Borregaard

Creating value from wood – The Borregaard biorefinery

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Biorefinery in context

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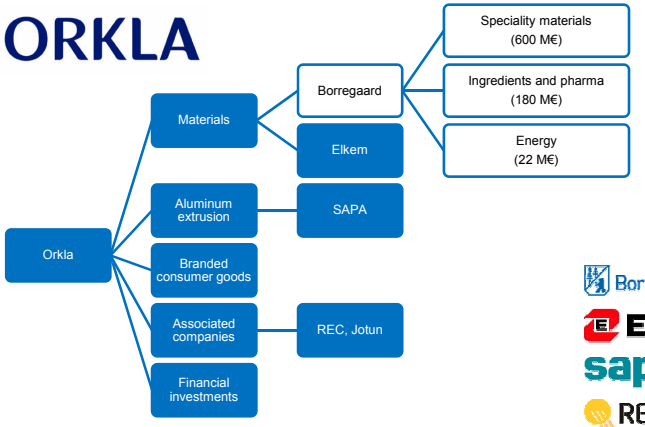
ORKLA



Borregaard
Elkem
sapa
REC
JOTUN

Turnover

Orkla: NOK 74 billion (35.000 employees)

Borregaard: NOK 5 billion (1.400 emplyees)

120 years of innovation

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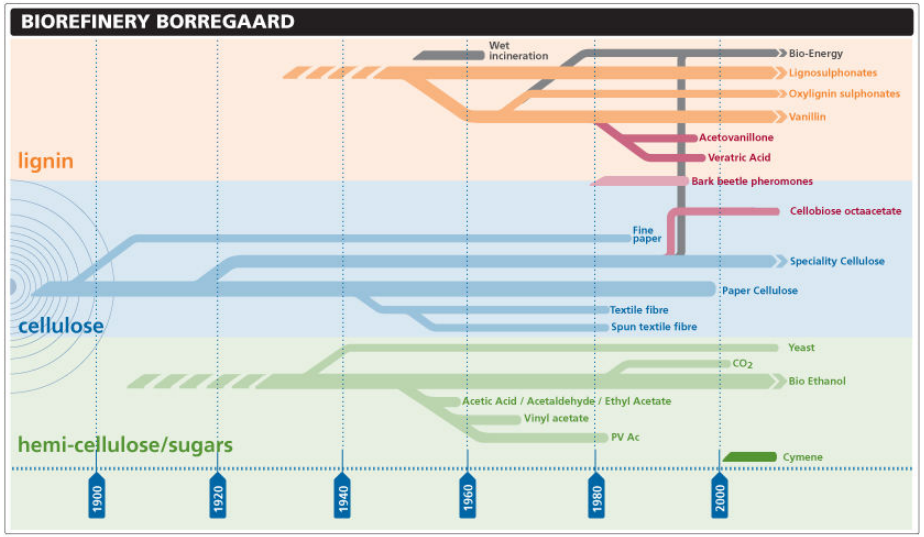

Borregaard in IEA classification

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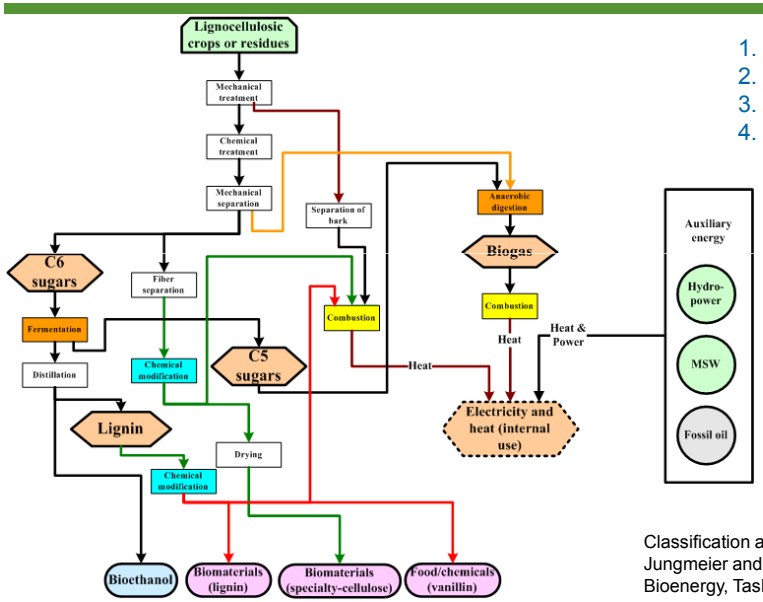

