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.
Bioethanol

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
EU and US: Market Projections

- US and UE markets will be dominated by starch technology up to 2016
- Bioethanol starch markets are presently limited by raw material
  - US: 15 - 24,000 Bgal per year
  - EU: 18,000-20,000 ML per year
- From 2012 to 2017 biomass plants will start to be under operation,
  - Up to 5 Bgal/year in US in 2017
  - Up 2,000-3,000 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 oils 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

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

Abengoa Bioenergy carries out its R+D through its subsidiary company ABRD, 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 commercialise 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 recalcitrante of lignocellulosic biomass to processing
- Understand cellulase and cellulosome
- Develop new enzymatic systems to soften thermochemical pretreatment conditions

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

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

- York Pilot Plant (DOE)
  - Pilot plant: construction completed
  - Startup and operation July 2007
- 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: End 2007
Biomass Demonstration Plant in BCL (Salamanca, Spain)

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- Raw material: Wheat and Barley Straw
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- Start-up Operations: End 2007

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.: Mid 2007
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

- DOE proposal based on South Central KS location, however location changed to South West KS based on economic reasons

- Opportunity to leverage infrastructure and many plant operations
Site Selection – Why Kansas?

- Biomass Risk factors considered for our first facility
  - Inclement weather during biomass harvest period
    - Due to this risk factor, Eastern US corn-belt was not considered as a viable location for plant location until one-pass harvest technology is available (potential for one in seven years for biomass harvest to be limited)
  - Biomass crop residue abundance
    - As the DOE is focused on cereal crop residues, areas such as California and South East US (wood residue) were not considered as viable locations for proposal
  - Multiple sources of biomass
    - Multiple biomass sources demonstrate plant replicability over a wider geographic area
    - Multiple biomass sources with harvest periods during different times of the year reduce risk of biomass harvest being compromised by bad weather
    - Multiple biomass sources and harvest times spread harvest machinery investment and will reduce feedstock costs
Site Characteristics

- Grain elevator next to proposed site. Willing to upgrade to handle unit trains
- Located on the Cimarron Valley rail line
  - Connects to BNSF at Dodge City KS and Boise City OK
- 2 million head of cattle on feed at area feedlots – all DG sold wet
- Grain basis ~ +25 to Chicago
- Water is plentiful
- Abundant crop residue
- Land is cheap
- Most if not all ethanol would have to be sold via unit train
Water availability in South West Kansas

Estimated Usable Lifetime for the High Plains Aquifer in Kansas

(Based on ground-water trends from 2000 to 2006 and the minimum saturated thickness required to support 400 gpm well yields under a 90 day pumping period with wells on 1/4 section)

B.B. Wilcox, Kansas Geological Survey, University of Kansas, 1930 Constant Avenue, Lawrence, KS 66047

Years from 2004 Until the Saturated Thickness (ST) Reaches Minimum Threshold

- Water Table Above 2000 Levels
- ST Already At Minimum Threshold
- Under 25
- 25 to 50
- 51 to 100
- 101 to 250
- Over 250

Extent of the Saturated Portion of the High Plains Aquifer

MAP

DOE Hybrid Project
2005 Estimated Annual Agricultural Residues and Switchgrass

Total Feedstock (dry tons/yr x 1,000)
- 0 - 50
- 50 - 100
- 100 - 200
- 200 - 400
- 400 - 800
- Over 800

Ethanol Facilities
- Red: Planned/Engineered
- Green: Under Construction
- Blue: Operational
- Blue Line: Limited Access

Note: Data includes estimated residues for corn stover, wheat straw, milo stubble, and switchgrass potential.
Biomass logistics – key component for profitability

- **Biomass inputs**
  - 50 mile radius of plant site
  - 65% wheat straw, 20% milo residue, 15% corn stalks
  - Opportunistically use other residues such as gin trash, wood chips, etc.
  - Areas evaluated = ~5% of total available

- **80 to 85% of input needs**
  - Producer harvests and stores material field side
  - Abengoa collects material as needed

- **15 to 20% of input needs**
  - Producer delivered material to plant site
Biomass economics

- 80 to 85% of material
  - Contracted at least one year in advance
  - Crop residue is valued at $10/short ton in the field
  - Added to the $10/ton
    - Custom rates for harvesting
    - Custom rates for transporting/stacking at field side
    - Storage fee dependant on amount of time between harvest and
      Abengoa collection – to include competitive insurance rate and
      weather protection
  - $10 plus rates above = price paid for biomass at field side

- 15 to 20% of material
  - Spot market pricing
Biomass economics
What $10/ton means to biomass producers

- Of the $10/ton, between $3 to $4 needs to be returned to the soil for nutrient loss
  - Producer net will be $6 to $7 per ton
    - Wheat @ 1 ton/acre net = $6 to $7 per acre
    - Corn/milo @ 2.4 ton/acre net = $14.4 to $16.8 per acre
    - Switchgrass @ 5 ton/acre net = $30 to $42 per acre

- Many producers live on $25 per acre profit
Needs to make cellulosic ethanol cost effective/competitive with grain ethanol (>2 to 1)

- **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
Future Integrated Biorefinery

Assembly/Preprocessing

“Depot Concept”

Cereal Crops
- Grain
  - Starch
  - Cellulosics
  - Feed
  - Cellulosics
  - Fiber
- Stover/Straw

Sugar Crops
- Sugar
  - Sugar
  - Cellulosics
  - Cellulosics
  - Fiber
- Bagasse

Energy Crops
- Biomass
  - Cellulosics
  - Food
  - Fiber

Biochemical Conversion

Pretreatment Fractionation

Thermochemical Conversion

Fuel Co-products

Heat and Power

Cellulosic Carbohydrates

Non-fermentables

Other Crop Uses
- Starch
- Food
- Feed
- Fiber

Slide courtesy of US DOE
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
Thank you

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