Inbicon Biomass Refinery
Cellulosic Ethanol Technology Platforms
Growth and Sustainability through Biomass Refining, CHP

Technology Review – July 2012
$100MM+ investment in technology and a demonstration refinery

- Ongoing optimization, reduction in capital and operating costs = reduced risk
- Quality assurance for commercial development world-wide
- Proven integration with Coal Power Generation

100 tons/day production facility in Kalundborg, Denmark
Cellulosic Ethanol available for Danish drivers, now
DONG Energy – Inbicon Profile
Feedstock Supply
Technology and Scale Up
Sugar Platform
Engineering and Project Execution
Project Development Pathway
Denmark’s largest energy company

- Traditional Oil & Gas Company in transition to Renewables
- Reduce CO2/kWh to 15 percent of current levels by 2040
- $10 Billion Revenues in 2010, 5000 employees
Inbicon A/S Facts

The headwaters of Cellulosic Ethanol…

- Formed in 2003 to develop **Biomass Refining Technology**
- 85 employees, experienced North American team
- DONG Energy R&D since mid-1990’s
- Headquarters, R&D, Pilot plant in Skærbæk, DK at local power station
- Demonstration plant in Kalundborg at 4 MT/Hr - 5 mmly cellulosic ethanol production - startup in 2009

**Cellulosic ethanol available now in Denmark at 98 fuel stations**
Denmark
Consistent, Long-term Renewable Energy Policy

30+ years of focused policy after the 1973 Arab oil embargo catapulted Denmark ahead in the use of renewable energy, from 99% import dependent to complete independence

• Widespread use of wind, MSW and renewable energy technologies
• Northern Europe leader in wind, biomass
• Net exporter of energy - oil, gas, and power
Inbicon – DONG Energy
20+ Years Biomass Experience in Combined Heat & Power
DONG Energy – Commercial operations, logistical experience. Proven biomass collection and handling systems

The Avedøre Power Station - 810 Megawatts of electricity and 915 MJ/s of heat. At maximum production, 25 tonnes of straw are fired per hour, corresponding to 50 straw bales of 500 kg each, the largest biomass to power plant in the world.
Biomass Supply: Over 163 million acres of crop-residues exist. Purpose grown crops increase potential.
Corn Stover Feedstock Development
North American Harvest Trials

Gathering feedstock for The New Ethanol takes new farm machinery, like this New Holland harvester and cornrower used for our biomass tests done in Indiana, USA Fall 2011.
Indiana Harvesting Trials
Custom Harvesters, Supply Models
Inbicon Biomass Refinery
Feedstock Trials and Validation

- Corn Stover
- Wheat Straw
- Sorghum
- Arundo
- Bagasse
- Palm Oil Residue
Purpose Grown Energy Crops

- **Perennials**
  Switchgrass, Miscanthus

- **Annuals**
  High biomass sorghum, sorghum sudan

- **Grow well on under-utilized lands**

- **High yield/acre = shorter transport, fewer acres**
Inbicon Biomass Refinery Technology

- Molasses Outlet
- Lignin Outlet
- Ethanol Outlet
- Biomass Receiving
- Pre-treatment
- Liquefaction
- Fermentation
- Distillation
Advantages of Inbicon’s enzymatic process.
• Process Guarantees
• Proven at Pilot and Demonstration Scale
• Proven Integration with other energy-producing processes
• Economical route to cellulosic ethanol
Focus on Pretreatment
Simplifies downstream processes, diversifies business

- Optimal use of biomass
- Unlocks three primary biomass components
- Synergy with other industries
- Avoids technical hurdles, high CAPEX
Enzymatic Hydrolysis
Liquefaction of pretreated biomass at ~ 30% solids
Inbicon Biomass Refinery™
Pretreatment & Enzymatic Reactor
Inbicon Biomass Refinery™
Fermentation & Distillation
Inbicon Biomass Refinery™
Optimal Use of Biomass, Maximizing Value

Farm residues (straw, stover)
Energy crops, bagasse

C5 molasses

Bio-based chemicals
Biogas / Power

Ethanol

85% reduction of CO2 emission

Lignin biofuel

Renewable solid fuel, replaces coal in power and heat generation

Animal Feed

C5 conversion to Ethanol
Inbicon Biomass Refinery
Energy integrated solutions

Wheat Straw
50 t/h
(at 86 % dm)

