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Agriculture: a Source of Green Energy

By

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Agriculture: a Source of Green Energy

Introduction

Renewable or green energy and agriculture can be a winning combination, and could provide significant rural economic development opportunities in many countries. Technically, agriculture biomass energy produced from plants and organic wastes can produce an array of energy products including electricity; liquid, solid and gaseous fuels; heat; and chemicals. The extent to which countries around the world have developed the green energy potential of agriculture varies enormously with perhaps the two most well known examples including the biofuel schemes of the United States and Brazil. A key driver for realising more of the undoubted substantial potential for green energy from agriculture is the climate change debate and the near-ratification of the Kyoto protocol with its reduction targets for green house gas emissions. Biomass energy is the main energy source that is CO2 neutral, meaning it does not increase the amount of CO2 in the atmosphere.

The dominance of sugar to the agriculture sector of Mauritius primarily puts the spotlight on the potential for sugarcane biomass as a source of green energy. In spite of its renewable energy potential the commercial value of sugarcane for centuries has been based on the extraction of sucrose for use as a sweetener. Only more recently has it been more widely recognized that the sugarcane plant offers bioenergy resources that are potentially more valuable than sugar. The sugar industry of Mauritius was one of the first to identify the value of bagasse as a fuel for electricity generation. Brazil was the first during the 1970s to recognise the potential for sugarcane biomass as a feedstock for fuel ethanol. Crucially renewed enthusiasm for biofuels is presently being manifested as new policy initiatives and the establishment of fledgling fuel ethanol schemes in an increasing number of countries, which together are about to unleash massive global demand for fuel-ethanol. A likely
growing international trade in ethanol could afford an interesting opportunity for Mauritius.

Although the majority of arable land in Mauritius is under sugarcane, there are other agriculture crops and activities from which green energy possibilities may exist, so the first part of this presentation overviews the array of possible agriculture biomass to green energy chains. Attention is then focussed on cane biomass and its two major green energy possibilities – biopower and biofuels. The biopower from bagasse option is to be addressed by other speakers, so the emphasis is on fuel ethanol from sugarcane, with particular consideration of the factors driving commercial viability.

For Mauritius, as for many other countries, the key question when considering green energy as a strategy for longer term viability is how to close the gap between current utilisation of sugarcane for sucrose and the tremendous potential that could be gained through bioenergy – a real-world issue in light of the expectations for continued erosion of preferential trade benefiting ACP countries together with little prospect for a world sugar market price over the medium to longer term of greater than 8-10 US cents/lb. In this context, there is an important regional initiative that is working towards closing the gap: the Cane Resources Network for Southern Africa – or the CARENSA network, which includes Mauritius in its membership.

**Green Energy: background**

Renewable or green energy is any energy source that can be either replenished continuously or within a moderate timeframe, as a result of natural energy flows. The term “renewable” captures: solar energy, wind power, hydropower, geothermal power and biomass energy. Biomass energy, or bio energy is the key focus for agriculture. Biomass is composed of many raw material sources\(^1\) and therefore bioenergy can be derived from a wide

\(^1\) The term biomass means any plant derived organic matter available on a renewable basis, including dedicated energy crops and trees, agricultural food and feed crops, agricultural crop
range of “organic” raw materials and produced in a variety or ways. Biomass fuel can be processed via combustion, distillation, gasification, fermentation and pyrolysis\(^2\).

For agriculture: there are 4 key biomass – energy chains:

- Wet co-products (like manure) for methanisation;
- Dry-co products like straw and trash for thermo-chemical conversion;
- Dedicated lingo cellulose crops for thermo-chemical conversion; and
- Growing conventional crops (depending on geographic location) for liquid biofuels production - ethanol and biodiesel.

In short, agricultural biomass can come from traditional food crops (for instance sugarcane, grains such as corn, and oilseeds) as well as dedicated energy crops (Herbaceous crops, woody crops), crop residues, and other animal residues (manure). An array of bioenergy technologies converts biomass resources into several energy related products including electricity; liquid, solid and gaseous fuels; heat; chemicals, and other materials. Generally, its convenient to consider two major categories of green energy from agricultural biomass: biopower and biofuels.

**Bio power**

Bio power technologies burn biomass to generate electricity. Presently direct-combustion technology is dominant, but the future is focused on the introduction of high-efficiency gasification combined-cycle systems\(^3\).

