The BALI Project

Borregaard Background
Project Summary

Jerry Gargulak
Business Development
Borregaard LignoTech
BAS is an international bio-refinery company headquartered in Norway and the global leader in lignin based bio-chemicals.

Lignin based bio-chemicals are replacing oil based chemicals in a broad range of application areas.

BAS is the largest producer of ethanol from wood. 6 mill g/y.

Annual sales $750MM USD
Borregaard then and now

- Competitive edge in 1889
  - cheap timber
  - cheap energy
  - cheap labor

- Austrian technology
- British capital

- High cost
  - raw materials
  - energy
  - labor

- Competitive edge in 2012
  - technology
  - market
  - innovation pipeline
From paper mill to biorefinery

BIOREFINERY BORREGAARD

lignin

Bio-Energy
Lignosulphonates
Oxylignin sulphonates
Vanillin
Acetovanillone
Veratric Acid
Bark beetle pheromones
Cellulose octaacetate
Fine paper
Microfibrillar Cellulose
Speciality Cellulose
Paper Cellulose
Textile fibre
Spun textile fibre
Yeast
CO₂
Bioethanol

cellulose

1900
1920
1960
1980
2000

hemi-cellulose/sugars

Acetic Acid / Acetaldehyde / Ethyl Acetate
Butanol/2-Ethylhexanol/DOP
Vinyl Acetate
PV Ac

Borregaard
Innovation Management

R&D center in Norway – key figures and core competence

- **Number of employees**: 80
- **Number of MSc**: 12
- **Number of PhD**: 28
- **Pilot/demo plant personnel**: 20
- **Average experience (years)**: 10
- **Female employees (%)**: 40
- **Average age**: 41

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- Flexible, experienced and competent
- Unique and strong competence platform
- Attractive working environment
- Specialists and generalists
- Benefitting from each others’ core competences
Lignin Chemicals – the driver for BALITM

- Largest supplier with a global footprint
- Unique technical and application expertise
- A sustainable and versatile product portfolio
- Large, diverse and stable customer base
- Strong R&D in new applications
- Technical staff approximately 100

Gross average sales price (USD/MTDS)

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<th>Q3'12</th>
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</table>
The BALI project
Borregaard value chains

Sarpsborg sulphite mill
Cellulose
Bioethanol
Vanillin
Lignin

External sulphite mills
Lignin

BALI™ plant
Cellulose
Lignin

Sarpsborg biorefinery

Borregaard LignoTech production sites
Lignin

Biochemicals
What is dissolved during pretreatment?

- Lignin
- Cellulose
- Hemicellulose

Conventional pretreatment followed by hydrolysis

Pulping process "BALITM"
BALI™: Possible 1st Plant Pathway

- Softwood/Bagasse
- Sugars
- Lignin
- Cellulosic Ethanol
- Sale
BALI™: A biorefinery technology platform

- Sugars
- Lignin

Biomass

- Sale
- Cellulosic Ethanol
- Drop-in Fuel
- Biochemicals

- Sale
- Combustion
- Gasification /conversion
BALI™ produces clean hydrolysates

- BALI™ hydrolysates are easily fermentable to ethanol, indicating the absence of fermentation inhibitors

- Company A (chemical process):
  - "Borregaard hydrolysates were converted very efficiently"

- Company B (fermentation process):
  - "Results for conversion of the acid and neutral hydrolysates are the best we have ever observed"
Pretreated bagasse with 75% water
The solution: continuous enzymatic hydrolysis

Borregaard’s BALI™ hydrolysis process solves problems related to high solids loading

It works because the average residence time is longer than the liquefaction time
Significantly reduced viscosity during continuous operation

Viscosity measurements
Viscosities on a Physica MCR 101 rheometer equipped with a cup with a stirrer (FL 100/6W) operated at 50 °C.
The BALI project
Scaling up the BALI concept – Biorefinery Demo

• Demo plant commissioned January 2013
  – 23 MM USD investment (total Capex)
  – 10 MM USD grant from Innovation Norway

• Minimum size commercially available equipment

• 450 mt biomass processed
  – Softwood, hardwood and sugar cane bagasse
  – Continuous operations

• Demonstration mission
  – Process demonstration and optimisation
  – Product qualification
The BALI project
BALI Demo - Pretreatment step

Biomass feedstock → Pretreatment → Cellulose

Lignin raw material
water soluble
The BALI project
BALI Demo: Enzymatic hydrolysis step

Cellulose → Enzymatic hydrolysis → Sugars

Sugars → Bioethanol
Sugars → Biochemicals
The BALI project
BALI opportunities

• **Feedstock flexible process**
  – Low cost biomass options are enabled
  – Lignin performance and value determined by choice of feedstock

• **Significant revenues from both lignin and cellulosic sugars**
  – Only known 2nd generation bioethanol process with commercially viable lignin raw materials

• **Moderate Capex**
  – Significantly lower investment cost compared to traditional sulphite pulp mills

• **Enables lignin logistics optimization**
  – World wide lignin distribution costs may be reduced
The BALI process has three layers of IP protection:

- **BALI process patents**
  - Main patent granted in Europe, pending in USA
  - Enzymatic hydrolysis of cellulose (pending)

- **Multiple lignin application patents**

- **Trade secrets**
  - Unique application and market knowledge
The BALI project
Development of a business model for the first full scale BALI plant

• **Products**
  - Lignin and bioethanol

• **Biomass**
  - Softwood or bagasse

• **Partner selection criteria**
  - Local presence
  - Strategic fit – strategic interest in bioethanol or cellulosic sugars
  - Willingness to co-invest
  - Available brownfield assets
  - Process integration opportunities

• **Regional selection criteria**
  - Price and long term availability of biomass
  - Lignin market
  - Bioethanol market
  - Outbound logistics
  - Acceptable business environment
Partner discussions under secrecy agreements are ongoing in all 3 regions

GO/NO GO decision and region selection late 2014

Production startup approx. 24 months after final investment decision
The BALI project
Example: Softwood based BALI plant

- **Scale assumptions**
  - 300,000 dry mt softwood
  - 140-150,000 dry mt lignin
  - 25-29 mill. gallons ethanol

- **Investment estimate USD 160-320 MM**
  - Quotes from key suppliers
  - Basic engineering
  - Trade knowledge of process
  - Potential cost reduction through site repurposing
  - Borregaard share of Capex dependent on partnership/JV structure

**Capex elements**

- Greenfield infrastructure:
  - Raw material handling
  - Steam/power
  - Water
  - Waste water treatment

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<th>Capex elements</th>
<th>40-50 %</th>
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<td>Bioethanol plant</td>
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<td>BALI core process</td>
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<tr>
<td>Lignin plant</td>
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Conclusions

• Borregaard today
  - highly integrated wood based biorefinery

• BALI™ process
  - multifeedstock technology
  - water soluble lignin ensures good fractionation
  - continuous enzymatic hydrolysis with conventional equipment
  - demo plant running
  - profitable process
Acknowledgements

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**Biomass2Products**
3.3 MUSD from the Norwegian Research Council (2009 – 2012)

**BALI pilot plant**
10 MUSD for construction of pilot plant received from Innovation Norway