1.30
N=10

CHEMICALS MARKET
2.5 – 5.0
P=0.9
K=1.3
N=0.9

TRANSPORT MARKET
P=1
K=5
2.5 – 9.0

500
250

Power + water/space heating + space cooling + food freezing (hospital + hotel + shopping centres + schools)

TRIGENERATION
750

N=5

Sugar-beet

(microturbines + engines + absorption refrigeration systems)

COGENERATION

It is estimated that in this way production costs of about 250

$/m³ can be obtained also by small plants offering thus the opportunity to increase considerably the supply of bioethanol and increase of the general Index of Human Development, this being so much related to the energy availability and use.

$2/m³

Sugar-cane
Corn
Wheat
Potatoes
Sweet Sorghum
Cassava

M3/ton

€

Kg/t crop

Production of several coproducts from well-selected dedicated crops, to maintain the price of bioethanol at a preferential level: Cooking Fuel (ETOH jelly)

WATER & CHEMICALS

FUTURE MARKET

Large number repetition of standard optimised economics of decentralised Bioethanol production in microdistilleries (capacity 5-10 ton/day) is penalised for the scale-effect expressed by “Capacity 0.6 exponential factor”. But this negative effect can be compensated by:

Considering the production by small plants in general, the:

COSONS

SYPHISIS ETOH

otype

$7/m³

ECONOMICS

Plant: 10 t (ETOH) / day

COSTS

UNIT

COST/ UNIT ($)

Sugar-juice
ton
2,500
Steam
ton
7,700
ElectricitykW
0,080
Cooling watern
0,050
Process watern
0,070
Sulphuric acidkg
1,000
Saltsliter
0,600
Anti-Foamsliter
0,160
Yeastkg
1,300

Physical Properties of Bioethanol

Specific gravity: 0.79 gr/cm³
Vapour pressure (38°): 50 mm Hg
Boiling temperature: 78.5 °C
Dielectric constant: 7.7
Solubility in water: 0

Chemical Properties of Bioethanol

Formula: C₂ H₅ OH
Molecular weight: 46.1
Carbon (wt): 52.1%
Hydrogen (wt): 13.1%
Oxygen (wt): 34.7%
C / H ratio: 4
Stoichiometric ratio (air / CO₂): 9.0

Thermal Properties of Bioethanol

Lower heating value: 6,400 Kcal/kg
Ignition temperature: 35°C
Specific heat (Kcal/ Kg °C): 0.60
Melting point: -115° C

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In a very long term the estimated Bioethanol world-wide potential production is very large (2 billion t/year or more). The present bioethanol world production is around 2.5 million m3/year. Brazil is the leading country with an annual production of bioethanol from sugar cane around 13 billion m3/year and a consumption of 12.4 billion m3/year.

The average bioethanol production energy ration (energy output/input) is now 9.2 in Brazil. From the competitiveness point of view the anhydrous selling price (Dec 2002) to European companies is 2,500-3,000 €/m3.

Bioethanol is a good high-energy molecule and must be considered a good refined product to be compared to gasoil, its energy value is 70% of gasoil. The USA is the 2nd largest bioethanol world producer from corn (5.5 billion m3/year). Brazil is the leading country with an annual production of 21 million m3.

For Decentralised Bioethanol Production

In another economic analysis concerning the use of small plants in general, the economies of decentralised Bioethanol production in microdistilleries (capacity 5-10 ton/day) is penalised for the scale-effect expressed by "Capacity 0.6 exponential factor". But this negative effect can be compensated by:

- Large number repetition of standard optimised microdistilleries (production in series as indicated below).
- Adoption of small-scale bioenergy integrated complexes for the production of several coproducts from well-selected dedicated crops, to maintain the price of bioethanol at a preferential level.

It is estimated that in this way production costs of about 250 €/ton can be obtained also by small plants offering thus the opportunity to increase considerably the economic potential of bioethanol at world-wide scale and facilitating for developing countries the possibility of becoming large high value energy producers, with significant impact on their rural development and increase of the general index of Human Development, this being so much related to the energy availability and use.

**BIOETHANOL WORLD MARKET (year 2002)**

- Trading volume = 2 million m3/year
- Production Cost from Sugar Cane (Brazil) = 160 €/m3
- Price of anhydrous ETOH (Brazil) = 220 €/m3
- Dewaxing Cost (depending on capacity) = 30/60 €/m3
- Production Cost of anhydrous ETOH (USA) = 250 €/m3
- Production Cost of anhydrous ETOH from Casava (EU) = 380/480 €/m3
- EU import duty: 250 €/m3

