Status report on Demonstration Plants for advanced Biofuels Production
- Biochemical Pathway

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Disclaimer

The presenter has gathered most of the information from contacts with project owners and technology suppliers and to some extent from Internet.

Some deviations from factual situation may be presented.

The presentation does not claim to completely cover the given topic.
Lignocellulosic feedstocks

SUGARS

Ethanol and higher alcohols from sugar via FERMENTATION

5

Renewable hydrocarbons from sugar-containing biomass via BIOLOGICAL PROCESSES and/or CHEMICAL PROCESSES

6

Main markets: Renewable transport fuels as gasoline components, E85

Main markets: renewable transport fuels for jet and diesel engines

Aquatic biomass (e.g. macroalgae, microalgae)

Bioenergy carriers from CO₂ and light through MICRORGANISM-BASED PRODUCTION and upgrading into transport fuels and valuable bioproducts

7
Value Chain 5:

- Main issues
- Cellulosic EtOH demo and planned plants => potential
- Biobutanol plants
Cellulosic ethanol: generic process scheme

WOODY AND AGRICULTURAL BY-PRODUCTS RESIDUES ENERGY CROPS

PRETREATED BIOMASS

ENZYMATIC or CHEMICAL HYDROLYSIS

FERMENTATION

ETHANOL

DISTILLATION

FERMENTABLE SUBSTRATES

BACTERIA FUNGI ENZYMES

YEASTS
Value chain 5: main issues

- EtOH cost
  - Pretreatment
  - Enzymes
  - C5 conversion
  - By-products use
  - …
- Feedstock availability
- Biorefinery integration
- Biobutanol?
# Main cellulosic EtOH running demos (>1000 t/y) in EU

<table>
<thead>
<tr>
<th>Plant Owner</th>
<th>Location</th>
<th>Input capacity (t/year)</th>
<th>Output capacity (t/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clariant (ex Sud Chemie)</td>
<td>Straubing, Germany</td>
<td>Agriculture residues, wheat straw</td>
<td>1 000</td>
</tr>
<tr>
<td>Abengoa Bioenergy, Biocarburantes Castilla y Leon, Ebro Puleva</td>
<td>Babilafuente, Salamanca, Spain</td>
<td>25 000 t/year (barley/wheat straw, corn stover)</td>
<td>4 000</td>
</tr>
<tr>
<td>Inbicon (Dong Energy)</td>
<td>Kalundborg, Denmark</td>
<td>30 000 t/year (wheat straw, other lignocellulosics)</td>
<td>4 300</td>
</tr>
<tr>
<td>Chempolis</td>
<td>Oulu (Chempolis R&amp;D Center), Finland</td>
<td>25 000 t/year (non-wood, non-food raw material) formicobio™ process</td>
<td>running ?</td>
</tr>
<tr>
<td>Beta Renewables (JV Chemtex (M&amp;G), TPG, Novozymes)</td>
<td>Crescentino, Italy</td>
<td>Non-food biomass (giant cane and wheat straw)</td>
<td>40 000</td>
</tr>
</tbody>
</table>
Clariant facility

• Start up in July 2012
• Feedstocks
  • agricultural residues as feedstock (Phase 1)
  • dedicated energy crops (Phase 2)
• The Sunliquid® process involves: a hydrothermal pretreatment at mild process conditions, a process-integrated production of enzymes, enzymatic hydrolysis, a specialized fermentation organism that simultaneously converts C5 and C6 sugars into ethanol in a « one-pot reaction », adsorption-based separation of ethanol

Courtesy Clariant
Abengoa facility

• **Start up in September 2009**

• **Feedstocks:**
  • Wheat straw, barley straw

• **The production process** involves: preparation of biomass, thermochemical pretreatment, enzymatic hydrolysis and fermentation with enzymes and yeast, distillation to produce ethanol and a solid co-product.

*Courtesy Abengoa*
Inbicon facility

- **Start up in Dec 2009**
- **Feedstocks**
  - process developed on wheat straw
- **Process:** hydrothermal pretreatment (30-40% Dry Matter), continuous enzymatic liquefaction and hydrolysis, use of externally-produced enzymes, production of C5 molasses, Energy co-production

*Courtesy Inbicon*
Beta Renewables facility (M&G Chemtex)

• Start up in December 2012
• Feedstocks: non-food biomass
  • developed on Arundo donax (Giant cane) and wheat straw
• Initial capacity 40,000 tons/y then 60,000 tons/y
• Production process: PROESA®