Combined Heat and Power (CHP) facilities, also called cogeneration achieve high efficiencies by using both the power and the excess heat from burning the biomass. This not only lowers costs but also reduces emissions. There is

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2 For biomass energy proponents this is a key advantage over solar and wind power which can only produce electricity, mechanical power or heat. Furthermore, biomass is not an intermittent renewable energy source.

3 Biomass is heated to convert it into a gas. The gas is used directly in a gas turbine, which drives a generator. The waste heat from the gas turbine is then used to drive a secondary steam turbine, thus converting more of the fuel energy into electricity.
also a greater flexibility in the range of possible biomass feedstocks. Combined heat and power (CHP) can achieve an efficiency level as high as 85%, compared to separate generation of steam and power. Despite the obvious advantages of cogeneration, it remains an untapped potential in most countries. For example, CHP accounts for just 6% of total electricity production in the European Union; although about 30% of total electricity production in Denmark, the Netherlands, and Finland is cogenerated. About 7% of total electricity generated in the U.S. is cogenerated. Of interest is the fact that the United Kingdom government now offers a specific support mechanism for CHP (providing a premium for so-called green electricity).

**Biofuels:**
Agriculture biomass can be converted into a variety of fuels including liquid fuels ethanol, methanol, biodiesel, Fischer-Tropsch diesel and gaseous fuels such as hydrogen and methane. Ethanol is made by converting the cellulosic portion of biomass into sugar, whereas sugar and starch crops can be used directly for ethanol production.

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**Overview Conversion Pathways to biofuels**

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F-T = Fischer-Tropsch diesel; DME = Dimethyl ether


5 Starch crops first need enzymatic hydrolysis to break down starch into 6 carbon sugars.
Cellulose is a major component of wood, and other materials such as bagasse and grass. Cellulose consists of sugar molecules, but cellulose molecules are polysaccharides, which are much larger than starch molecules. Again, cellulose can be broken down into its component sugar molecules using acid or enzymes, but other components of wood (particularly the lignin) hinder this breakdown process. While methods for sugar recovery are known, they are currently too expensive to make cellulose a cost competitive feedstock, so predictions vary as to when cellulose might be used to produce ethanol commercially. Recovery of sugars from cellulose and hemicellulose continues to be the subject of considerable research. There are several companies with different technologies (for instance Cargill Dow, Iogen Corporation (Canada) with Shell Oil, BC International), but proving the technology is taking longer than expected and the lack of a first commercially viable plant proves the technology presently remains high risk. Even so, expectations remain for the first commercially viable plant to be operating by 2005 (see Smith M., 2002, “Cellulosic Biomass Ethanol: Barriers and Opportunities”. Paper presented to F.O.Lichts World Ethanol 2002 Conference, London).

The countries that pioneered fuel ethanol production from agricultural biomass on a large scale were Brazil (from sugarcane), and the United States (from maize (corn)). Presently world production of fuel ethanol is around 25 bln litres annually (total ethanol at 37.9 bln litres in 2003). Crucially however, as will be discussed later, several countries are at various stages of implementing fledgling ethanol programs including India, Thailand, Colombia, Australia, while new biofuel directives in the European Union and a proposed renewable fuels standard in the United States, could see a massive jump in world production and trade in ethanol.

Although ethanol is typically used directly as a gasoline extender or oxygenate, it can also be used as a feedstock for the production of ethyl tertiary butyl ether (ETBE). ETBE is made by reacting ethanol with natural gas and petroleum derivatives (isobutylene) to produce a new clean-burning fuel
additive. This is in fact the main way in which ethanol is used in the European Union, and there is a growing opinion in the United States that ETBE would significantly expand the demand for ethanol as well as to maximise the reductions in greenhouse gas, toxins and VOC emissions. ETBE is an environmentally superior oxygenate and enhances vehicle performance because of a significantly lower fuel blend vapour pressure (ethanol directly raises the vapour pressure (as measured by Reid Vapor Pressure (RVP)) of fuels with which it is blended.

**Biodiesel** is produced through a process in which organically derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester. This can then be blended with conventional diesel fuel or used as neat fuel. The European Union is presently the major producer of biodiesel (accounting for around 80 percent of an estimated world total in 2003 of 1.55 mln tonnes) (Maniatis, K., 2003). The feed stock crop used differs in each country (rapeseed, soybean, sunflowers and vegetable oils for instance).

**Crucial Factors influencing bioenergy potential**

Although the range of technical possibilities for green energy from agriculture are impressive, the optimal biomass-energy possibilities for any particular country is driven by several key issues, where are overviewed below.

