Perspectives on ethanol sustainability in Brazil

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Aggregating science and technology to a traditional agro-industry, ethanol from sugarcane became a sustainable and competitive alternative for the current and future energy supply.

Outline

✓ Context: bioenergy is relevant abroad and in Brazil
✓ The evolution of Brazilian bioenergy agro-industry
✓ Sustainability of sugarcane bioenergy: new facts
✓ Final comments
More and more, the main drivers towards a global energy transition:
✓ concerns on oil dependence and energy costs,
✓ global and local environmental problems,
✓ opportunity for economic activation of agro-industrial sector,
are reinforced and fostered biofuels production and use abroad…

Global production of liquid biofuels
(IEA, 2011)

Source: IEA, 2010a.
Context: bioenergy in the global scenario

... as well as biofuel demand forecasts are indicating a huge market for bioenergy in the next decades.

Global energy use in the transport sector and use of biofuels in different transport modes in 2050
(BLUE Map Scenario, IEA, 2011)
Biofuels always accounted for a significant share of Brazilian energy matrix. Currently, sugar cane, wood and several waste biomass mean about 1/3 of total domestic energy consumption.
Context: the sugarcane energy in Brazil

Sugarcane energy products (ethanol and electricity) demand in Brazil is equivalent to about 800 thousand barrels of oil per day.

More than 30 million Brazilian cars run using ethanol, either pure (E100) or blended with gasoline (E25-E18).

The area occupied with sugarcane plantation for energy represents a small share of arable land (<1%), with reduced impacts on biodiversity and the production of other agricultural products.

Typical sugarcane mill in the Brazilian Center South region

(BNDES, 2009)
The ethanol use: from the beginning

Gasoline blended with ethanol has been a mandatory practice in Brazil since 1931 (minimum E5, average E7.5), reinforced after the oil crisis during the seventies, when the use of high blends (E25) in all gasoline motors and pure hydrous ethanol in dedicated motors was adopted.

Ford Model T adapted for pure ethanol, used for public demonstrations in the 20’s

Ethanol content in the Brazilian gasoline

(INT, 2006)
The ethanol evolution: flex-fuel motors

Vehicles with motors able to use any blend of pure hydrous ethanol (E100) and gasoline (E25), presenting good performance and accomplishing environmental requirements, were introduced successfully in the Brazilian market and today represents around 90% of new cars in the light vehicles fleet.
New frontiers for ethanol use

Besides the regular use as pure hydrous ethanol and in blend with gasoline, new interesting opportunities are opening new and promising markets for bioethanol.

Airplane regularly produced to use pure hydrous ethanol (EMBRAER, 2008)

Bus with Diesel engine able to use hydrous ethanol (BEST, 20099)
In the last three decades many improvements has been introduced in ethanol production, multiplying the total productivity by 2.6, due to agronomic and industrial gains.
There is a large area for expansion of sugarcane in Brazil, currently occupied by low productivity pastures.

Similar situation is observed in several developing countries.

(IBGE, 2008)
To reduce the competition for natural resources, efficiency is crucial at any level. For animal protein this aspect is more relevant yet.

In Brazil, better practices in calf breeding can liberated about 75 M ha.

(FGV, IBGE, 2008)
Innovation has been essential for ethanol development. In agronomic or industrial activities, in logistics or management, new techniques are frequently introduced, cutting costs, diversifying products and reducing environmental impacts of ethanol production.

The use of water, agrochemicals, fossil fuels in sugarcane energy production is reduced in comparison with other agro systems.

**Sustainability: role of R&D**

**Varietal diversification of sugarcane in Brazil**
(Burnquist e Landell, 2005)

**Biological control of sugarcane borer (Diatraea saccharalis) using a wasp (Cotesia flavipes)**
(Bento, 2006)
Sustainability: the energy balance

One fundamental feature of sugarcane ethanol is its high efficiency in solar energy conversion to chemical energy and consequently fuel energy.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Energy requirements or production (MJ/tonne of processed cane)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>average</td>
</tr>
<tr>
<td>Sugar cane production</td>
<td></td>
</tr>
<tr>
<td>Agricultural operations</td>
<td>38</td>
</tr>
<tr>
<td>Cane transportation</td>
<td>43</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>66</td>
</tr>
<tr>
<td>Lime, herbicides</td>
<td>19</td>
</tr>
<tr>
<td>Seeds</td>
<td>6</td>
</tr>
<tr>
<td>Equipment</td>
<td>29</td>
</tr>
<tr>
<td>Ethanol production</td>
<td>49</td>
</tr>
<tr>
<td>Electricity</td>
<td>0</td>
</tr>
<tr>
<td>Chemicals and lubricants</td>
<td>6</td>
</tr>
<tr>
<td>Buildings</td>
<td>12</td>
</tr>
<tr>
<td>Equipment</td>
<td>31</td>
</tr>
<tr>
<td>Total energy input</td>
<td>251</td>
</tr>
<tr>
<td>Energy output</td>
<td>2089</td>
</tr>
<tr>
<td>Ethanol</td>
<td>1921</td>
</tr>
<tr>
<td>Bagasse surplus</td>
<td>169</td>
</tr>
<tr>
<td>Net energy balance (out/in)</td>
<td>8,3</td>
</tr>
</tbody>
</table>

