LIGNIN FIRST:
THE BORREGAARD APPROACH TO LIGNOCOLLELULOSIC SUGARS AND BIOETHANOL

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Borregaard’s biochemicals are sustainable and environmentally friendly substitutes to petrochemicals
Business areas

**PERFORMANCE CHEMICALS**
48%

Technology leader and largest supplier of lignin-based products with global market access

**SPECIALITY CELLULOSE**
36%

Leading global speciality cellulose supplier. Significant producer of cellulosic ethanol

**OTHER BUSINESSES**
16%

Only producer of wood-based vanillin. Pioneer in cellulose nanofibrils.
Borregaard key figures 2017

<table>
<thead>
<tr>
<th>Main location:</th>
<th>Sarpsborg, Norway</th>
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<tbody>
<tr>
<td>Turnover:</td>
<td>470 mill. EUR</td>
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<tr>
<td>EBITA:</td>
<td>75 mill. EUR</td>
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<tr>
<td>Employees:</td>
<td>1050</td>
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<tr>
<td>Innovation spend:</td>
<td>22 mill. EUR</td>
</tr>
<tr>
<td>Operations:</td>
<td>Norway, Europe, USA, South Africa</td>
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<tr>
<td>Additional offices and labs.:</td>
<td>India (Mumbai), Singapore, China, Japan, Brazil</td>
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</tbody>
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Borregaard biorefinery in Norway

Lignin 85 kg
Specialty cellulose 80 kg
Bio oil 25 kg
Ethanol 10 liter
Biogas 8 kg
Bark 15 kg
Knots 4 kg
Vanilla flavor 1 kg
Exilva (MFC) 0.5 kg

EUR 20

EUR 180

210 ton concrete
3000 spectacle frames
15 liter heavy fuel oil
30 km bus rides
50 liter soil improver
30 sq. meter cardboard
2.000 liter ice cream
5.000 chocolate bars
Market introduction
The BALI project
Borregaard value chains

Sarpsborg sulphite mill
- Cellulose
- Bioethanol
- Vanillin
- Lignin

External sulphite mills
- Lignin

BALI™ plant
- Lignin
- Cellulose
- Sugar

Sarpsborg biorefinery
- Bleached cellulose
- Specialty cellulose

Borregaard LignoTech production sites
- Bioethanol Biochemicals
Borregaard’s biorefinery concept BALI™

- BALI™ is a biorefinery concept developed by Borregaard for production of cellulosic sugar and ethanol and lignin performance chemicals.
- The BALI™ technology has been scaled up and demonstrated in a 1 mt/day feedstock demo plant in Sarpsborg, Norway.
- The demo plant has been in continuous operation since Q1 2013.
- Feedstock tested: Poplar, sugar cane bagasse, spruce and pine.
- Excellent sugar and ethanol yield due to low level of inhibitors.
The BALI™ technology in a nutshell *)

Biomass -> Pretreatment and fractionation

Cellulose pulp -> Enzyme hydrolysis

Sugar -> Bioethanol, Bioplastics, Biochemicals

Crude lignin -> Processing and evaporation/drying

Lignin performance chemicals

*) Patents granted worldwide
**Excello™ - cellulosic sugar from Norway spruce**

- The BALI™ technology is feedstock agnostic, but current production of sugars is from Norway spruce.
- Extensive testing shows that Excello™ can replace 1G sugars without negatively affecting the chemical or biochemical conversion of the sugars.
- 100+ kg samples available immediately for testing under MTA.
**BALI™ compared to other processes**

**BALI™ biorefinery process**

- Pretreatment (< 170 °C)
- Separation
- Hydrolysis
- Hydrolysate
- BALI™ drop-in sugar with high purity

- Removal of water soluble lignin prior to enzymatic hydrolysis allows for production of pure hydrolysates

**Steam explosion/acid based processes**

- Pretreatment (> 170 °C)
- Hydrolysis with inhibitors
- Separation
- Hydrolysate with inhibitors
- Hydrolysis lignin

- Water insoluble lignin

Borregaard LignoTech’s lignin performance chemicals
**Lignin based Performance Chemicals**
Technology leader and largest supplier of lignin-based products with global market access

**Market position**
- Largest supplier with a global footprint
- Unique technical and application expertise

**Production**
Norway, UK, Germany, Spain, Czech Republic, USA, South Africa

**Operating revenues 2017**
EUR 225 mill.

**Applications**
- Construction
- Agro chemicals
- Animal feed
- Ceramics
- Lead acid batteries
- Soil conditioner
- Gypsum board

**Key attractions**
- A sustainable and versatile product portfolio
- High barriers to entry
- Large, diverse and stable customer base
Further scale up of BALI™

- Triggers for a full scale BALI plant (250,000 tons/year sugar or 150 mill. l ethanol)
  - Lignin pull
    - Cellulosic sugar/ethanol valorization
    - JV partner for chemical production or advanced bioethanol distribution

- Location criteria for a full scale plant
  - Biomass; sustainability and price
  - Regional advanced biofuels policy
  - Regional lignin market and logistics
  - Regional stability

- Timing: 2023 – 2028 (based on expected time of lignin pull)