1. Platforms
2. Products
3. Feedstock
4. Processes

Classification according to G. Jungmeier and F. Cherubini, IEA Bioenergy, Task 42 "Biorefineries"

Production – Borregaard Sarpsborg

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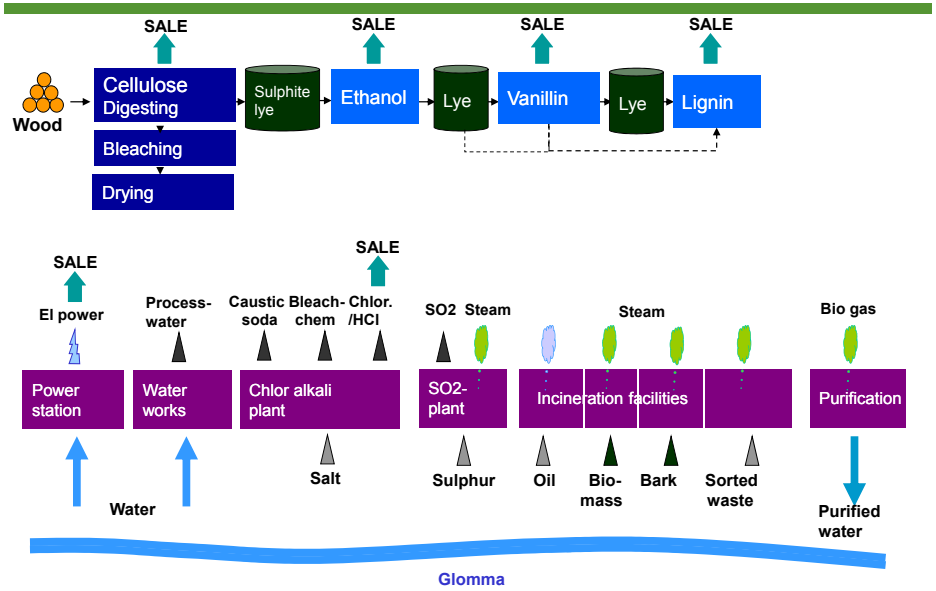

Sulfite pulping

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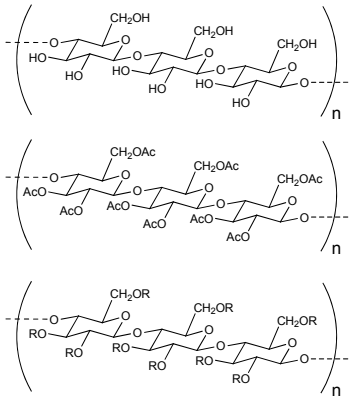
- Variation of parameters allows for great specialization
  - rawmaterial (moisture, aging)
  - impregnation time
  - temperatureprofile
  - ratio free/bound SO_2
- Cellulose as a chemical, not as a fiber
- Raw material for cellulose acetate
  - very low lignin content
  - good brightness
  - high reactivity
- Raw material for cellulose ethers
  - high viscosity



R = Me, Et, Pr etc.

Fermentation to ethanol

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Lignocellulosic ethanol produced since 1938

20 million liters yearly

Rawmaterial is monosaccharides from spruce hemicellulose

glucose
mannose
galactose

xylose
arabinose

yeast

$2C_2H_5OH + 2CO_2$

Feedstocks

1G ("food crops")
sugar, starch, vegetable oil, animal fats

2G ("non-food crops")
lignocellulosic biomass

3G, 4G
algae, designed crops

Oxidation of lignosulfonate to vanillin

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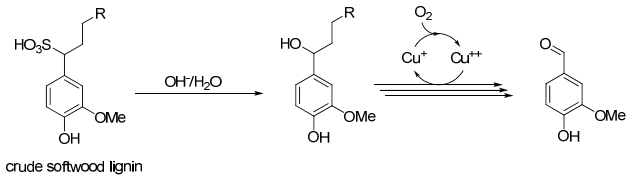

crude softwood lignin

Copper catalyst is recycled due to strict limitations on copper in effluent

Properties of Lignosulfonates

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MW	20,000 – 80,000 Da
Polydispersity	6-8
Sulfonate groups	0.6-1.2 per monomer
Organic sulfur	4-8%
Solubility	soluble in water at all pH insoluble in most organic solvents
Color	very light to very dark brown

sold in powder or liquid form

non-toxic, LD_{50} > 5 g/kg

several hundred applications:

