Biomass Conversion

On the cusp of commercialization

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Session outline

• Progress and challenges last 18 months
• Reasons to believe in biomass conversion
• Innovation priorities
• Raízen: Views from leading brazilian sugar cane crusher and biomass conversion pioneer
15 years of continuous development and one of our largest R&D investments

2001

One of largest R&D investments in Novozymes’ history was initiated

2005

Biomass conversion pilot plants worldwide testing Novozymes enzymes

2009

Launch of Cellic® CTec for the first cellulosic ethanol demonstration plants

2012

The first commercial cellulosic ethanol plant: Crescentino – using Novozymes’ Cellic® technology

2013

Exclusive partnership with Brazil’s largest sugar-based ethanol producer

2015

Five of seven large scale biomass conversion ethanol plants globally use Cellic® technology

Foundation

Pilot stage

Demo stage

Initial commercial stage

Optimization stage
Progress towards commercialization since Capital Markets Day 2013

Biomass conversion industry in fall 2013

- Beta Renewables’ Crescentino plant is the world’s first and only commercially operating cellulosic ethanol plant
- Three plants under construction in the US and two in LA
- Large number of publicly announced biomass conversion projects
- Expectation of a relatively fast industry commercialization
- Novozymes’ Cellic® CTec3 is the leading enzyme technology (one size fits all enzyme product)

Biomass conversion industry today

- Six commercial plants are in operation with Novozymes supplying five of them. DuPont to be #7
- All process steps undergoing optimizations
- 20+ solid biomass conversion projects are under development globally (not all publicly announced)
- Recognition that industry commercialization will take longer
- Novozymes is committed to pursue further process optimizations beyond enzymes. Our customized next generation Cellic® enzyme solutions are being launched
- Novozymes heavily engaged in project development with “boots on the ground” globally
Headwinds and longer timelines than anticipated, but several reasons lead us to believe that these will be overcome

Prolonged industry ramp-up
- Up-scaling of commercial plants takes longer than expected. From serving 15 plants by 2017 to an assumption of ~15 by 2020
- New projects struggle to find financing, as everyone is in waiting mode to get confirmation of the economics
- Some projects have been cancelled or on hold

Macro and regulatory uncertainty
- Lower oil price casts uncertainty and makes for a tougher environment for biofuels – particularly in the US and Asia
- US ethanol demand stuck in limbo due to the blend wall and unclear regulatory framework

New industries take time
- it's a marathon, not a sprint

Many industries deliver lower Capex over time

Novozymes as a full biotech solutions provider to bolster biomass conversion process optimization

Healthy project pipeline continues to mature

Expectation that internal combustion engines / liquid fuels will play a substantial role in the future

National blending mandates in the EU (Italy announced, more in the making)

Brazil ethanol blending mandate increase to E27
Comparable disruptive technologies have taken 15+ years to take off; enabling an industry is a “marathon” with multiple hurdles to be overcome.

### Corn ethanol

**Installed corn ethanol capacity (U.S.), 1990–2014**

<table>
<thead>
<tr>
<th>Year</th>
<th>Million gallons/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>5,000</td>
</tr>
<tr>
<td>1992</td>
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<td>1994</td>
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<td>2000</td>
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<td>2002</td>
<td>8,000</td>
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<td>2004</td>
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<td>2006</td>
<td>9,000</td>
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<td>2010</td>
<td>10,000</td>
</tr>
<tr>
<td>2012</td>
<td>10,500</td>
</tr>
<tr>
<td>2014</td>
<td>11,000</td>
</tr>
</tbody>
</table>

- +9% in 2000
- +29% in 2004
- +4% in 2012

### Solar

**Global solar power cumulative installed PV capacity 2000–2012**

<table>
<thead>
<tr>
<th>Year</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0</td>
</tr>
<tr>
<td>2001</td>
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<td>2002</td>
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<td>2011</td>
<td>0</td>
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<tr>
<td>2012</td>
<td>120,000</td>
</tr>
</tbody>
</table>

- +31% in 2006
- +57% in 2012

### Shale gas

**Gas production from shale gas**

<table>
<thead>
<tr>
<th>Year</th>
<th>Billion cubic feet per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0</td>
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<td>2007</td>
<td>10</td>
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<td>2008</td>
<td>15</td>
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<td>2009</td>
<td>20</td>
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<td>2010</td>
<td>25</td>
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<td>2011</td>
<td>30</td>
</tr>
<tr>
<td>2012</td>
<td>35</td>
</tr>
<tr>
<td>2013</td>
<td>40</td>
</tr>
</tbody>
</table>

- +25% in 2005
- +29% in 2012

### Wind

**Global cumulative installed wind capacity 1996–2013**

<table>
<thead>
<tr>
<th>Year</th>
<th>MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>0</td>
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<td>1997</td>
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<td>2010</td>
<td>0</td>
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<tr>
<td>2011</td>
<td>0</td>
</tr>
<tr>
<td>2012</td>
<td>350,000</td>
</tr>
<tr>
<td>2013</td>
<td>375,000</td>
</tr>
</tbody>
</table>

- +23% in 2012
- +27% in 2013

Source: US Renewable Fuels Association (annual capacities) after 1999 and SRI (from 1990); Industry reports; McKinsey analysis.
Significant learnings in first biomass conversion plants and the example of the US 1G industry suggest that Capex will reduce for the next wave of biomass conversion plants.