Ethanol
7.0 t/h

C5 molasses used for biogas production

The Lignin and biogas are used in power plant for both production of steam for the INB plant and electricity for own consumption. A surplus of Green electricity can be sold to the grid:
27 MWe

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Inbicon Biomass Refinery
Products – Clean Lignin

• Produce Steam, Power, CHP
• Reduced Slagging/Corrosion
• Low in Salts and Maintenance
• High Coal Displacement Levels
• Proven Emissions and GHG reduction
• RPS price incentives, renewable power targets
Inbicon Biomass Refinery
50 ton/hr commercial scale facility

Requires 450,000 tons/yr stover, straw, or energy crop

• 50 MT/hr plant design produces*:
  28 mmgy cellulosic ethanol from C6/C5 combined sugars
  152,000 ton/yr lignin solid biofuel

Or
  20 mmgy cellulosic ethanol from C6 sugars
  200,000 tons/year C5 molasses
  152,000 tons/yr lignin solid biofuel

* Feedstock composition dependent
Inbicon Biomass Refinery
Competitively advantaged, commercially scalable, today

**Inbicon advantages**
- Simple Hydrothermal Pretreatment and Enzymatic
- Cleanest Co-products for Power and Heat
- Denmark is Center of advances in Enzymes
- Less Intensive Metallurgy Requirements – CAPEX reduction
- Core Technology utilized for Fuel, Feed, Power, Chemicals

**Compared with Acid /Base Hydrolysis**
- Acid/Base hydrolysis is more chemical intensive
- Residues in co-products
- Requires more expensive metallurgy

**Compared with Thermo-chemical**
- Thermo-chemical is much more expensive to build
- Scaling issues have not been overcome
Inbicon Biomass Refinery™ - Integration Examples
50 MT/hr stover ethanol plant with lignin CHP

- **Stover**: 50.0 MT/hr (463k tpy)
- **Steam**: 87.0 MT/hr, 1.0MW/MT stover
- **Electricity**: 12.3MWH/hr, 246 KWH/MT stover
- **CO₂**
- **Inbicon Cellulosic Ethanol Plant**: Ethanol 7.3 MT/hr (20.5M gpy), Lignin BioFuel 17.4 MT/hr (90% dm), 0.35 ton/ton as-is
- **Lignin BioFuel CHP Plant**: Lignin BioFuel Powder 14.2 MT/hr (90% dm), 0.18 ton/ton as-is
- **Lignin BioFuel Pellets**: 3.2 MT/hr (90% dm), 0.20 ton/ton as-is
- **C5 Molasses**: 23.3 MT/hr (65% dm), 0.47 ton/ton as-is

**No External Energy Required**
(Start Up Utilities only)
Inbicon Biomass Refinery™
Why Integrate with Grain Ethanol Operations?

- Enhanced Margins and Asset Value
- Gallons for RFS2 – Ethanol Industry Growth
- Same Farmers supply Feedstock – More Value
- Skills and Staff, Know-How
- Heat and Power for both Grain and Biomass plants
- Compliance - RFS2, CARB/LCFS, EU regulations, DoD
Corn Ethanol Integration

Inbicon 50MT/Hr Stover Refinery

Lignin CHP (Combined Heat and Power)

110mmgy Corn EtOH Plant + DDGS

Requires no new grain acres

$20-$30 million In value for area farming
55Mgpy Corn ethanol

25 MT/hr stover

Lignin to coal power market

Integration with Anaerobic Digestion & Biogas CHP plant
Inbicon Biomass Refinery™ Co-Location Projects
Integrated, Diversified Platform Example

GREEN POWER TO GRID
* 2.6 MW available

40 mmgy Corn Ethanol Plant
Corn 5.2 MT/hr 14.6 M bu/yr

CO2

Ethanol ** + WDGS
Modified Wetcake
* Economics will decide. Could be used on site or exported.
** Low carbon intensity, LCFS compliant