Key issues include:

- Availability of land for energy crops production (as against for food crops production) and other competing land uses.
- Alternative land use options for degraded land, such as protected and recreational areas, carbon sequestration, or crops for nitrogen fixation (for example).
- Productivity levels of energy crops, as determined by physical factors – climate, water availability, soil quality- as well as socio-economic factors, primarily the costs of labour and land.
• The available technology for energy crop production, handling and transport and conversion to energy. Technology is a major issue as it impacts energy costs as well as being critical to ensuring optimal carbon/energy balances, and also to lowering local emissions (air quality issues).

• Biomass production improvements could likely improve biomass yields (plant genetic and breeding technology), as well as to reduce production costs and improve environmental quality.

• Biomass handling issues. Handling systems can account for a large proportion of the capital investment and operating costs of a bioenergy conversion facility. The handling requirements vary according to the type of biomass to be processed as well as the feedstock preparation requirements of the conversion technology.

• Biomass collection logistics and infrastructure: harvesting biomass crops, collecting residues, storing and transporting are all critical elements to consider in a biomass resource supply chain.

• The price of biomass crops as against other crops (farmers involvement depends on financial aspects: profitability is a key decision criteria), as well as the ultimate production cost of the renewable energy which determines its competitiveness with fossil fuels.

• Policy and regulatory environment, and the extent it is conducive to the development of renewable energy opportunities.

The importance of these key issues will become all the more lucid by turning out attention to sugarcane biomass, the dominant biomass source in Mauritius (covering more than 80 percent of its arable land).
**Green energy from sugarcane**

Sugarcane is a highly efficient converter of solar energy, and has the highest energy-to-volume ratio among energy crops. Indeed it gives the highest annual yield of biomass of all species. Roughly, one tonne of sugarcane biomass – based on bagasse, foliage and ethanol output – has an energy content equivalent to one barrel of crude oil\(^6\).

The sugarcane plant therefore takes on special significance as the world’s most economically significant **energy crop** and presents exciting opportunities as well as challenges if it is to reach its potential as a **developing country bioenergy resource**. This is all the more paramount in light of the likely increasing incentives for sugar producers around the world to diversify their product portfolio, as the competitive pressures from the world market are likely to increase with widely expected ongoing sugar policy reform.

### Sugar Cane Resources

![Sugar Cane Resources Diagram](image)


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In this chart the sugarcane resource is broken down into three key product streams: sugar/solids; molasses/juice and crop residues. The sugar/solids category includes various feedstocks and intermediate products in addition to sugar. Molasses/cane juice are valued for the fermentable sugars that can be converted into alcohol, as well as being used as industrial and agricultural inputs (fertilisers). Cane residues, namely bagasse and trash, are valued for their fibre content and organic residues, as well as their use as fuel in cogeneration plants.

In terms of green energy then, it’s clear that the major cane biomass-energy chains are:

- Cane juice/molasses for conversion to ethanol;
- Bagasse for heat and electricity generation; and
  - In the medium term (more than 5 years), bagasse for conversion to ethanol.
- Stillage/vinasse for conversion to methane (methanisation).

Each of these are discussed in turn.

**Cogeneration using bagasse**

Mauritius was one of the first countries to establish cogeneration capacity based on the use of cane bagasse, an option that is to be further actively pursued as part of the country’s Sugar Sector Strategic plan\(^7\). Several studies in India, and other parts of the world, point to the sugar industry as a prime candidate for supplying low-cost, non-conventional power via cogeneration.

The advantages of sugar mill cogeneration include relatively low capital cost requirements and the use of a renewable, indigenous waste as a “non-polluting” fuel. Indeed, the fact that the sugarcane plant provides its own source of energy for sugar production in the form of bagasse has long been a special feature of the sugar industry. In the traditional case the sugar factory/distillery cogenerate just enough steam and electricity to meet their

\(^7\) For a target for the period 2001-2005 is to generate as much electricity from renewable sources, in particular bagasse. Available at http://ncb.intnet.mu/moa/sssp.htm
on-site needs. Boilers and steam generators are typically run inefficiently in order to dispose of as much bagasse as possible. With the availability of advanced cogeneration technologies, sugar factories can now harness the on-site bagasse resource to go beyond meeting their own energy requirements and produce surplus electricity for sale to the national grid or directly to other electricity users. In the diagram, the energy flows for a low efficiency system are illustrated.