(Macedo et al., 2006)
Sustainability: new frontiers

1. Biofuels utilization in cane agriculture and transport

Fuel corresponds to approx. 40% of energy consumed in sugarcane production. During the 80’s, alternatives for replacing the conventional diesel oil used in sugarcane agriculture were evaluated.

Basically two routes were assessed, with a limited outcome:

- **Ethanol additivation** (lubricity and cetane improvers) to allow its use in conventional Diesel motors.

- **Diesel engine conversion** ("Ottolization"), reducing compression rate and adding ignition systems in order to make possible hydrous ethanol use.

Tractor for ethanol use (66 CV, carbureted electronic ignition) (Ford, 1985)
Sustainability: new frontiers

1. Biofuels utilization in cane agriculture and transport

More recently:

• **High performance Diesel engines using low additivation (5%) hydrous ethanol have been launched** (Scania, 2008).

• **Biodiesel has been regularly used. Since January 2010 all diesel used in Brazilian trucks has 5% biodiesel (B5).**

Electronic injection Diesel engine for hydrous ethanol (270 CV) (Scania, 2008)
Sustainability: new frontiers

1. Biofuels utilization in cane agriculture and transport

Considering biofuels utilization in agriculture operations and sugarcane transportation, five scenarios were evaluated, taking into account current and prospective conditions of composition and feedstock used in biofuels.

Reference scenario: conventional diesel oil

Scenario 1: current B5 (methyl biodiesel, 85% soybean oil, 15% tallow)

Scenario 2: improved B5 (methyl biodiesel, 85% palm oil, 15% tallow)

Scenario 3: optimized B100 (ethyl biodiesel, 85% palm oil, 15% tallow)

Scenario 4: E100 (hydrous ethanol, 5% cetane improver additive)
To estimate the impact of different fuels on energy consumption and GHG emissions associated to ethanol production and use, a set of data was prepared, considering the current and prospective Brazilian conditions.

<table>
<thead>
<tr>
<th>Biofuel</th>
<th>Fossil energy consumption in production (MJ/L)</th>
<th>GHG emission factor (kg CO₂/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convencional diesel oil</td>
<td>41,22</td>
<td>2,489</td>
</tr>
<tr>
<td>Methyl soybean oil biodiesel</td>
<td>11,16</td>
<td>1,019</td>
</tr>
<tr>
<td>Methyl tallow biodiesel</td>
<td>5,50</td>
<td>0,469</td>
</tr>
<tr>
<td>Methyl palm oil biodiesel</td>
<td>10,53</td>
<td>0,796</td>
</tr>
<tr>
<td>Ethyl palm oil biodiesel</td>
<td>7,40</td>
<td>0,250</td>
</tr>
<tr>
<td>Ethyl tallow biodiesel</td>
<td>2,25</td>
<td>0,135</td>
</tr>
<tr>
<td>Hydrous ethanol, additived</td>
<td>2,71</td>
<td>0,257</td>
</tr>
</tbody>
</table>
Sustainability: new frontiers

1. Biofuels utilization in cane agriculture and transport

For more details on the energy balance and emissions for biodiesel production in Brazil:

Does biodiesel make sense?

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Abstract

In several countries biodiesel blending programs have been implemented looking for reduction in fossil fuel dependence and environmental benefits, including climate change mitigation. The current global biodiesel production, from different fatty raw materials, reaches about 6 billion liters per year and represents 10% of whole biofuel production. Nevertheless, in many cases the actual advantages of biodiesel production and usage are not clearly evaluated. Essentially, the feasibility of biodiesel production can be determined by its efficiency in solar energy conversion, as indicated by agro-industrial productivity and energy balance parameters, which expresses a relative demand of natural resources (land and energy) to produce biofuel. Taking into account the Brazilian conditions, in this paper an assessment of biodiesel production is presented, comparing four different productive systems. According to this evaluation, soybean and castor are limited feasible, whereas tallow and palm oil represent more suitable alternatives. The selection of an efficient productive system is crucial for the rationality of biodiesel production.
Sustainability: new frontiers

1. Biofuels utilization in agriculture and transport

Assuming a typical South-Center mill operation, the impact on renewable energy yield and GHG mitigation were assessed.
**Sustainability: new frontiers**