Natural Gas
(Process) 42.5 MT/hr 17,000 BTU/gal
(Drying) 0 MTU/hr 0 BTU/gal

Electricity 3.1 MWH/hr 0.75 KWH/gal

Wheat Straw, Energy Crops
10.0 MT/hr 93k tpy

10 MT/Hr Biomass Refinery

10 mmgy Biomass Refinery

CO2

Ethanol ** + CS Molasses
4.4 MT/hr (55% dm) 0.44 ton/ton as-is

Cellulosic Sugars to market - chemicals, feed, additional ethanol
Near term - Higher value fuel and chemical markets

No External Energy Required
(Start Up Utilities only)

Lignin BioFuel (Clean burning)
3.8 MT/hr (90% dm) 0.38 ton/ton as-is

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Lignin (Powder)

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Lignin (Powder)
Biomass Refinery Platform
N.A. cellulosic and grain ethanol vs. Brazilian sugarcane

Use of Co-Products for process heat and power

Fossil Energy Use (BTU / mm BTU)

- Can be achieved using low-risk proven technologies
- Assumes use of co-product as process heat / power fuel, like bagasse in sugarcane ethanol

Gasoline: 1,200,000
Corn Ethanol: 600,000
Cellulose Ethanol: Projected, with co-product CHP
Inbicon Biomass Refinery™
Surpassing the EPA’s RFS2 Compliance Standards

GHG Emissions (g CO₂ e / mmBtu)

-60,000 -40,000 -20,000 0 20,000 40,000 60,000 80,000 100,000

2005 Gasoline Baseline
Corn Stover Ethanol
Corn, Base Dry Mill NG, DDGS

- Coproduct Credit
- Fuel Production
- Tailpipe
- Fuel and feedstock transport
- Domestic Farm Inputs and Fertilizer N2O
- International Land Use Change
- International Farm Inputs and Fertilizer N2O
- International Livestock
- Domestic Soil Carbon
- International Rice Methane
- Domestic Livestock
- Domestic Rice Methane
- Net Emissions

Inbicon Biomass Refinery™
LifeCycleAssociates, LLC
Biomass Refining and Cellulosic Ethanol
What is required for first movers?

PROJECT RISK ASSESSMENT and MARKET CERTAINTY

Feedstock Supply

Technology and Scale Up

Policy and Legislative Certainty

Project Execution

Economics – CAPEX and OPEX
Inbicon Project Execution
50 MT/Hr – 20 mmgy Commercial Plant + sugars, lignin
Inbicon Biomass Refinery
Project Execution Battery Limits

A. Soft Biomass Storage
B. Soft Biomass Preparation
   DONG Energy Know-How
C. Soft Biomass Pretreatment
D. Soft Biomass Conversion
   Inbicon Proprietary Technology

A. Fermentation
B. DD&E
C. Centrifuge Building
D. Lignin Pad
E. Dryers
F. Cooling Towers
G. Ethanol Storage
   Established Ethanol Process Technologies

H. Co-Gen Facility
   CHP Known and Established Technologies
**Equipment Supplier Agreements**
Companies with decades of experience, at scale
Pulp and Paper

**North American Engineering Partners**
Pöyry Engineering, Harris Group, APS

**EPC Alliances**
World’s largest EPC – project in FEED phase
EPC alliances with Engineering Partners
US and Canadian EPC companies

**Engineering work completed for other projects**
Equipment Drawings
M&E Balances, P&ID’s, Deliverables
Inbicon Biomass Refinery Project Development and Contracts

Contract set-up, main topics
- Technology Sales Product Portfolio - During The Project Model (example: Inbicon)

The objective of the screening is to analyze the technical and economic factors for the further development of an Inbicon Biomass Refinery Technology plant.

The results from the screening include the following:
- Biomass description
- Product description
- General mass and energy balance
- General economy.

Screening of a specific biomass is free.
The following steps will trigger a contract:
- PDP = Process Description Package
- FEED = Front End Engineering and Design
- BRT = Biomass Refinery Technology
- License = License Contract
- Service = Service Management Contract
- Support = Operational Support (Production Royalty)
CAPEX 20 Yr Straight Line
No RIN’s. Tax Credits, Premiums