Major reasons for reduced Capex:

- Optimized plant and process design including less over-engineering
- Bolt-on solutions use existing infrastructure and utilities
- Development of standard modules

In spite of existing challenges, we see a solid project pipeline that continues to mature across regions

While several biomass conversion ethanol plants are already operating, more than 20 solid biomass conversion projects are under development globally (not all publicly announced)

Different business models:

- Co-marketing with Beta Renewables
- Project development
- Large strategic partners e.g. Raízen

Publicly announced, commercial biomass conversion projects under development by region (Q1/2015)*

*Non-exhaustive
Major improvements in Novozymes’ enzyme technology have been a key enabler of biomass conversion commercialization and will drive further plant optimization.

Customized Cellic® enzyme technology: Further improvement is achieved through customization of enzymes to match specific process and feedstock.

Enzymes as a valuable tool: Sweet-spot optimized enzyme dosing ensures the lowest unit cost of ethanol cost. For example, improved enzyme performance has been shown to reduce the use of acid in pretreatment.

Pretreatment severity | Enzyme dosing | Total solids loading | Hydrolysis time | Biomass to sugar conversion

Sweet spot optimized to get the lowest unit cost of ethanol

Enzyme use costs development (indexed)

0 20 40 60 80 100

2007 2008 2009 2010 2012 2015 2018

Cellic® CTec Cellic® CTec2 Cellic® CTec3 Customized Cellic® 1.0

Years
Novozymes biotech solutions continue to bolster biomass conversion process optimization and its competitiveness

- Novozymes launches new family of customized Cellic® enzymes tailored to reduce enzyme cost and improve production performance

- Ongoing optimization of all process steps will further reduce production costs

**New customized Cellic® solutions and further process optimizations continue to reduce biomass conversion costs**

Note: Based on NREL acid pretreatment process

![Diagram showing the reduction in cellulosic ethanol production costs](image-url)
Customer-centric Novozymes Cellic® enzyme development – tailored to the individual process and feedstock

- Diverging processes with different feedstocks are being established at industrial scale
- For every combination of process and feedstock, there will be an optimal enzyme system
- Every enzyme system benefits from optimization work

**Biomass**

<table>
<thead>
<tr>
<th>Pretreatment</th>
<th>Steam</th>
<th>Acid</th>
<th>Alkali</th>
<th>Org. solvents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass after pretreatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Steam
- Acid
- Alkali
- Org. solvents

Cellulose

Hemicellulose

Lignin

- Energy crops
- Bagasse
- Wheat straw
- Corn stover

Tailored Cellic® solutions
Customized Cellic® enzyme solutions; process, feedstock, temperature and pH

Key benefits vs. Cellic® CTec3

- **Yield boost** – Improved hydrolysis performance on xylan-rich substrates
- **Robust activity** – Broader pH and temperature profiles provide robust activity
- **Contamination control** – Higher hydrolysis temperature and lower pH inhibit contamination
- **Lower OPEX** – Reduced base consumption and waste treatment costs

What’s next?

- Adapt customization to evolving partner processes
- Continue optimization efforts together with partners – to drive out cost not only of enzymes but also of process and potential Capex
E2G Program
João Alberto F. de Abreu
Agenda

Introduction to Raízen
Raízen's strategy
How 2G fits into this
Current status on Raízen's 2G efforts
Learnings from plant #1 (in broad terms)
Obstacles to overcome for the industry/Raízen
Opportunities and plans for the future
Raízen

Lubrificantes

Downstream

50%

Upstream

50%

Cosan Lubrificantes e especialidades

Natural no seu vício
Business dimensions
World’s largest sugar producer and Brazil’s largest sugarcane ethanol producer

915,000 ha of cultivated area

2 bi liters of ethanol

96% mechanized harvesting

4 m tons of sugar

941 MW of installed capacity
Fuel distribution
A highly efficient and reliable network

5245 Retail stations
910 Convenience stores
60 Distribution depots

58 Airports bases
23.6 Billion m³
Raízen – general numbers in 2013/14

World cane crushing (mln t)

1º Brazil 640
2º India 240
3º Thailand 110
4º China 100
5º Raízen 61.4
6º Mexico 58
7º Pakistan 50
8º Australia 32

