GHG savings with 2G Ethanol Industrial Plant

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Beta Renewables Introduction

Beta Renewables is a joint venture, created in October 2011, between BioChemtex and the investment firm TPG (Texas Pacific Group). Novozymes, Denmark-based world-class biotech company acquired 10% share of Beta Renewables in October 2012.

Beta Renewables owns and licenses the Proesa® technology.

1st commercial-scale 2G bioethanol plant operating in Crescentino (Italy)
A solid family of companies

Polymers
One of the top 3 PET producers worldwide.

Engineering and R&D
60 years of excellence in process development and commercialization of plants

Sustainable Chemistry
Proesa™: technology leader in biofuels and chemical intermediates from non-food biomass
PROESA™ Technology - The Process

PROESA™ Technology benefits:

✓ Feedstock flexibility
✓ Innovative proprietary continuous biomass cooking process with no chemicals addition
✓ Unique process design for a constant and continuous liquefied sugars stream production, together with Novozymes enzyme action
✓ Fully integrated process design using continuous equipment to enable large scale plants
✓ Best in class technology with lowest capex and opex backed with process and performance guarantees
Biomass cooking – Why a steam based technology?

MAIN ADVANTAGES:

✓ No need of additional feedstock conditioning in terms of grinding or size reduction
✓ High flexibility toward different feedstocks: possibility to treat worldwide crops in a wide range of moisture content, size and density
✓ No chemicals addition reduce process complexity (no neutralization operation required, no chemical recycling...)
✓ No special construction material required
✓ Perfect fitting to agrochemical industry
✓ Lowest environmental impact
Deep study of different biomass from various sources

Extensive experience on 55 cellulosic biomasses lab analysis for the determination of composition and physical characteristics:

- food industry residues
- agricultural waste
- forestry residues and woods
- energetic cultivars
- pulp and paper industry streams

Experience on 20 cellulosic biomasses pilot scale testing for the definition of:

- Sugars recovery
- Substrate accessibility-to-enzymes and enzyme affinity to substrate
- EtOH conversion
- Physical characteristic of the stream for proper equipment sizing

✓ Arundo donax
✓ Napier grass
✓ Switchgrass
✓ Energycane bagasse
✓ Sorghum
✓ Poplar
✓ Eucalyptus
✓ Alder
✓ Red maple
✓ Sweetgum
✓ Oil palm EFBs
✓ Oil palm fronds
✓ Oil palm trunks
✓ Sugarcane straw
✓ Sugarcane bagasse
✓ Wheat straw
✓ Rice straw
✓ Corn cobs
✓ Corn stover
✓ Cotton stalks
Crescentino the site... in number...

Footprint of 15 Ha

Ethanol Capacity: 40000 Mt/yr with Arundo Donax; 25000 Mt/yr with straws and woody biomass (poplar/chestnut)

Some interesting facts about the site:
- 370 pieces of equipment
- 1500 tons of steel structures
- 1400 tons of pipes and valves
- 30’000 m³ of concrete
- 18 km of underground piping

13MW green electricity from lignin

100% water recycle = zero water discharge

100 operators on staff
Lifecycle analysis (LCA)

Main goal: to evaluate the environmental impact of PROESA™ technology for 2nd gen bio-EtOH production on a lifecycle basis, from biomass cultivation to fuel burning on vehicles (considering a baseline plant configuration)

Beta Renewables PROESA™ bio-EtOH has been compared to gasoline on the basis of two environmental impact categories:

- **Global Warming Potential** impact (GWP 100a), which represents the lifecycle emissions of Greenhouse gases (GHG)
- **Resource depletion: non-renewable energy** use per unit of fuel produced and burned
2nd gen bio-EtOH produced through the PROESA™ technology shows consistent advantages with respect to the gasoline energy equivalent, under both:

✓ **Climate change**: saving around **1.8 metric tons of CO₂ equivalent per ton of ethanol***, with respect to the production and use of an equivalent energy amount of gasoline (73% of saving)

*Results depend on feedstock and plant configuration considered*
Lifecycle analysis (LCA) - Results

✓ Depletion of non-renewable energy resources (cumulative amounts of crude oil, natural gas, hard coal, lignite and uranium ore consumed over the whole fuel lifecycle): net saving with respect to the energy equivalent fossil reference is around 29 GJ per ton of ethanol* (80% of saving)

* Results depend on feedstock and plant configuration considered
Example: GHG Savings of a 20ktpa PROESA™ Biorefinery

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Energy density (MJ/kg)</th>
<th>CI Score (gCO2eq/MJ)</th>
<th>GHG emissions (kgCO2eq/kg)</th>
<th>tons CO2 saved by Biorefinery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>44</td>
<td>96</td>
<td>4,2</td>
<td></td>
</tr>
<tr>
<td>Corn ethanol (midwest average)</td>
<td>26,8</td>
<td>70</td>
<td>1,9</td>
<td>46’000</td>
</tr>
<tr>
<td>PROESA™ Cellulosic ethanol (rice straw study by JRC)</td>
<td>26,8</td>
<td>23,4</td>
<td>0,6</td>
<td>72’000</td>
</tr>
</tbody>
</table>

A 20’000 ton ethanol biorefinery will save 72’000 tons of CO2, through its bioethanol fuel production. Additional (not considered) benefit is the removal of CH4 due to rotting of biomass on the field. Also, possible valorization and recovery of CO2 from fermentation has not yet been factored into the model.
## EU regulation on GHG savings

<table>
<thead>
<tr>
<th>Biofuel Production Pathway</th>
<th>Typical Greenhouse Gas emission savings</th>
<th>Default Greenhouse Gas Emission savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>wheat straw EtOH</td>
<td>87%</td>
<td>85%</td>
</tr>
<tr>
<td>waste wood EtOH</td>
<td>80%</td>
<td>74%</td>
</tr>
<tr>
<td>farmed wood EtOH</td>
<td>78%</td>
<td>70%</td>
</tr>
</tbody>
</table>

*Extract from Dir 2009/28/EC*

In EU, it is possible to avoid detailed calculation of GHG savings and directly apply the “Default GHG emission savings” reported in the **Directive 2009/28/EC – Annex V**
Beyond Ethanol – PROESA™ Biorefinery Platform

Biomass

PROESA™

Cellulosic Sugars

C5-DERIVED CHEMICALS
C6-DERIVED CHEMICALS
(C5+C6)-DERIVED CHEMICALS

NOW

Ethanol

N-Butanol
Iso-Butanol
Butanediol
Fatty Alcohols
Ethylene Glycol

NEXT

POTENTIAL

Lactid Acid
Green Diesel
Succinic Acid
Acrylic Acid
Adipic Acid
Green Gasoline

POTENTIAL

ENERGY

LIGNIN-DERIVED CHEMICALS

Aromatics
Terephthalic Acid
Phenols

Heat / Steam

Power

CRESCENTINO, Italy
The World’s First Commercial Cellulosic Ethanol Facility
Conclusions

Cellulosic Ethanol can bring relevant contribution in terms of global warming reduction **NOW!**

PROESA™ technology is proven at **industrial scale** with hardwood and other different feedstock

PROESA™ technology does not need harsh chemicals in pretreatment
- **Clean lignin**
- **Low Capex**

Beside EtOH, **sugars-to-chemicals** is an additional opportunity
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