Courtesy Beta Renewables
### Main announced EtOH G2 demos (>1000t/y) in the EU

<table>
<thead>
<tr>
<th>Plant</th>
<th>Location</th>
<th>Input raw material</th>
<th>Output capacity (t/year)</th>
<th>Planned Start-up date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogasol (BornBio-Fuel 2)</td>
<td>Aakirkeby, Bornholm, Denmark</td>
<td>Various lignocellulosics incl. grasses, green waste, straw</td>
<td>4 000</td>
<td>2013</td>
</tr>
<tr>
<td>INEOS Bio</td>
<td>Seal Sands, Tees Valley, UK</td>
<td>Biodegradable household and commercial waste</td>
<td>24 000</td>
<td>2015</td>
</tr>
<tr>
<td>Procethol 2G (Futurol)</td>
<td>Lillebonne, France</td>
<td>Various lignocellulosics</td>
<td>1 500</td>
<td>2015</td>
</tr>
<tr>
<td>NER300 project CEG (Sekab)</td>
<td>Goswinowice, Poland</td>
<td>Agricultural residues: wheat straw, corn stover</td>
<td>48 000</td>
<td></td>
</tr>
<tr>
<td>NER300 project BEST</td>
<td>Crescentino, Italy</td>
<td>Giant cane, wheat straw</td>
<td>40 000</td>
<td></td>
</tr>
</tbody>
</table>
Main running EtOH G2 demos (>1000t/y) in North America

<table>
<thead>
<tr>
<th>Plant Owner</th>
<th>Location</th>
<th>Input capacity (t/year)</th>
<th>Output capacity (t/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IOGEN Corporation</td>
<td>Ottawa, Ontario, Canada</td>
<td>30 t/d (wheat, barley and oat straws)</td>
<td>1 600</td>
</tr>
<tr>
<td>BP (Jennings Demo Facility)</td>
<td>Jennings, LA, US</td>
<td>Sugarcane bagasse, switchgrass, wood products</td>
<td>4 180</td>
</tr>
<tr>
<td>Blue Sugars Corporation (KL Energy Corporation)</td>
<td>Upton, Wyoming, US</td>
<td>33 500 t/y (bagasse, wood, pulp) (integ. enz. prod.)</td>
<td>4 500</td>
</tr>
<tr>
<td>BlueFire Renewables</td>
<td>California, US</td>
<td>acid hydrolysis, various wood and paper wastes, bagasses</td>
<td>11 100 ?</td>
</tr>
</tbody>
</table>
2G Ethanol projects running or in construction 2012 - UE/USA (> 1000 t/y)

- **Abengoa – USA**: 74 kt/yr
- **Blue sugars – USA**: 4.5 kt/yr
- **BP/Verenium – USA**: 4.2 kt/yr
- **Iogen – CA**: 1.6 kt/yr
- **Inbicon – DK**: 4.3 kt/yr
- **Abengoa – ESP**: 4 kt/yr
- **Poet /DSM – USA**: 60 kt/yr
- **DuPont/Danisco – USA**: 90 kt/yr
- **Clariant – GER**: 1 kt/yr
- **BP – USA**: 100 kt/yr
- **INEOS BIO – USA**: 24 kt/yr
- **Beta Renewables – IT**: 40 kt/yr

Projects are marked as **Running** or **Under construction**.
Main EtOH G2 demo units outside EU

**Running**
- BP/Verenium j-v – USA – 4180 t/y
- DuPont Danisco/UT-Genera Energy – USA – 750 t/y
- Blue Sugars – USA – 4500 t/y
- Mascoma – USA – 600 t/y
- Jigen – Canada – 1600 t/y
- Jilin Juxin Industry group – China – 30000 t/y
- Beijing Tiandi Riyue Biomass technology – China – 8000 t/y
- Chinese Academy of Agricultural Engineering – China – 4000 t/y
- Henan fuel ethanol – China – 8000 t/y (2 units)
- CNPC – China – 3000 t/y (2 units)
- Shandong Longlive Bioenergy – China – 40000 t/y
- Shandong Wande – China – 8000 t/y
- Shandong Xueling Starch – China – 3000 t/y
- ZTE Energy – China – 30000 t/y
- Bioethanol – Japan – 1000 t/y
- Kirin Brewery – Japan – 8000 t/y
- Kirov Biochemical – Russia – 15000 t/y
- Thai Roong Ruang Energy – Thailand – 25000 t/y
- BlueFire Renewables- USA – 11 100 t/y ?

