"Perspectives of Sweet Sorghum Refineries for Viable Coproduction of Biofuels and Green Power"

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EUBIA

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General Context

• 1) Large expected increase of world biofuels production, in particular of bioethanol.
• 2) We estimate that 10% of world gasoline and 3% of diesel-fuel could be displaced by bioethanol from sugar cane alone.
• 3) Because sweet-sorghum requires lower quality soil, lower water inputs, is tolerant to wide-ranging climatic conditions, but with bioethanol yield/ha similar to sugar cane, we can anticipate a much bigger worldwide potential.
Energy Context

World Bioethanol and Biodiesel Production (projections to 2020)

- Projections of biodiesel production to 2020
- Fuel ethanol production projections to 2020
Energy Context

World Bio-electricity Market

TWh

World Bio-electricity Market

year

2000  2010  2020  2030  2040

TWh

0  500  1000  1500  2000  2500  3000  3500  4000  4500  5000

Energy Context
In the near future (next 25 years), a major demand increase is expected for:

- **Liquid transport fuels** & **Electricity**.
- **S.S. Biorefineries** (capable of massive centralised and decentralised coproduction of bioethanol & biopower) could play an important role and provide a significant contribution to these sectorial markets.
4) FORECAST OF INCREASED WORLD CONSUMPTION (period 2005 to 2030)

% Annual Increase

- Total primary En.Consumption: 2.20%
- Liquid fuels: 2.60%
- Nat.Gas: 1.90%
- Coal: 1.10%
- Electricity: 3.20%
- Co2 Emission: 2.30%

Source: IEA
Policy & Financial context.

- Production and use of biofuels require in general **policy support measures** (e.g. detaxation 140 $/m³ for ETOH in USA,…).  
- Many investors, fearing a change of such policies, refrain from supplying the **large investments** needed for production, generating thus an important obstacle to the development of the biofuels market. 
- Furthermore obstacles still exist for free **international trading** of biofuels as for hydrocarbons. 
- S.S. can overcome most of the present obstacles for the establishment of large biofuels markets, infact:  
  - Sweet-Sorghum Biorefineries offer the possibility of a viable co-production of bioethanol + bioelectricity offering the safer recovery of the investments and independent of specific policy-measures and will not lead to market fluctuation of food commodities (grains, sugar, beet, corn…)


Why Sweet Sorghum?

Sweet Sorghum is an extraordinarily promising multifunctional crop for several reasons:

• A high productivity of several components (grains, sugars, lignocellulose);
• It requires common soil even with high % of sand and it is also adapted to salty areas;
• It requires low water inputs (~ 200 m3 /ton), 1/3 of sugar cane requirements, 1/2 of corn;
• It has a shorter growing cycle (4/5 months), 1/3 of that sugar cane;
• Many varieties are available for genetic improvement (~4,600)
• It can be grown in all continents, in tropical, sub-tropical and temperate regions (covering sugar-cane and most sugar-beet areas);
NOTE

Sweet Sorghum is not a food crop but a multi-functional (energy) crop, thus not a competitor crop for the food market!

• Sweet Sorghum absorbs large amounts of CO₂ (~50 t CO₂/ha cycle);
• 1 ltr of bio-ethanol saves ~2.2 kg CO₂ (transport);
• Low energy, production inputs; ~ 0.5 TOE
• Respect of biodiversity in large plantations (wide range of varieties);
• Soil erosion loss (on marginal erodible sites) ~10 t/ha/y, within the tolerance level (11 t/ha/y);
• Biofertiliser production (compost) from Sweet Sorghum residues can improves the sustainability of cropping;
High level of competitiveness of Sweet-Sorghum

- For its high productivity (~100 fresh ton/ha) sugars and lignocellulosic residues are available at low cost (i.e. sugars ~50€/ton, residues: ~20€/ton) making possible a viable Co-production of bioethanol and bioelectricity.

- Since the growing cycle of S.S. is ~140 days, in tropical areas, two plantations per year are possible (10-12m³ ETOH/ha/y) with large increase of the ROI (but sustainability considerations must be carefully taken in account)

- Optimized S-S. Biorefineries present a high Energy Ratio (outputs/Inputs) ~5-8 is therefore very efficient for atmospheric CO₂ absorption and development (in future) of substantial Carbon Credits benefits.
Vast Areas (agricultural, marginal, semi-arid lands) are available on all continents for S.S. plantation.

AREAS WHERE SS COULD BECOME AN INSTRUMENT OF DEVELOPMENT.
VAST AREAS OF THE WORLD HAVE SCARCITY OF ELECTRICITY & TRANSPORTATION FUELS.