In many countries there are several barriers related to the policy, regulatory framework, fiscal incentives, technology upgradation and capacity building that have limited achievement of cogeneration potential from cane biomass. In contrast, in Mauritius, it is well known that a clearly defined government policy on the use of bagasse for electricity generation was instrumental in the successful implementation of the cogeneration program.

The next two speakers will consider the ongoing potential for additional cogeneration in Mauritius in much more detail. Presently, there is insufficient bagasse to allow year-round cogeneration and instead coal is used during the “off-season”. Collection and use of cane trash could be considered for extending the biomass fuel supply, but issues remain related to collection and transport of the biomass. There may also be potential for the use of other C4 tropical grasses (such as elephant grass) to be harvested in the sugarcane off-season, using existing harvesting and transport infrastructure.

**Fuel ethanol**

Ethanol from sugarcane is produced through biochemical processes based on fermentation using cane juice or molasses as a feedstock (or a mixture of both). After preparation of a mash with the appropriate concentration of sugars and solids, the sugars are transformed into alcohol using yeasts as the catalyst. Fermentation takes 4-12 hours. The chemical reaction liberates a
significant amount of CO2 and heat. After fermentation, the ethanol is distilled from other by-products, resulting in a level of purity of around 95 percent (hydrous ethanol). The advent of continuous fermentation has increased the productivity of fermentation, reducing the volume capacity required for fermentation tanks, thereby reducing costs. Similarly, in distilleries, low steam utilization technologies use waste heat in heat exchangers, which is then reused to increase the temperature and/or pressure of other processes. Effectively, this approach uses less steam and leaves more steam than otherwise for electricity generation.

**Renewed enthusiasm for fuel ethanol**

Crucially, renewed enthusiasm for biofuels over the past few years is now being manifested as new policy initiatives and the establishment of fledgling fuel ethanol\(^8\) schemes in an increasing number of countries, which together are about to unleash massive global demand for fuel-ethanol. It’s no accident that renewed interest in ethanol from the sugar world originated in late 1998 and early 1999 when price developments in the sugar and oil markets started to diverge – see figure below. Sugar prices were suffering a downturn, but then oil and petroleum prices surged, leading some governments and industry analysts to believe bio-ethanol schemes had become much more economically viable than ever before. At the same time governments are beginning to implement energy and environmental policy to deal with climate change, urban air pollution, and energy security. It seems, more than ever before, that the sugar world has a realistic opportunity to broaden its revenue base and to assure continued financial viability by pursuing the ethanol option.

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\(^8\) Ethanol is a high octane oxygenated hydrocarbon produced from the fermentation of sugar or converted starch. Its chemical formula is \(\text{C}_2\text{H}_5\text{OH}\), and is commonly known as ethyl alcohol. Ethanol blended with gasoline at concentrations of 5 or 10 percent serves as an oxygenator, enhancer and extender.
Fuel ethanol from sugar crops: achieving commercial viability?

The terms “commercial viability” and “commercial feasibility” are normally used interchangeably and refer to there being sufficient expected profitability from ethanol production, which may be conditional on government support. We also need to mindful of commercial viability related to the continued operation of existing capacity as opposed to commercial viability of planned investment in the creation or expansion of an industry.

At the simplest there are three key drivers of commercial viability. The first is the price of sugar – as it represents the opportunity cost of the sugar crop used to produce ethanol. The second is the price of crude oil – which drives the price of gasoline, providing a benchmark against which to gauge the competitiveness of ethanol. The other key determinant of commercial viability is the existing level of government support, expectations about its continuance, and possible new forms of future support.

**Condition 1: Opportunity Cost**
The opportunity cost for ethanol production from sugar crops is the return otherwise achievable from sucrose production. In other words, determining the commercial feasibility of producing ethanol from sugarcane/beet involves a comparison of alternative revenue streams from sugarcane/beet with ethanol or raw/white sugar product forms.

More specifically, in the case of sugar cane, the implied opportunity cost of ethanol production varies according to the feedstock used. The value of the embodied sucrose in C molasses is far less than A and B molasses. The cost of sugarcane juice as a fermentation feedstock would be the raw sugar values minus savings (in operating, energy, capital) relating to the operation of the “process end” of the sugar factory.

C molasses, typically a low value by-product of cane-based sugar (its value often set by the livestock feed market), offers the lowest-cost substrate (yielding 270 litres of ethanol per tonne at 50 percent fermentables). If distillers paid the true value of sugar contained in C molasses, then ethanol production costs would be higher. Taking sugar as a feedstock gives the upper limit to possible feedstock costs.

