gallons per ston of molasses produced for sale.

Report (1) page 26 uses prices for sugar and molasses as follows:

Sugar		=	\$0.211 per lb
Molasses		=	\$63.00 per ston
Molasses density	at 78.5 Brix, approximation	=	12 lb per US gal
Molasses	63 x 12 / 2000	=	\$0.378 per US gal

The income per ton cane derived from the sale of sugar and molasses would be:

Sugar	210 lb/ton x \$0.211/lb	=	\$44.31 per ston cane
Molasses	5.5 US gal/ton x \$0.378/US gal	=	\$ 2.08 per ston cane
Sugar & Molasses		=	\$46.39 per ston cane

If, instead of making sugar and molasses, ethanol is made at a yield of 141 US gallons per short ton of sucrose and 276 lb sucrose per ston cane (or 276/2000 ston sucrose per ston cane) and at a price of \$2.05 per US gal (Chicago Board of Trade price as of April 17, 2007) plus a \$0.51 per US gal Federal excise tax credit, the income derived would be:

Sucrose per ton cane		=	276/2000 ston sucrose per ston cane
Ethanol per ton sucrose		=	141 US gal per ston sucrose
Ethanol per ton cane	141 x 276 / 2000	=	19.458 US gal per ston cane
Ethanol price + credit	\$2.05 + \$0.51	=	2.56 per US gal
Ethanol income	19.458 x 2.56	=	\$49.81 per ston cane

The income from producing and selling ethanol alone would be 49.81 - 46.39 = \$3.42 per ston cane more, at the current prices, than the income from producing and selling sugar and molasses.

This is still not a good comparison of the relative benefits of producing and

is 200 lb per ston). The cost of producing ethanol is about \$2.40 per US gal of ethanol (or \$2.40 x 19.458 US gal per ston cane = \$46.69 per ston cane).

The relative profit per ton cane which stands to be made from either producing sugar and molasses or from producing ethanol might be as presented below:

ethanol would be \$49.81 + \$3.27 = \$53.08 per ston cane. This would require an ethanol price of \$53.08 / 19.458 = \$2.73 per US gal.

Electricity generated from surplus bagasse would need to generate an income of \$3.27 per ston cane.

Ethanol yield would need to be increased from the present 19.458 US gal per ston cane to about 53.08 / 2.56 = 20.73 US gal per ston cane by the cellulosic conversion of surplus bagasse to ethanol, at no extra cost.

### Government Price Support

Government price support for ethanol is provided through a Federal excise tax credit of \$0.51 per US gal. This has already been added to the price above.

Product	Income \$/ston	Cost \$/ston	Profit \$/ston
Sugar and molasses	46.39	40	6.39
Ethanol	49.81	46.69	3.12
Difference			3.27

selling ethanol as opposed to producing and selling sugar and molasses. The cost of producing and selling sugar and molasses is about \$0.20 per lb sugar (or \$40.00 per ston cane if the sugar content

In order to make up for this difference there are various possibilities as follows:

Ethanol price would need to increase so that the income from the sale of

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## Exported Electrical Power

In report (2) electricity for export of about 95 kWh per ston cane might be expected. For a 10,000 ston per day factory, this equates to a daily energy output of 950 MWh per day or about 40 MW of installed generating capacity, if all the surplus bagasse is consumed every day. The sale of electricity to a public utility has many hurdles and, depending on the particular circumstances of the utility to which power is being sold, the price, received for that electricity, may vary considerably. Purchase of electrical power from a public utility in Louisiana is presently about \$0.09 per kWh. The sale of surplus electricity to a public utility in Louisiana will result in an income of about \$0.04 per kWh. Therefore the sale of surplus electricity using the model in report (2) would represent about  $95 \times 0.04 = \$3.80$  per ston cane. This amount is sufficient to make up for the \$3.27 per ston difference between the income from producing sugar and molasses and from producing ethanol alone.

Renewable energy credits (RECs) will

also provide some income for a generator of electricity from renewable energy sources. The expected income which might be derived from RECs is about \$0.004 per kWh. When this is added to the sale price the total income from electricity sales would be  $\$0.044$  per kWh or about  $95 \times 0.044 = \$4.18$  per ston cane. This further compensates for the \$3.27 per ston difference.