World-wide Co production of Green-Power & Bioethanol from S.S. could have a large impact on Development and G.H.G mitigation

Source: www.isofoton.it
Internation Cooperation Promoted by EUBIA on Biorefineries
Commercial sweet-sorghum biorefineries for centralized/decentralized coproduction of bioethanol, power and DDGs

Expressions of Interest and Cooperation promoted by EUBIA:

- USA
- Mexico
- Caribbean (Haiti – S. Domingo)
- Columbia
- Chile
- Brazil
- Uruguay
- South Europe: Portugal – Sicily – Greece
- East Europe: Romania
- Africa: Gabon
- Russian Federation
- India
- China
- Pakistan
- Philippines
### E.U.-25 TRANSPORT LIQUID FUELS.

#### OUTLOOK (M.TOE/Year).

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>130</td>
<td>142</td>
<td>145</td>
<td>141</td>
</tr>
<tr>
<td>Diesel-Oil.</td>
<td>150</td>
<td>182</td>
<td>207</td>
<td>223</td>
</tr>
<tr>
<td>Kerosene</td>
<td>45</td>
<td>53</td>
<td>63</td>
<td>72</td>
</tr>
<tr>
<td>Biofuel share</td>
<td>~5%</td>
<td>10% (37 MTOE/y)</td>
<td>20% (74 MTOE/y)</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>325</td>
<td>377</td>
<td>415</td>
<td>436</td>
</tr>
</tbody>
</table>
Concept of Sweet Sorghum Biorefinery
(1st generation)

Pictures: EUBIA, Bioethanol plant, Cogeneration plant, Pelletisation unit, D.D.G.s unit.
Which size of Sweet Sorghum Biorefinery (1st generation) to be economically viable in the E.U.? 

- Minimum plantations size (Decentralised production):
  • 1000 ha/2000 ha.
  • Bioethanol capacity (microdistillery): 6,000/12,000 m³/ y
  • Power Capacity: 3.3/6.6 MWe.

- Large plantations size (Centralised production): 
  • 10,000 - 50,000 ha (or more)
  • Bioethanol capacity 60,000 - 300,000 m³/ y
  • Power Capacity: 45MWe – 225MWe
Transport energy and vehicle journeys for S.S. biorefineries (Baum and Rumpp, 1993)
Concept of sweet-sorghum Biorefinery

Integrated Bio-energy Complex:
Utilizing all crop components to obtain several products (animal feed, power, agro-pellets and bioethanol), keeping the priority product “bioethanol” at the minimum cost.

Bioethanol can be produced at 250 €/m³
(South, Central, East EU)
Typical Sweet Sorghum Processing

(1,000-50,000 ha) (1st Generation).

Sweet Sorghum Plantation → Harvesting → Cane Crushing → Sugar juice Purification → Grains Drying & Stor.

- Trashes
- Bagasse

Pelletisation → CO₂ → Agro-pellets Storage & Sale

CHP For complex operation

- Distillation
- Dehydratation

Heat for sale

- Fermentation
- Liquefaction & Saccarification
- Centrifugation
- Pelletisation

ETOH Storage & Sale

DDG Storage & Sale
Why a target figure of 250 €/ton for the bioethanol-cost is possible?

• Considering that sugar could be available at 50€/t-lignocellulosic residues at ~20€/d.t.

• Assuming that 60% of the ETOH production cost is due to the feedstock (sugar cost), the anticipated cost for bioethanol from Sweet-sorghum is:

\[
\frac{50 \text{ €/t}}{0.6 \times 0.96 \times 0.932 \times 0.53 \times 0.954} = 200 \text{ €/t ETOH}
\]

Conservative figure: 250 €/m³

The anticipated cost for the first Biorefinery in Portugal is around 200€/m³
<table>
<thead>
<tr>
<th>Biofuel</th>
<th>Production Cost (2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>€/m³</td>
</tr>
<tr>
<td>Bioethanol from Corn (USA).</td>
<td>~ 320€/m³ (477 €/TOE)</td>
</tr>
<tr>
<td>Bioethanol from sugar-cane (Brasil).</td>
<td>~ 170 €/m³ (253 €/TOE)</td>
</tr>
<tr>
<td>Cellulose Bioethanol (year 2030).</td>
<td>~350 €/m³ (500 €/TOE)</td>
</tr>
<tr>
<td>Vegetal oil (Palm)</td>
<td>~ 680 €/m³ (755 €/TOE)</td>
</tr>
<tr>
<td>Vegetal oil (Soybean)</td>
<td>~ 533 €/m³ (592 €/TOE)</td>
</tr>
<tr>
<td>Natural Gas.</td>
<td>~ 327 €/TOE</td>
</tr>
<tr>
<td>Gasoline</td>
<td>~ 430 €/m³ (505 €/TOE).</td>
</tr>
<tr>
<td>Diesel fuel</td>
<td>~ 546 €/m³ (470€/TOE).</td>
</tr>
</tbody>
</table>
Typical Configuration of a S.S. Biorefinery (1°. Generation).
Coproduction (2007 Trials)