- flow modifier in cement and concrete
- crystal growth modifiers in lead batteries
- dispersing agent/emulsion stabilizer
- corrosion inhibitor for organic acids
- soil conditioning

Spectrum of marketable products

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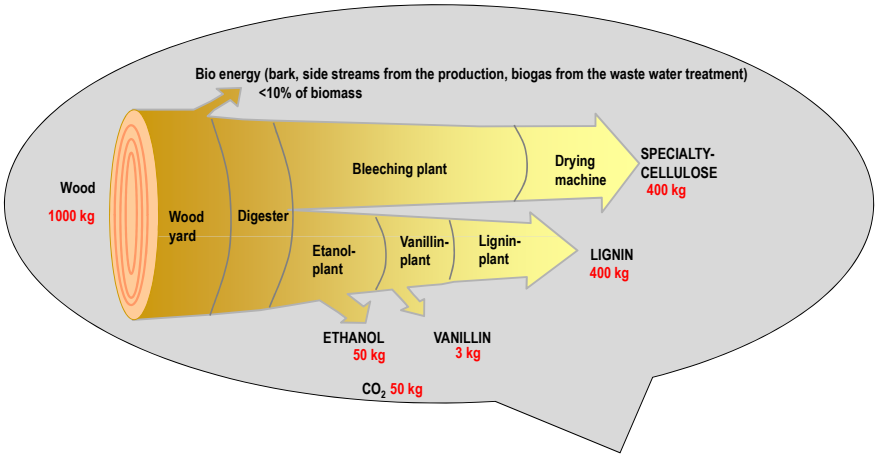

~ 90% of incomming biomass converted to marketable products

What is a biorefinery?

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IEA definition of biorefinery:

"Biorefinery is the sustainable processing of biomass into a spectrum of marketable products"

- Biorefinery: concepts; facilities; plants; processes; cluster(s) of industries.
- Sustainable: maximising economics, and minimizing environmental aspects; fossil fuel and feedstock replacement.
- Processing: upstream processing; transformation; fractionation; thermo-chemical and/or biochemical conversion; extraction; separation; downstream processing.
- Biomass: crops; organic/forest residues; aquatic biomass.
- Spectrum: more than one marketable product.
- Marketable products: both intermediates and final products (i.e. fuels; power; heat; food; feed; chemicals; materials).

Sustainable processing

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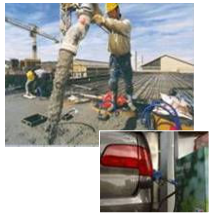
Biomass

Natural
Renewable
Non-toxic

Processing

Reduced emissions
Energy saving
Renewable energy
Raw material utilization
Risk management

Products



Good performance
Replace oil based chemicals

Reducing the CO_2 footprint ~84% of energy renewable within 2010

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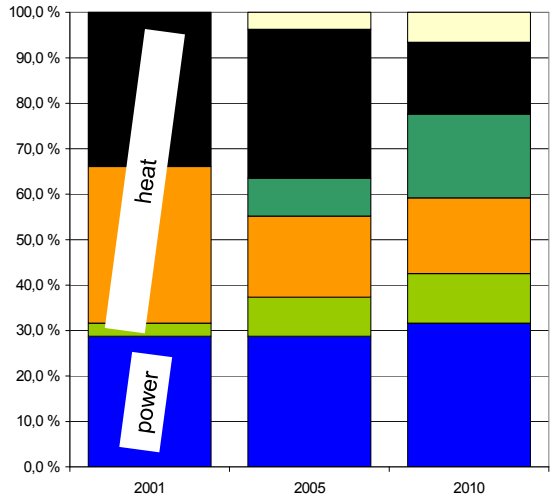

Split of total 1740 GWh in 2001	Renewable	Oil	Reduced toal consumption
2001	66 %	34 %	0 %
2005	64 %	33 %	4 %
2010	78 %	16 %	7 %

✓ Sustainable processing

Key figures from LCA analysis

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Environmental impact		Cellulose	Ethanol (96%)	Lignin (powder)	Lignin (liquid)	Vanillin
Global warming potential	kg CO_2-eqv.	1211	335	704	1227	1343
Acidification potential	kg CO_2-eqv.	11,3	3,8	7,1	10,4	11,7
Eutrophication potential	kg PO_4^{3-}-eqv.	3,26	0,95	1,64	2,75	2,47
Photochemical ozone creation potential	kg C_2H_4-eqv.	0,7	0,24	0,42	0,69	0,76
Ozone depletion potential	kg CFC-11-eqv.	8,90E-05	2,60E-05	4,30E-05	1,10E-04	9,70E-05
Cumulative energy demand	MJ LHV	33000	8700	18200	31500	36500
Waste	kg waste	57,8	26,8	37,8	59,6	82,8

