Cellulosic Ethanol: An Abengoa Market Perspective

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Abengoa is a technological company that applies innovative solutions for sustainable development in the infrastructures, environment and energy sectors. It is present in over 70 countries where it operates through its five Business Units: Solar, Bioenergy, Environmental Services, Information Technology, and Industrial Engineering and Construction.

Abengoa is a listed company in the Madrid Stock Exchange.

Abengoa Bioenergy generates energy from renewables resources, thus contributing to Abengoa’s main focus on sustainable development.
Ethanol is the most significant alternative to reduce greenhouse gases and reduce our petroleum dependence in the transportation sector.
EU and US: Demand and Opportunities

- Biofuel demand depends on
  - Policies
    - Mandates
    - Energy crops incentives
    - R&D and innovation supporting and grants
  - GHG reduction incentives
  - Oil price
  - World stability in oil production regions

- Opportunities
  - EU and US governments are defining and implementing policies to increase the biofuel demand
  - Biofuel demand from lignocellulosic biomass will create great opportunities for those players with technology and capacity available
US and UE markets will be dominated by starch technology up to 2016

Bioethanol starch markets are presently limited by raw material

- US: 15 – 24 BGal per year
- EU: 18 – 20 ML per year

From 2012 to 2017 biomass plants will start to be operational,

- Up to 5 BGal/year in US in 2017
- Up 2 – 3 ML/year in UE in 2017

Hybrid plants present advantages for early technology deployment

After 2017 biomass stand alone biomass plants will be viable due to technological and mainly energy crops market development
Additional areas to be taken into account

- China and Brazil will represent great production and marketable areas for biofuels from nonfood raw materials
  - China is expanding quickly the transport sector
  - China oil resources are limited
  - China will use non food starch and lignocellulosic crops for ethanol
  - Sugar cane factories in Brazil generate great amount of bagasse residues
  - The bagasse conversion into ethanol will represent an opportunity for lignocellulosic technology
- India and South Africa are starting to look into ethanol as an option to reduce their energy dependence
- South East Asia could will become a significant production region

Lignocelullosic biomass represents a great opportunity for ABNT
Abengoa Bioenergy is the main ethanol producer

The Global Ethanol Player

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<th>EU (MG)</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
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<tr>
<td>Production</td>
<td>142</td>
<td>142</td>
<td>208</td>
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<tr>
<td>Construction*</td>
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Abengoa Bioenergy carries out its R+D through its subsidiary company ABNT, Inc.

- More than 50 investigators in Europe and US working in R+D
- Use partnerships, JVs and equity investments to develop key production technologies

**Strategy Plan**

- Develop and commercialize price competitive biomass technology
- Increase co-product value and develop new co-products
- Improve current dry mill technology
- Develop final use programs
- Promote development of energy crops
Biorefinery concept

- Biorefinery is understood as a further stage in the development of technologies based on biomass as feedstock.
- Optimal combination of biological, thermo-chemical, and chemical processes, aimed to produce a complete range of products, using a wide range of feedstock, and getting advantage of synergies between technologies.
Objective

Develop custom made energy crops for the different conversion pathways and for particular regions ensuring sustainability and environmental quality. Main crops characteristics:

- Domestic crops, high starch and biomass yields per acre, stress tolerances, etc..
- Minimum inputs
- Composition to maximize ethanol production
- Ensure sustainability and environmental quality (from...analysis of microbial communities underlying soils... to formulation of management guidelines for biomass removal)
Steps (continue)

Research in the biological deconstruction of the biomass to produce tailor made enzyme mixes for each specific case:

- Determine fundamental physical and chemical factors in the recalcitrance of lignocellulosic biomass to processing
- Understand cellulase and cellulosome
- Develop new enzymatic systems to reduce thermochemical pretreatment conditions

Advance in the sugar fermentation to ethanol through the engineering of microbial systems to achieve:

- high yield with complete sugar utilization, minimal by-product formation, and minimal loss of carbon into cell mass.
- high final ethanol concentration
- tolerance to inhibitors present in hydrolyzates
- higher overall volumetric productivity, especially under high solids conditions
Current activities

- York Pilot Plant (DOE)
  - Pilot plant: construction completed
  - Startup and operation now
- BCyL biomass plant
  - Economic models completed
  - Construction 75% completed
- Hybrid DOE Project
  - Conceptual engineering completed
  - Contract under negotiation

BCyL Biomass Plant

- Capacity: 1.3 MGPY
- Raw material: Wheat and Barley Straw
- Technology: Enzymatic Hydrolysis (glucose)
- Objective: Demonstrate biomass-to-ethanol process technology at commercial scale
- Start-up Operations: Spring 2008
### R&D Assets

#### Biomass Demonstration Plant in BCL (Salamanca, Spain)
- **Capacity**: 1.3 MGPY
- **Raw material**: Wheat and Barley Straw
- **Technology**: Enzymatic Hydrolysis (glucose)
- **Objective**: Demonstrate biomass-to-ethanol process technology at commercial scale
- **Start-up Operations**: Spring 2008

#### Residual Starch Pilot Plant in York (NE, US)
- **Capacity**: 0.45 MGPY
- **Raw material**: cereal (flexible)
- **Technology**: Dry-mill cereal technology
- **Objective**: Achieve higher starch conversion
- **Start-up Oper.**: Operating

#### Biomass Pilot Plant in York (NE, US)
- **Capacity**: 0.02 MGPY
- **Raw material**: corn stover
- **Technology**: Enzymatic Hydrolysis (glucose & xylose)
- **Objective**: Competitive process with grain ethanol
- **Start-up Oper.**: Now
Biomass gasification and synthesis (BtL) technology – current situation

- Available catalysts are not productive enough to make the process economically feasible.
  - Low conversion per pass
  - Mixed alcohols product with low ethanol selectivity

- Several existing technologists licensing gasification processes for syngas production for further chemical synthesis.

- Catalysts development programs in European research centers, combined with process design and analysis.

- Recently granted by the US-DOE a program (3 MM$) for synthesis catalysts development
Abengoa’s hybrid plant concept

- 35 million bushel grain facility
  - 88 million gallons ethanol
  - 290,000 tons feed co-product

- 245,000 BD metric tons biomass (315,000 short tons-as is)
  - 400 BD metric tons/day
    - 15 million gallons ethanol

- 300 BD metric tons/day
  - Syngas production
  - 1,597,200 MMBTU (syngas+flue gas)
    - 100% steam needs of biomass processing
    - ~30% steam needs of grain to ethanol processing
  - Syngas can be utilized for production of chemical intermediates

- Located in South West Kansas

- Start-up 2011

- Opportunity to leverage infrastructure at many plant operations
Need to make cellulosic ethanol cost effective/competitive with grain ethanol

**Process**
- Cost effective enzymes
- Pentose to ethanol organism(s)
- Fractionation process
- Plant design and operational learning curve

**Feedstock**
- High density balers
- One-pass harvesting systems
- Storage infrastructure and systems to maintain quality
- Improved genetics of feedstock varieties
- Energy efficient harvesting systems
- Transportation infrastructure and biomass friendly regulations
Abengoa Bioenergy

- Leader in production capacity
- Global supplier to oil companies
- Technology innovator and provider to third parties
- Ability to use multiple feedstocks
- World-wide logistics player

Future Market

- Ethanol Competing with gasoline
- Users demanding more ethanol
- Ethanol available at the pump
- Source of energy for under developed countries
- Ethanol flowing to different markets

Bioethanol a sustainable solution to our transportation sector
Abengoa Bioenergy

Thank you