Opportunity cost also varies with changes in sugar price. For example, B molasses might be used for ethanol production when the export price of raw sugar is at the lower end of its range.

**Brazil: ethanol vs sugar**

The opportunity cost of ethanol production is not of theoretical relevance. Relative returns as between sucrose and fuel ethanol is a key factor driving the allocation of cane as between sugar and ethanol in Brazil, the world’s biggest sugar/ethanol industry.
The trade-off between relative sugar and alcohol returns (ex-mill) is illustrated in the below diagram. The oblique line shows the point of break-even between the two products. To the left of this line, the profitability of alcohol is greater, and to the right, the profitability of producing sugar is greater. The position of break-even of course depends on the yields of alcohol and sugar per tonne of cane crushed (average assumed to be 74.5 litres of ethanol (from juice) and 0.14 tonnes of sugar).

In the **United States**, because of the sugar program, the opportunity cost of using beet and cane for fuel ethanol is too high as against using sugar crops for their sucrose content. This is why maize is the most competitive feedstock. The same is true in the **European Union**, where sugar beet used for bioethanol production (incidentally beet are the dominant feedstock for the production of ethanol for ETBE in France) is typically dedicated crops grown in set-aside land.

For **Mauritius**, the opportunity cost of using cane for ethanol production would also be very high, as the returns from sugar for the preferential markets in the European Union are likely to be far higher than returns from ethanol.
Condition 2: Ethanol production costs vs gasoline prices

The issue of ethanol costs versus price of gasoline is critical and underlies the need for fiscal incentives to attract investment in biofuels productive capacity. For a given crude oil price, an ex-refinery price for gasoline can be derived. From this can be estimated a maximum competitive price for ethanol, against which expected costs of production can be compared. In a nutshell, over the past decade or longer, despite technological progress in the biofuel/ethanol production process that has lowered the unit costs of production, the economics spoke always in favour of conventional fossil fuels. Therefore, the profitability of biofuels production has depended heavily on the extent of subsidies or other fiscal incentives afforded them by governments, and the taxation levels imposed upon fossil fuels as against ethanol. Consequently, development of large biofuel sectors, including ethanol from sugar crops, has only occurred in countries where governments have advanced support in the form of favourable fiscal regimes and other forms of support (e.g. capital grants).

Production cost estimates

In the following table, several production cost estimates for fuel ethanol as given in the recent literature, are collated.

<table>
<thead>
<tr>
<th>Region</th>
<th>Cost Estimates</th>
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<tbody>
<tr>
<td>United States</td>
<td>Variable costs @ US$0.25/litre from corn.</td>
</tr>
<tr>
<td>Brazil</td>
<td>US$0.15-0.21/litre from sugarcane juice/molasses</td>
</tr>
<tr>
<td>Australia</td>
<td>US$0.30/litre from C molasses</td>
</tr>
<tr>
<td>European Union</td>
<td>US$0.48/litre from sugar beet;</td>
</tr>
<tr>
<td></td>
<td>US$0.60 if beet valued at EU quota value.</td>
</tr>
</tbody>
</table>

All cost estimates higher if expressed in terms of gasoline equivalent. The energy density of a litre of fuel ethanol is 70% that of gasoline.

The highlight is the strong competitiveness of Brazil against gasoline and crude oil. According to a leading Brazilian analyst (Natari\textsuperscript{9}), by late 2000 a new paradigm had arisen in the Brazilian industry, as ethanol was being produced at a cost that was competitive with the price of gasoline in the world market. Anhydrous ethanol can be produced in Centre-South Brazil at US$28.40 per barrel (at exchange rate of R$1.96/US$) meaning that it can compete with gasoline in the world market, when the price of crude oil is between $22.70 and $23.70/barrel. Brazil’s currency has devalued significantly against the US dollar since that time (reaching a high of R$4.00/US$ mid-October 2002), making Brazilian fuel ethanol even more competitive.

However, the scale of the Brazilian distillers is very important: these are large-scale units achieving significant economies of scale and throughput, utilising state of the art technology and using bagasse as a major part of the fuel source for distillation. Costs could be significantly higher for smaller scale distillers in other countries.