* Source: LMC.
Ethanol, sugar and bioenergy
Strategic drivers

Aspiration:
Lower cost of production per sugarcane tones

<table>
<thead>
<tr>
<th>Business drivers</th>
<th>Cost reduction</th>
<th>Productivity</th>
<th>Portfólio management</th>
<th>Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enablers</td>
<td>HSSE</td>
<td></td>
<td></td>
<td>People</td>
</tr>
</tbody>
</table>

ROACE X%
Crushing 65,4MM TC
Ethanol, sugar and bioenergy Production

24 Mills

1. São Francisco, Rafard, Bom Retiro, Santa Helena, Costa Pinto
2. Barra, Dois Córregos, Diamante
3. Bonfim, Tarumã, Maracaí, Ipaussu
4. Univale, Destivale, Mundial, Benálcool, Junqueira
5. Jataí
6. Caarapó

Greenfield in MS 2,3 Mtc
Greenfield in GO 4,1 Mtc

Santos Port
Tops & leaves can be the main feedstock for 2G if the industry overcomes logistics challenges

- Mechanization process has been increasing significantly and has reached 65% in industry
- Not burning means extra 45M ton of biomass available in the industry.
- Two process must be selected:
  - Bring biomass together with the sugarcane
  - Bales collection system
Potential of biomass
Ethanol production per hectare

CANE STALK: 85 tons
MILL: 23.8 tons
JUICE: 23.8 tons
BAGASSE
SUGAR
ETHANOL
Max. 7 to 8 m³

DRY LEAVES: 14.1 tons
GREEN LEAVES
BIOMASS
ETHANOL

TOPS
Extra 2 m³
# Integration opportunities
## Plug & play 2G with a 1G plant

<table>
<thead>
<tr>
<th>Opportunities</th>
<th>120 MM Liters</th>
</tr>
</thead>
</table>
| Steam/Power Supply            | 1. Retrofit of an existing boiler instead of installing a new boiler.  
                                | 2. Lignin burning supplies steam and power required by 2G process.                                                                                                                                              |
| Biomass Handling              | 1. Synergies with existing assets;  
                                | 2. Existing know-how.                                                                                                                                                                                          |
| C6 Fermentation               | 1. Existing know-how.                                                                                                                                                                                             |
| Distillation                  | 1. Synergies with existing assets;  
                                | 2. Existing know-how.                                                                                                                                                                                          |
| Water / Vinasse Utilities     | 1. Synergies with 1G water balance (final molasses dilution);  
                                | 2. Retrofit of existing vinasse disposal system;  
                                | 3. Existing know-how about vinasse disposal.  
                                | 4. Operational synergies between 2G and 1G process (utilities, lignin handling, offices, warehouse, maintenance, etc.)                                  |
### Sugarcane segment scenario in Brazil

#### Enormous changes since 2009

- **Number of new production units in the Centre-South region**
  - 2005/06: 9
  - 2006/07: 18
  - 2007/08: 22
  - 2008/09: 29
  - 2009/10: 21
  - 2010/11: 10
  - 2011/12: 3
  - 2012/13: 2
  - 2013/14: 2
  - 2014/15: 0
  - 2015/16e: 1

- **Number of closed mills**
  - 2005/06: -2
  - 2006/07: -2
  - 2007/08: -3
  - 2008/09: -5
  - 2009/10: -14
  - 2010/11: -13
  - 2011/12: -9
  - 2012/13: -11
  - 2013/14: -10

*More than 50 kMT of crushing capacity lost*

*Fonte: UNICA. Nota: e - estimativa*
## Brazilian matrix of fuel

**Projections 2020-2025**

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sugarcane (million tons)</strong></td>
<td>641</td>
<td>600</td>
<td>650</td>
</tr>
<tr>
<td><strong>Sugar (million tons)</strong></td>
<td>35,6</td>
<td>40,5</td>
<td>46,3</td>
</tr>
<tr>
<td>Exportation assumption</td>
<td>24,4</td>
<td>28,8</td>
<td>34,0</td>
</tr>
<tr>
<td><strong>Ethanol (billion liters)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anhydrous (27%)</td>
<td>11,9</td>
<td>16,5</td>
<td>20,0</td>
</tr>
<tr>
<td>Hydrous</td>
<td>15,3</td>
<td>3,5</td>
<td>0,0</td>
</tr>
<tr>
<td>Exportation</td>
<td>1,0</td>
<td>1,2</td>
<td>3,3</td>
</tr>
<tr>
<td>Others</td>
<td>1,1</td>
<td>1,2</td>
<td>1,3</td>
</tr>
<tr>
<td><strong>Available ATR (million tons)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply</td>
<td>87,2</td>
<td>82,8</td>
<td>91,0</td>
</tr>
<tr>
<td>Demand</td>
<td>87,2</td>
<td>82,8</td>
<td>91,6</td>
</tr>
<tr>
<td>Volume gap</td>
<td></td>
<td></td>
<td>0,59</td>
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<tr>
<td>Sugar (million tons)</td>
<td></td>
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<td>0,567</td>
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<tr>
<td>EtoH anhydrous (billion liters)</td>
<td></td>
<td></td>
<td>0,340</td>
</tr>
<tr>
<td><strong>Fuels (billion liters)</strong></td>
<td></td>
<td></td>
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<tr>
<td>Current gasoline (EPE)</td>
<td>30,6</td>
<td>31,4</td>
<td></td>
</tr>
<tr>
<td>Gasoline demand</td>
<td>44,7</td>
<td>54,1</td>
<td></td>
</tr>
<tr>
<td>Volume gap</td>
<td>14,2</td>
<td>22,7</td>
<td></td>
</tr>
</tbody>
</table>