**Announced**
- **Abengoa Bioenergy Biomass of Kansas** – USA – 74000 t/y
- ADM - USA - 3000 t/y
- BlueFire Ethanol - USA – 55000 t/y
- BP – USA – 100000 t/y (canceled)
- Colusa Biomass Energy – USA – 30000 t/y (canceled?)
- **Fiberight** – USA – 11000 t/y
- ICM – USA – 150000 t/y
- **INEOS Bio** - USA – 24000 t/y
- Mascoma – USA – 60000 t/y
- Poet / DSM – USA – 60000 t/y
- IOGEN – Canada – 68000 t/y (canceled)
- Blue Sugars/Petrobras – Brazil – 7900 t/y
- DuPont Danisco - 90000 t/y
- GraalBio – Brazil – 65000 t/y
- TMO/Usina Santa Maria - Brazil- 7880 t/y
- Beta Renewables – USA – 60000 t/y
- Zeachem – USA – 75 t/y
Projects statistics

- 65 running projects
- 11 under construction projects
- 52 total projects

Bar chart showing:
- 0-1 Ml (<800 t/yr)
- 1-10 Ml (0.8-8 kt/yr)
- >10 Ml (>8 kt/yr)

- 36 projects in 0-1 Ml category
- 17 projects in 1-10 Ml category
- 11 projects in >10 Ml category
- 9 projects in >10 Ml category

Number of EtOH G2 projects
Potential EtOH G2 announced capacities

- 600 kt/y
- 190 kt/y
- 175 kt/y
- 150 kt/y
- 1350 kt/y
- 160 kt/y
- 275 kt/y

Not including projects under construction

Source: CEDIGAZ
Biobutanol

- **Butamax** (JV Dupont/BP): Demo 30t/y Hull, UK (Startup 2010)
- **Gevo:**
  - 55,000t/y Luverne, USA (Operating 17 weeks since May 2012 then switch to EtOH production for flexibility demonstration)
- **Cobalt Technologies**: 1440t/y Thomaston, USA (Startup 2013)
- **Green Biologics**
Ethanol hybrid processes

- **Zeachem**: fermentation of C5-C6 sugars to acetic acid, esterification and hydrogenation to EtOH with hydrogen from gasification of lignin:
  - 750t/y: Boardman, USA (Construction completed in October 2012; EtOH production should have started since end 2012; conversion of sugar to ester operational)
  - 75000t/y: co-located with pilot plant

- **Coskata**: Gasification then fermentation of syngas to EtOH (Syngas now produced from gas and not biomass)

- **INEOS Bio**: Indian River, USA: 24000t/y + 6 MW (Construction completed in June 2012; power production in October; EtOH production should have started since end 2012)
Value Chain 6: Biological processes

- **LS9** – fermentation pathway from sugar to fatty acid/alcohol; 270t/y, Okeechobee, USA (operating since Sept 2012)
- **Amyris** - fermentation pathway from sugar to «Biofene»; 40,000t/y at Paraiso, Brazil (production since 27/12/2012; full capacity for 2015)
Value Chain 6: Chemical processes

- **Virent** - Chemical pathway from sugar (Aqueous Phase Reforming). 38t/y, Madison, USA (Demo operating since 2010)

- **UPM** - Chemical pathway from tall oil (residue of chemical pulp production) to UPM BioVerno (biodiesel) by hydrotreatment; 100,000t/y at Lappeenranta, Finland (plant should be ready in 2014)
Value Chain 7:

- Heterotrophic and autotrophic organisms
- Difficult to obtain reliable data on demo plants (capacity and production)
- Refer to the Algae Task Force of the EBTP

Aquatic biomass (e.g. macroalgae, microalgae) → Bioenergy carriers from CO₂ and light through MICRORGANISM-BASED PRODUCTION and upgrading into transport fuels and valuable bioproducts → Main markets: renewable transport fuels for jet and diesel engines
Conclusions

• Cellulosic EtOH development still faces technical and economic issues but many large projects announced all over the world

• RFS2 maintains 2022 targets on advanced biofuels
  • In 2013, 14 Mgal (52 000 t) cellulosic EtOH should be produced in USA (Abengoa Bioenergy, Fiberight, INEOS Bio and KiOR Inc)
  • « 2013 will be a “pivotal” year for the cellulosic and advanced biofuels industries to demonstrate commercial and economic viability in order to contribute toward the proposed 2013 volumes » (Bio Association)

• Slower development of the other pathways (value chains 6 & 7)

• Europe:
  • The first commercial plant (Beta Renewables)
  • + 2 new large demo plants (NER300) (and may be more)
Converting straw to biofuel still needs to be demonstrated!

Thank you