EU import duty: 250 €/m3

**LARGE PLANTS**

<table>
<thead>
<tr>
<th>TYPE</th>
<th>m3 ET0H/ha</th>
<th>COST $/m3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar-beet</td>
<td>2,500-3,000</td>
<td>300-400</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>3,500-5,000</td>
<td>~160 (best)</td>
</tr>
<tr>
<td>Corn</td>
<td>2,500</td>
<td>250-420</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.5-2.0</td>
<td>380-480</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1.2-2.7</td>
<td>800-900</td>
</tr>
<tr>
<td>SweetSorghum</td>
<td>3.0-5.0</td>
<td>200-300</td>
</tr>
<tr>
<td>Cassava</td>
<td>1.5-6.0</td>
<td>700</td>
</tr>
<tr>
<td>Synthesis</td>
<td>-</td>
<td>540 (min)</td>
</tr>
</tbody>
</table>

**WATER & CHEMICALS INPUTS**

<table>
<thead>
<tr>
<th>TYPE</th>
<th>WATER m3/ton</th>
<th>FERTILISERS Kg/crop</th>
<th>Energy/OUTPUT</th>
<th>Energy INPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar-beet</td>
<td>750</td>
<td>N=5</td>
<td>1.76</td>
<td>2.5-9.0</td>
</tr>
<tr>
<td>Sugar-cane</td>
<td>500</td>
<td>N=4</td>
<td>2.5-5.0</td>
<td>1.30</td>
</tr>
<tr>
<td>SweetSorghum</td>
<td>250</td>
<td>N=0.9</td>
<td>2.5-5.0</td>
<td>1.30</td>
</tr>
<tr>
<td>Corn</td>
<td>500</td>
<td>N=4</td>
<td>2.5-5.0</td>
<td>1.30</td>
</tr>
</tbody>
</table>
Why Bioethanol

by Dr. Giuliano Grassi

Transport is a vital strategic sector for modern society. The car industry is a pillar of most countries’ economy accounting for up to 1-2% of GNP and large percent of all consumer expenditures. Yet vehicles also endanger the quality of life contaminating both urban areas and global atmosphere (greenhouse emissions). The fuel and car industries must overcome unprecedented technical, political, social, financial challenges to mitigate these serious environmental consequences and health risks. There is now a large consensus that a transition to new clean alternative fuels and in particular biofuels (together innovative efficient propulsion systems) is urgently required.

Among the most interesting transport biofuels there are:
- Bioethanol
- Bio-methanol
- Biodimethylether
- Biodiesel

Bioethanol has the largest potential (billion of t/year), as it can be produced from all type of biomass resources (bagasse – sugar – lignocellulosic) and can be produced at reasonable cost by large and small plants (decentralized production).

Simple hydrocarbon fuels (i.e. ethanol, methanol, kerosene) burn cleanly, forming mostly CO₂ and water. Gasoline molecules (i.e. isoctane) are considerably more complex and their combustion generates more polluting emissions.

THE DECENTRALIZED BIOETHANOL PRODUCTION BLOCK SCHEME

THE MAIN CHRACTERISTICS

- It is now possible to supply modern bioenergy complexes for remote rural villages based on the utilization of different crops available for the production of several high value commodities.
- The comprehensive utilization and processing of the biomass in integrated complexes with the simultaneous production of several high value commodities is essential for the improvement of the economic activity and for a large scale sustainable deployment of these bioenergy complexes.
- These integrated complexes can provide a vital contribution for a general rural socio-economic development and for considerably increasing the Index of Human Development of the population. 25-70%. It seems that a specific investment of 0.5-1.5 Mio € is sufficient for very poor situations to change the life of one person forever.
- Significant efforts to expand the availability and local manufacturing of commercial small size technologies (for technical assistance and for education & training) for a sustainable bioenergy production must be envisaged as vital measures to ensure a viable and sustainable operation.

The project can include other possible processing integration to improve the economical performance of the complex and the feasibility of the activity. The focus is here on the treatment, besides sweet sorghum, of other sugar-cane crops such as sugar beets, apples, etc., corn, beet melasses and cereal (wheat, barley, etc). As most can use the same fermentation and distillation equipment, the proposed technologies and strategies will be generally applicable to a large number of technologies.

The main components of the bioethanol plant are:
- Raw material receiving and conditioning
- Fermentation
- Distillation

The proposed technologies are well proved and commercial and only the processing of sugar-juice has been taken into account.

MOTIVATION FOR SMALL BIOETHANOL PLANTS

- Main potential benefits of small bioethanol plants:
  - Flexibility: miniaturization of facilities, uses all types of biomass (sugar – starch – lignocellulosic)
- Large flexibility
- Low capital costs
- Low operating costs
- High profitability

Panel: bioethanol production costs

The investment in fuel production plant is estimated at 0.5-1.5 Mio € for a production capacity of 10,000 liters per day (i.e. 3.5 Mio € for a production capacity of 100,000 liters per day).

INVESTMENT (BUDGET FIGURES) FOR SMALL BIOETHANOL PLANTS

- 1 plant (i.e. 10 t ETOL/day) 2.90 mio €
- 10 plants (i.e. 10 t ETOL/day) 1.50 mio €
- 100 plants (i.e. 10 t ETOL/day) 1.00 mio €

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