Even considering no hydrous ethanol supply, sugarcane volume is slightly lower than market requirements.

Conservative importation volume (low fuel consumption growth and decreasing Brazilian sugar global market share).
Project E2G COPI (Costa Pinto)

Located in
Costa Pinto Mill
Piracicaba, SP

- Capacity: 42,200 m³/year
- Capex: ~230 MM R$
- Commissioning:
  Out/2014 – C6 Fermentation;
  Out/2015 – C5 Fermentation.
E2G plant
Project details

- Construction area:
  10,000m² + 30,000m² for biomass storage*.

- * Biomass storage area considers existing one.

- Budget: R$ ~230MM.

- Contractors: average 200 with a peak of 500.

- 800,000 working hours with no lost time incident

- Timing: 14 months.

- Equipments: 98% produced in Brazil.
2014 operation
Main achievements

- All process units in E2G plant tested;
- Biomass handling and storing as expected;
- Perfect integration between E2G plant and existing mill;
- Successful technology scale up from demo to commercial scale;
- Enzyme logistics validated;
- Process Control implemented and tested.
2014 operation
Action plan based on learnings

- Evaluation of process and equipment performance;
- Evaluation of main operation issues; erosion
- Process optimization in order to reach maximum capacity;
- Implement improvements based on lessons learned;
- Commissioning of dedicated boiler for E2G plant.
Challenges
Fermentation

- Develop GMO yeast to produce ethanol from C5 (xylose);
- Choosing best fermentation design (once-through vs recycle);
- Develop process/equipment for yeast propagation on-site;
- Operation according to GMO regulation (CTNBio);
- Fermentation engineering and construction.
E2G roadmap

Plan

2012 Demonstration
- Biomass Trial;
- Technology Validation;
- Project Starts.

2014 COPI
- COPI Operation;
- Technological Platform Advances;
- Progress of Innovation Program;
- Begin 2nd Plant Design

1 billion liters technology licensing
- 8 integrated plants;
- Technology Licensing;
- Technology to maximize biomass economics;
- Integration with Chemical plants.

Second Gen. Ethanol
Current land use in Brazil
Sugarcane for ethanol occupies less than 1% of the Brazilian land mass

- **Total Area**: 851.48 Million Hectares (100%)
- **Protected & Native**: 495.61 Million Hectares (58%)
- **Arable Area**: 329.94 Million Hectares (38%)
- **Other**: 25.92 Million Hectares (3%)

- 33% Available
- 48% Pasture
- 16% Agriculture
- 8.14 Million Hectares Sugarcane
- 2.4% Available

- 38% Total Area
- 158.75 Million Hectares Arable Area
- 51.7 Million Hectares Agriculture
- 58% Protected & Native
- 25.92 Million Hectares Other
Production map
Sugarcane in Brazil
Bonsucro certification

Only international certification for sugar and ethanol made from sugarcane

Bonsucro:
- Non-profit organization with 176 members of various countries and sectors: agricultural producers, mills, consumers, NGOs, traders
- Multi-stakeholder process to measure, through metric indicators, the environmental, social and economic performance of sugarcane-based activities
- Chosen by the EU as one of seven authorized schemes to allow for the export of sugarcane products to Europe

Raízen:
- 1st certified mill in the world
- 10 mills already certified: Maracaí, Jataí, Costa Pinto, Bom Retiro, Bonfim, Univalem, Gasa, Dois Córregos, Junqueira and Serra.
  - 32.1% of total sugarcane crushed by the company
  - 712,000 m³ of ethanol
- Member of Bonsucro’s executive board
- Commitment to certify all mills
CO2 emissions

2G improves the carbon footprint of Raízen
Conclusion

• Biomass conversion remains a transformative opportunity
• Getting biomass conversion off the ground has taken longer time than anticipated
• Steady improvements and significant progress made over last 2 years
• Ramp-up process key to biotechnology development and industry commercialization