## Conversion Of Cellulose In Sugarcane Bagasse To Ethanol

In the process scheme described in report (2) the steam required to be exhausted from the turbine for process use is 915 lb per short ton of cane. This is the minimum amount of steam that will need to be produced from bagasse. This amount of steam will generate 50.84 kWh per tonne cane or  $50.84 \times 2000 / 2204.6 = 46.12$  kWh per ston cane. The internal electricity consumption is 24.26 kWh per tonne or 22 kWh per ston. The amount of surplus electricity, at minimum bagasse used for steam production, now becomes  $46.12 - 22 = 24.12$  kWh per ston cane and

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could generate an income of  $24.12 \times \$0.044 = \$1.06$  per ston cane.

Instead of utilizing all the available bagasse to generate 1,576 lb of steam per short ton of cane, only 915 lb per ston is used. The total bagasse available is 571 lb per ston cane, but only  $571 \times 915 / 1576 = 332$  lb bagasse per ston cane will be required for steam production, leaving  $571 - 332 = 239$  lb bagasse per ston cane available for cellulosic conversion to ethanol.

Bagasse comprises of cellulose, hemicellulose, lignin and other materials in approximately the following proportions:

<b>Cellulose</b>	<b>50</b>
<b>Hemicellulose</b>	<b>23</b>
<b>Lignin</b>	<b>22</b>
<b>Other</b>	<b>5</b>
<b>Total</b>	<b>100</b>

In February 2007, Dr. Day of the LSU Ag Center, Audubon Sugar Institute, presented a paper at the ASSCT Louisiana Division meeting, captioned "Why Ethanol"(3). The slides for that presentation are posted on the LSU Ag Center website. In this presentation it is stated that it is possible to recover about 80 US gallons of alcohol from 1 ton of dry biomass. 239 lb of bagasse at 40% moisture represents  $239 \times (1 - 40/100) = 143$  lb dry biomass. This would yield  $143 \times 80 / 2000$  US gal of alcohol = 5.72 US gal per ston cane by converting the surplus bagasse to ethanol. At an income of \$2.56 per US gal, this surplus bagasse, if converted to ethanol, could potentially return  $5.72 \times 2.56 = \$14.64$  per ston cane. This would be substantially more than could be earned if the bagasse is used to produce electricity. There is no commercial data to confirm the yield of ethanol from biomass and neither is there

data to confirm what this conversion from biomass to ethanol will cost. Included in the cost of producing ethanol in this manner must be the cost of disposing of any waste from the fermentation and distillation processes. This latter option is as yet unproven but there appears to be a huge potential to gain benefit from the conversion of cellulose, and hemicellulose to ethanol. The lignin, which is another byproduct from the process, has some fuel value and could be potentially burnt to generate some of the steam for the process thereby releasing more bagasse for conversion to ethanol.

### Summary Of Financial Benefits

The relative financial benefits from utilizing the sugarcane in the variety of different ways described above can be summarized as follows:

Utilization of Sugarcane To Produce	Income from sale of product	Production Cost	Net Gain
	\$/ston	\$/ston	\$/ston
Sugar and molasses	46.39	40.00	6.39
Ethanol	49.81	46.69	3.12
Ethanol and Electricity	+4.18	+2.00	
	53.99	48.69	5.30
Ethanol, Electricity and Cellulosic Ethanol	+1.06	+2.00	
	+14.64	+5.46*	
	65.51	53.69	11.82

\* The cost of processing the cellulosic ethanol is based on \$0.95 per US gallon and from above it is expected to yield 5.72 US gal per ston cane. Therefore the cost per ton cane is  $5.72 \times 0.95 = \$5.36$  per ston cane. This cost assumes the cost of the feed material, bagasse, to be zero.

### References

1. "The Economic Feasibility Of Ethanol Production From Sugar In The United States" USDA, Sharpouri and Salassi, July 1996
2. "Production Of Ethanol From Sugarcane" ISJ, U. C. Upadhiaya, March 1996.
3. "Why Ethanol" ASI - LSU AgCenter, D. Day, February 2007.

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