Furthermore, in Brazil, over the course to two decades, new technologies increased sugar and fermentation yields significantly (Henrique\textsuperscript{10}). Increase field productivity, development of cane varieties, better soils and fertiliser practices and increases in the sugar content of cane (from 9.5 percent in 1977 to 14 percent in 1999) were all important factors. New technologies and control of industrial processes were developed with gains of up to 17 percent in fermentation yield (from 75 percent in 1977 to up to 92 percent today). In 1997 fermentation yield was 70-80 percent in distilleries, but now it is 85-92 percent. Better extraction of the juice from cane also was important. Together, these factors have increased ethanol productivity from 3,000-4,000 litres/ha to 5,000 to 10,000 litres/hectare (expressed in absolute ethanol/ha).

\textsuperscript{9} Dr Pilinio Mário Nastari, ‘Brazil’s Market Dominance – a reason to be frightened?’ paper presented to 9\textsuperscript{th} ISO Seminar, \textit{Hot Issues for Sugar}, London, November 2000.
Not only has this impressive productivity gain been a key driver lowering production costs, it also has meant a smaller sugar cane area than otherwise to meet ethanol demand.

A study in Australia\(^\text{11}\) estimates total production costs for fuel ethanol at $A0.56/litre, (US$ 0.30) assuming a C molasses feed stock valued at $A50/tonne. That level was found to be competitive with gasoline with an exchange rate of US$0.50, a crude oil price of US$32/barrel, and factoring in an excise exemption of $A0.38/litre. Costs would be significantly higher using A or B molasses.

The European Commission in framing its draft legislation on targeted biofuels incorporation noted that at “current” oil prices ($25/barrel), biofuels are not competitive. Biofuel production costs were put at €0.5/litre (equivalent to US$ 0.48 at April 2002 values). This costing is supported by an analysis of prospective ethanol production costs in Germany from both wheat and sugarbeet, putting production costs at between €0.48-0.60/litre.

<table>
<thead>
<tr>
<th>ETHANOL PRODUCTION COSTS IN GERMANY</th>
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<tr>
<td>PLANT SIZE</td>
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<td>RAW MATERIAL</td>
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<tr>
<td>Plant Buildings</td>
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<tr>
<td>Machinery</td>
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<tr>
<td>Total Investment</td>
</tr>
<tr>
<td>Labour</td>
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<tr>
<td>Insurance, Fees and Reparation</td>
</tr>
<tr>
<td>Feedstock (incl. Transport)</td>
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<tr>
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<td>Gross Production Cost</td>
</tr>
<tr>
<td>By-Product</td>
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<tr>
<td>Net Production Cost</td>
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</tbody>
</table>


\(^{11}\) ABARE 2001, Factors Impacting the Commercial Viability of Ethanol Production, Report to Client, Canberra.
Maximum ethanol selling price driven by gasoline price

A key question for any prospective ethanol producer is what is the relevant gasoline price benchmark against which to determine the competitiveness of ethanol. Put another way, commercial feasibility is clearly heavily dependent on the prospective selling price for ethanol. The maximum competitive price for ethanol will be set by the ex refinery price for gasoline or the cif cost of imported gasoline, depending on a country’s status as a net exporter or importer of oil and gasoline. For a country such as Mauritius which would need to be export orientated (given the modest size of any domestic market for fuel ethanol), this pricing issue is paramount.

Spot Crude and Product Prices

Put simply if ethanol production costs are greater than the implied maximum competitive price, (and don’t forget that the selling price of ethanol has to allow a suitable margin to yield a satisfactory return on the high capital cost
of ethanol production) then commercial viability can only be achieved with
government support for ethanol.

**Condition 3: Government Support**

The importance of long-term government support to biofuels simply reflects
that fact established above: that the costs of ethanol generally exceeds the
price of gasoline it replaces, or the price of other oxygenates. Indeed the well
established fuel ethanol schemes of Brazil and the United States have relied
on a number of government support measures.

**Brazil**’s massive ethanol industry is now operating more or less in a
deregulated environment (apart from the mandatory inclusion of ethanol in
gasoline). But deregulation and reform of the fuel alcohol sector only began in
the late 1990s, whereas PROALCOOL was launched in 1975 with massive
support by the government. Today, the reformed ethanol sector still benefits
from a captive market for anhydrous alcohol but prices are freely determined
by the market. Crucial also is the fact that ethanol still benefits from a
favourable tax excise arrangement as against gasoline. Gasoline attracts a
tax of R$0.5709/litre where as anhydrous is taxed at 0.06/litre and hydrous
0.0485/litre\(^{12}\). This is against the pre-tax price level of R$0.75/litre for
gasoline, R$0.66 for anhydrous ethanol and R$0.60 for hydrous ethanol.