1 ha. S.S. Plantation

- ~ 5-6 m³ bioethanol.
- ~ 21-27 dt (lignocellulosic residues).
- ~ 0.5-2.5 t DDG

Production (average) useful biofuels: ~14 TOE (34dt/ha).
Sweet Sorghum Biorefineries for Massive Production of Bioethanol & Power

Typical data for Centralized Production (20,000 ha) in the E.U.

<table>
<thead>
<tr>
<th>Results</th>
<th>Temperate Areas (EU) [one cycle per year]</th>
<th>Tropical Areas [one cycle per year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioethanol Production</td>
<td>120000 m³/y</td>
<td>120000 m³/y</td>
</tr>
<tr>
<td>Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>12 MWe</td>
<td>12 MWe</td>
</tr>
<tr>
<td>Max</td>
<td>85 MWe</td>
<td>85 MWe</td>
</tr>
<tr>
<td>DDG Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>45000 t/y</td>
<td>45000 t/y</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sale of agro-pellets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Max</td>
<td>320000 t/y</td>
<td>320000 t/y</td>
</tr>
<tr>
<td>Total Investment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>251 M€</td>
<td>175 M€</td>
</tr>
<tr>
<td>Max</td>
<td>144 M€</td>
<td>90 M€</td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>97 M€/y</td>
<td>82 M€/y</td>
</tr>
<tr>
<td>Max</td>
<td>117 M€/y</td>
<td>129 M€/y</td>
</tr>
<tr>
<td>R.O.I.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min</td>
<td>19.5%</td>
<td>41%</td>
</tr>
<tr>
<td>Max</td>
<td>29%</td>
<td>44%</td>
</tr>
</tbody>
</table>
Which R.O.I. can be expected?

- Decentralised Bioethanol Production: (~1,000 ha)
  * Investment ~16 mio.
  * R.O.I. ≤10 %.

- Centralised Bioethanol Production: (> 20,000 ha)
  • Investment: ~ 140 – 250 M€
  • R.O.I. ~ 20 - 30 %

  (With Bioethanol market value: 500 € /m³)
Sweet Sorghum Plantation

Harvester machine
Sweet Sorghum Biorefinery (2nd. Generation).

Pictures: EUBIA, Bioethanol microdistillery, Methanol Plant (Venezuela): 700 000t/y (Siemens Cogeneration plant)
Bio-H2 productivity

From Biofuels
- Agro-Pellets (via carbonization) ~ 18 t
- Charcoal ~ 7 t
- Bioethanol ~ 6 t
- Biogas 10,000 m³

From Fossil resources
- Coal (50$/t) 10.1 t
- Oil (40$ Bbl) 5.1 t
- Nat. gas (6 – 7 $/MMBTU) 6,400 m³
- Nafta 4.8 t

1 ton H₂
New technology for production of Agro-pellets from humid biomass or mixtures (mechanical drying & compacting) in view of large-scale supply to the utilisation plants.
Bioethanol Plant
CONCEPT OF LARGE INDUSTRIAL BIO-ENERGY COMPLEXES. ECHI-T
Conclusions

• Sweet-sorghum appears to be a promising viable multi-functional crop for massive production (centralised & decentralised) of Bioethanol & Power, worldwide.

• S.S. biorefineries have the capacity to overcome the major challenging problems existing now in the E.U:
  * Very high production cost based on the use of expensive food-crops (wheat-corn-sugar beets).
  * Low production from cereals, integrated processing not yet adopted.
  * Modest energy Ratio (En. Outputs/ En. Inputs ≤ 2)
  * Limits of scale (difficulty for a decentralised production).

• The anticipated production cost of bioethanol from S.S. is ~ 250 €/m$^3$.

• The first world-wide S.S. Biorefinery (~ 9000 ha plantation) is now under implementation in Southern-Europe.
  • Expected start-up: end year 2009.
Thank you for your attention!