Integrated Biorefineries

How the Advanced Bioindustry is Reshaping American Energy

Gerson Santos
Abengoa Bioenergy
Washington, DC
The global biotech ethanol company

1994
- Acquisition of High Plains Corporation in U.S.
- 650 ML (170 MG) capacity in US and EU
- Need for lignocellulosic ethanol identified; Enzymatic Hydrolysis technology selected

2004
- Acquisition Dedini Agro, Brazil
- Assets in 5 countries, three continents; global 3175 ML capacity
- 2G technology program developed; 2G ethanol pilot & demo plants built
- Construction of 1st cellulosic ethanol commercial scale plant started

2013 Forward
- Startup of first cellulosic ethanol commercial scale plant
- 2G technology licensed to 3rd parties
- Waste-to-biofuels technology
- Development of biobased products, e.g. butanol

Abengoa Bioenergy is evolving...
The global biotech ethanol company

The number one producer in Europe and the fifth largest in the US

...becoming a global diversified bioenergy company

<table>
<thead>
<tr>
<th>Plants</th>
<th>Biofuel Capacity (mgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>6</td>
</tr>
<tr>
<td>Europe</td>
<td>6</td>
</tr>
<tr>
<td>Brazil</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
</tr>
</tbody>
</table>
The global biotech ethanol company

...and through our diversified technology portfolio

Technology investment

Main programs

- Enzymatic Hydrolysis
- W2B
- Bioproducts by fermentation
- Bioproducts by catalysis
- Enzyme development

Collaborations with DOE & EU

- DOE financing validates 2G technology
- DOE supports the EH technology development
- EU supports the development of Abengoa’s technology programs

<table>
<thead>
<tr>
<th>Year</th>
<th>Investment (MM EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>29.5</td>
</tr>
<tr>
<td>2011</td>
<td>134</td>
</tr>
<tr>
<td>2012</td>
<td>207.2</td>
</tr>
</tbody>
</table>
Waste to biofuels technology

MSW

Pretreatment

Sorting (Foucalt, size, magnetic, optical)
Inert compound removal
Accessibility increase
PH adaptation

Organic Fraction

Hydrolysis – Fermentation - Distillation

Stillage concentration

Energy Recovery

Ethanol

Recyclables

Inert Rejection

HC

L

C

$
W2B Demonstration plant has initiated operations; Grand opening done in **June 2013**
Butanol Project

Project Objective

- Develop a process to produce butanol from ethanol at a competitive cost with the fossil route to start the commercial production in 2015

Project and Technology Status

- More than 3,000 h in operation
- Industrialization trials
- Validation in the synthesis loop
- Start up purification
- Finish trials at pilot scale

- Engineering: process concept defined
- Permitting: air permit application already submitted for 4 US plants
- Commercial development: contact with potential customers

IP

- Two patents filed covering several catalyst compositions and the production method
Enzyme Project – Overview

**Economical goal for feasibility**
“reduction of enzyme cost contribution to 2G ethanol cost”

**How?**
- Reducing enzyme cost
- Reducing enzyme dosage

**Two main areas of R&D**
- Enzyme performance
- Enzyme production

**Enzyme Production**
- **Fermentation**
  - Microbial strain
  - Lab cultures
  - Seed stages: 20 m³
  - Production: 150 m³
- **Downstream**
  - Filtration / separation of biomass
  - Conditioning and Stabilization
  - Storage
  - Logistics

**Enzymatic hydrolysis**
- Cellulose fiber
- Beta-glucan chains
- Endoglucanase (EG)
- Beta-glucan oligomers
- Exoglucanase (CBH)
- Beta-glucan oligomers
- Cellobiose & cellotriose
- Beta-glucosidase (BGL)
- Glucose

**Enzyme improvement via genetic modification of producing organism**
# C5 Project – Overview and Status

- Propagation targets achieved
- Finalizing procedures to adjust raw material cost and the operability
- Toll manufacturing to produce dry or cream yeast to:
  - simplify propagation steps
  - minimize internal risk
  - increase shelf life

## Propagation

1. Increase yeast production
2. Scale down ABBK conditions

## Cost reduction

- [Graph showing cost reduction for different strains]

## Sugar conversion

- [Graph showing fermentation byproducts profile vs strain]

<table>
<thead>
<tr>
<th>Item</th>
<th>2012</th>
<th>Current status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fermentation conversion</td>
<td>90%</td>
<td>✅</td>
</tr>
<tr>
<td>Fermentation conditions</td>
<td>ABBK</td>
<td>✅</td>
</tr>
<tr>
<td>Propagation replications</td>
<td>50g/l; 35x</td>
<td>✅</td>
</tr>
<tr>
<td>Propagation procedures</td>
<td>Optimal</td>
<td>✅</td>
</tr>
<tr>
<td>SOTA protocol for C6&amp;C5</td>
<td>70 gal/DUSST</td>
<td>✅</td>
</tr>
<tr>
<td>Close contract manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete tech transfer to toller</td>
<td>Pending</td>
<td></td>
</tr>
</tbody>
</table>
Our 2G biomass to ethanol technology is competitive with the 1G one.
First-of-its-kind commercial-scale facility
Proprietary enzymatic hydrolysis
Financing of USD 132 MM through DOE loan guarantee
Awarded USD 97 MM grant from DOE

Snapshot
- Capacity: 25 MGPY, 21 MW
- Location: Hugoton, KS
- Site: 400-acre parcel
- Feedstock: Corn stover, wheat straw
- Estimated start: Cogen Q3 2013
  EH Q1 2014
- Biomass: ~330,000 d tons per year
Abengoa’s 1st commercial-scale biomass-to-ethanol plant in the USA
Abengoa Bioenergy envisions **sugar** as a **platform** for biobased compounds.

...and **biotechnology** as one of the **greatest technologies** for conversion of sugars to products.
The global biotech ethanol company

Exceptional platform

- Only truly global biotech platform
- Diversified and differentiated product mix
- Unique risk mitigating attributes for each asset
- Serving large, established and growing markets

Superior technology with significant growth prospects

- Leader in second generation (2G) biotech
- Ability to target new growth industries
- Platform to capture growth opportunities globally

Best in class strategy and execution

- Strong financial performance
- Robust risk management systems
- Experienced leadership and operations expertise