In the **United States** the key production incentive is the 52 cents/gallon
(13.7 cents/litre) tax break, scheduled to fall to 51 cents (13.4 cents) in 2005.
Without it, production of ethanol would not be viable against its main
competitor, gasoline. In addition, 15 States also offer production incentives.
Mandated markets have also been a key factor supporting the ethanol sector.
Key among these is the Clean Air Act of 2002, the reformulated gasoline
programme and the winter oxygenated fuels programme.

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\(^{12}\) Source: Luiz Carlos Correa Carvalho 2003, The Brazilian Ethanol Experience, paper
presented to Seminario Internacional de Alcohol Carburante, 17-18 June, Cali, Colombia.
In **France**, a differentiated rate of excise duty is applied to biofuels (after EU Council of Ministers in March 2002 approved a Derogation under Article 8.4 of Directive 92/81/CEE. Until recently the excise duty used could not exceed €0.53/litre for bio-ethanol used in authorised mixtures. The limits were set to limit tax losses to the government’s budget. The French government recently lowered the exemption to €0.38/litre because they saw too great a gain to biofuels as a result of the high world crude oil prices.

None of the **fledgling schemes** in India, Thailand, and Australia for example, envisage fully applying the Brazilian model of mandated blending ratios of as high as 25 percent. Australia at most will blend 10 percent ethanol in gasoline, with the government hoping the tax exemption for ethanol, together with the incentives offered under the Greenhouse Gas Abatement Scheme will be sufficient to attract the interest of petroleum companies to commence blending. India’s government has approved a 5 percent blend (but in a later phase will approve a 10 percent blend), Thailand has a 10 percent blend with fiscal and other production incentives. In the United Kingdom, the government offers a tax incentive of £0.20/litre (29 US cents/litre). The longer-term success of these government incentives in ensuring a commercially viable and sustainable ethanol sector remains to be seen.

**Stillage/Vinasse for methanisation**

The third key energy source from sugar biomass is stillage (vinasse/dunder), the effluent of alcohol production. As can be seen in the table, production of 1 litre of ethanol can result in a waste stream of 2.5-15 litres of vinasse, depending on the feedstock used. Vinasse can be characterised as high in solids and unstable organic compounds, having bad odour, dark colour and containing toxic salts. An important issue therefore is how to optimally extract energy from this waste steam of a distillery. Importantly, income can
be gained by transforming vinasse into bio fertiliser and biogas, two of the key options for the treatment of vinasse shown in the figure. Biogas can be used as a boiler fuel whilst vinasse can also be used as a partial replacement for molasses in animal feeds. Perhaps then, optimal utilisation of vinasse can also contribute to attaining commercial viability for ethanol production.

**Characteristics of Vinasse**

<table>
<thead>
<tr>
<th>Raw Material Parameters</th>
<th>Juice</th>
<th>Syrup</th>
<th>Molasses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volume (Lit / Lit)</strong></td>
<td>12 to 15</td>
<td>2.5 to 4</td>
<td>8 to 15</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>4 to 4.5</td>
<td>4 to 4.5</td>
<td>4 to 4.5</td>
</tr>
<tr>
<td><strong>C.O.D. (mg / Lit)</strong></td>
<td>25,000 to 30,000</td>
<td>70,000 to 80,000</td>
<td>1,00,000 to 1,50,000</td>
</tr>
<tr>
<td><strong>B.O.D. (mg / Lit)</strong></td>
<td>15,000 to 20,000</td>
<td>35,000 to 40,000</td>
<td>50,000 to 70,000</td>
</tr>
<tr>
<td><strong>Total Solids (%w/w)</strong></td>
<td>1.5 to 2.5</td>
<td>6.5 to 7.5</td>
<td>8 to 15</td>
</tr>
</tbody>
</table>

Source: PRAJ INDUSTRIES LTD, PUNE, INDIA., Latest Technologies For Treatment & Disposal Of Vinasse, presented to Seminario Internacional de Alcohol Carburante, June 17-18 2003, Cali, Colombia.
CARENSA

From the above discussion its clear that there are different potential sources of green energy that can be derived from agriculture but that for the sugarcane resource, the two key opportunities are in bio power and bio fuels. Sugar mills are also inherently CHP (cogeneration) systems, where heat is an important product. For Mauritius, as for many other countries, the key question is how to close the gap between current utilisation of sugarcane for sucrose and the tremendous potential that can be gained through bioenergy – a real-world issue in light of the expectations for continued erosion of preferential trade benefiting ACP countries together with little prospect for a world sugar market price over the medium to longer term of greater than 8-10 US cents/lb.