2. Increase of sugarcane mill capacity

*Induced by the scale factor in the cost of industrial equipment, the expansion of ethanol production in new areas has been associated with the increase of processing capacity. In the last two years the average capacity rose 9.5%.*

*In this context, is important to assess the impact of increase in sugarcane transportation energy cost, which can be reduced by the intensification of cultivated areas in the mills vicinity.*
To evaluate the effect of mill capacity on energy demand and thus on GHG emission, it was adopted as parameter the average densification of sugarcane fields, which is the ratio of the sugarcane cultivated area (determined by the capacity) and the area determined by the average distance of transport.

$$AM = \frac{\text{Sugarcane cultivated area}}{\text{Total area as defined by the average radius of transport}} = \frac{0.01 \cdot AC_{\text{ref}}}{\pi \left( \frac{3R_{\text{transp}}}{2} \right)^2}$$
Sustainability: new frontiers

2. Increase of sugarcane mill capacity

Considering as baseline a typical ethanol mill (2.27 Mtc/ano, R=23 km, AM=7%, 36.8 MJ/tc), it was possible to evaluate the effect of increasing capacity on sugarcane transport energy and GHG emission.

GHG emission as function of mill capacity and sugarcane field concentration
Sustainability: new frontiers

3. Adoption of efficient modals in ethanol logistic

The recent expansion of ethanol production in Brazil has fostered investment in logistics, particularly in more efficient transportation modals, such as pipelines and barges, considering also ethanol trade.

In the next years new systems of ethanol transport will be in place, reducing costs and improving efficiency in the whole production-use chain.

Sugarcane barges in Tiete-Paraná waterway (Globo Rural, 2009)
Sustainability: new frontiers

3. Adoption of efficient modals in ethanol logistic

A relevant initiative put forward to reduce logistic cost is Logum venture, joining six big Brazilian companies (Copersucar, Cosan, Odebrecht, Petrobras, Camargo Corrêa e Uniduto) in a R$ 7,0 billion deal to establish a 1,300 km pipeline for ethanol connecting new production areas to exporting harbors, able to move annually about 20 million cubic meters of ethanol.

Logum multimodal main routes (Logum, 2011)
Sustainability: new frontiers

3. Adoption of efficient modals in ethanol logistic

Modeling the energy performance of different modals is possible to assess the GHG emission for ethanol transportation in each alternative.
Sustainability: new frontiers

4. New processes for bagasse valorization

Introduction of new processes can improve its performance and increase the amount of ethanol produced per hectare.

Ethanol from bagasse demonstration plant, DEDINI (5,000 liters/day)

What is more attractive to produce: motor fuel or electricity?

Range of costs for conventional sugarcane ethanol in Brazil

- Gasification, FT liquids, medium term (Larson et al., 2006)
- Gasification, Ethanol, medium term (Phillips et al., 2007)
- Hydrolisis, SSCF, diluted acid pretreatment, long term (Wooley et al., 1999)
- Hydrolisis, SSCF, diluted acid pretreatment, short term (Wooley et al., 1999)
- Hydrolisis, SSCF, diluted acid pretreatment, short term (Aden et al., 2002)
- Hydrolisis, CBP with thermohydrolisis, long term (Hamelinck et al., 2005)
- Hydrolisis, SSCF, steam explosion pretreatment, medium term (Hamelinck et al., 2005)
- Hydrolisis, SSF, diluted acid pretreatment, short term (Hamelinck et al., 2005)
Bioethanol or bioelectricity?

From a Brazilian point of view and considering current costs and prices scenarios, sugarcane bagasse is more valuable for power.

Opportunity value of bagasse for power production.

Opportunity value of bagasse for ethanol production.
Final comments

Bioethanol from sugarcane offer an effective approach to face the new challenges posed by climate change, energy and food security and socio-economic activation.

The current performance of this route is the highest among all other biofuel productive systems (feedstock + processing). Besides, there are relevant opportunities for additional improvements.

In this direction, efficiency is name of the game.
Sugarcane Ethanol: Energy for Sustainable Development
Available in English, Spanish, French and Portuguese, 300 pg, 2008
For download: www.sugarcanebioethanol.org

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Chapter 3
Biomass Gasification for Ethanol Production

Luiz A.H. Nogueira, Joaquim E.A. Seabra, and Isaías C. Macedo

1 Introduction

For a sustainable future, it is essential for mankind to access the largely untapped solar resource by innovative bioenergy routes, an important way to overcome fossil fuel dependence and mitigate related environmental impacts. In this framework, as a good example of the potential to be exploited, among the several biomasses under scrutiny to be used for energy supply, sugarcane appears as one with the most
Obrigado por sua atenção.

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