In this context, there is an important regional initiative that is working towards closing the gap: the Cane Resources Network for Southern Africa – or the CARENSA network, which includes Mauritius in its membership.

CARENSA seeks to identify appropriate technologies, effective regional policies and feasible cane co-products strategies to sustainably harness the sugarcane energy resource through the production of biofuel and cogeneration in particular.

The network will facilitate improved regional cooperation and policy co-ordination, and help to break down barriers to cane-based bioenergy through an ongoing forum among researchers, policy-makers and industry representatives.

Most importantly, CARENSA is a Thematic Network and NOT a research project. It is about building partnerships, North-South, South-South, between private and public sectors, and among all the many diverse actors and stakeholders with an interest in bioenergy from sugarcane. The CARENSA
network addresses these issues in a holistic manner by considering, social, environmental and organisation issues alongside the technical and economic parameters.

The work program to achieve CARENSA’s objectives is designed around 5 key phases ranging through the lifecycle of the cane resource, from field to mill to market and through to the impacts on communities and the environment, including:

(1) **Agriculture**
- Agronomic and harvesting practices for optimising the biomass resource (including co-cropping of sweet sorghum for energy production).

(2) **Industry (factory and co-products)**
- Sugar and fibre resource streams, agro-industrial processes and technologies that exploit these streams

(3) **Markets & Policies**
- Articulation of product demand and formation of markets through appropriate government policies, regulations and economic incentives.

(4) **Impacts**
- Socio-economic and environmental impacts of different strategies to ensure that local and regional benefits are reflected in decision-making frameworks.

(5) **Integrating Issues.**
- Including sustainable development, risk, competitiveness, international comparisons and industry perspectives.
The project team/Funding and partners

CARENSA was launched in September 2001 and will continue until September 2005. The Stockholm Environment Institute originated the CANENSA network, as this institute has a long history in Southern African countries working on biomass and links to sustainable rural development.

The European Commission’s Directorate General for Research supports CARENSA to the amount of €0.5 mln. The EC has a clear development funding priority in Southern Africa. The Stockholm Environment Institute serves as Scientific and Administrative Coordinator to CARENSA.

An experienced project team with representatives from the research and the policy communities are implementing the network. The project team consists of:

- four European organisations;
  - Imperial College, London;
  - Stockholm Environment Institute;
  - Interuniversity Research Centre on Sustainable Development, Italy;
  - Agricultural University of Athens, Greece;
- four African organisations;
  - University of Mauritius;
  - University of Natal, South Africa;
  - Biomass Users Network, Zimbabwe;
  - Centre for Energy, Environment and Engineering, Zambia;
- three international organisations;
  - International Sugar Organization;
  - Food and Agriculture Organization of the United Nations;
  - Southern African Development Community;
- two from Brazil;
  - National Reference Centre for Biomass;
o Unicampinas;
- and one from India;
  o Winrock International, India.

In practical terms the main forms of interaction within the network will include workshops, meetings and exchanges in which participants will synthesise and compare knowledge of the state of the art with the current status of sugarcane resource utilisation in Southern Africa.

**Final Comments**

There are several key messages to draw from this presentation.

- Renewable or green energy and agriculture can be a winning combination, even more so with the expectations that demand for renewable energy will expand over coming years, as governments further implement energy and environmental policy to deal with climate change, urban air pollution, and energy security.

- Biopower and biofuels are the two major bioenergy opportunities from the sugarcane biomass....

- ..... but achieving commercial viability remains paramount to ensuring these green energy opportunities are fully realised by the cane sector in Mauritius, both in terms of within the domestic market and within a broader regional market.

- Optimally exploiting fuel ethanol opportunities from the sugar cane resource makes sense in an environment of likely continuing low world sugar prices, but an outlook for continuing firm crude oil prices.

- The CARENSA initiative offers an opportunity for which Mauritius can work with other countries in southern Africa to close the gap between current utilisation of sugarcane for sucrose and the tremendous potential that can be gained through bioenergy.
Finally, Mauritius could maximise its benefits from the bioenergy opportunity by exporting intellectual property pertaining to optimal configurations and policy environments for advanced sugarcane to energy systems.