Comparable fossil based products give 200-1500% higher GHG emissions

Application for swanlabelling of ethanol for fuel is in progress

Biorefinery technologies

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technology	temperature	output	opportunities
preatreatment hydrolysis fermentation	< 200 °C	polymers (glucan, xylan, lignin) monomers (monosaccharides)	biomaterials sugarplatform (ethanol, biomass, building blocks)
pyrolysis extraction	> 200 °C	monomers (biooil: phenols, acids, aldehydes, alcohols etc.)	pyrolysis platform (energy, chemicals)
gasification	> 700 °C	synthesis gas (CO/H_2)	FT diesel

Sugar platform pathways

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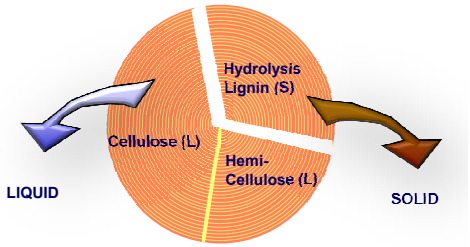
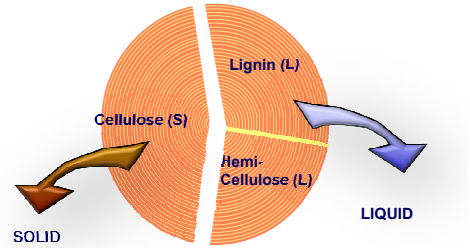
Hydrolysis process
Dissolving cellulose and hemicellulose leaving hydrolysis lignins undissolved

Strong acid
Weak acid
Enzymatic
Microbial



Pulping process
Dissolving lignin and (hemicellulose) leaving cellulose undissolved

Kraft
Soda
Sulfite
Solvent
Extrusion



Challenges for 2nd generation bioethanol
Technical

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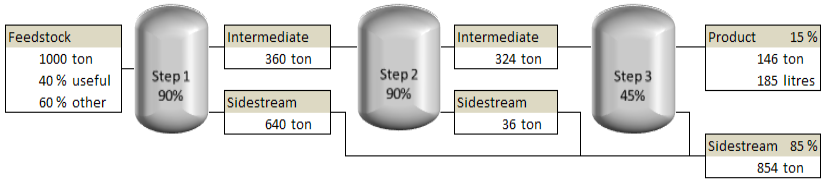

- Low % of feedstock useful
  - Only approx. 40%- 45% of biomass can be converted to product
- Low yield in several process steps
  - Theoretically maximum 51% yield of ethanol from C6 sugars
  - No industrial solution for fermenting C5 sugars to ethanol (will take long)
  - Several process steps with 80%-95% yield create loss and sidestreams
  - Lignocellulosic biomass is recalcitrant to degradation – tough demands on pre-treatment and liquefaction/hydrolysis steps
  - Sidestreams impure – challenge to convert into valuable products

Challenges for 2nd generation bioethanol
Solutions

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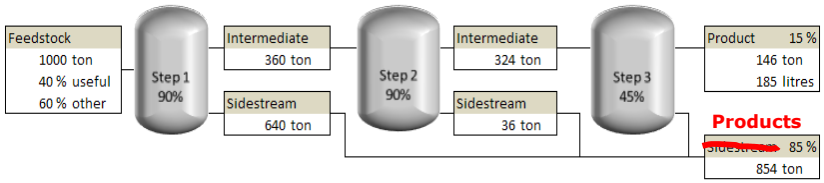

- Integrated biorefinery
  - Make value-added products from sidestreams
  - Plan for pre-treatment & separation processes that facilitate manufacture of products from all streams
  - Increase yields in each process step
  - Place manufacturing where cheap feedstock and energy is readily available and surplus energy could be utilized

Biomass2Products

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- Patent applied in 2008
  - Flexible feedstock
  - Good fractionation of cellulose, hemicellulose and lignin
  - Easy access to C5/C6 sugar plaform via enzymatic hydrolysis
  - Lignin applications identified
  - Process ready for scale up in pilot plant

19 mill til mer bioraffineriutvikling

Norges Forskningsråd (NFR) har tildelt Borregaard inntil 19 millioner kroner i forskningsstøtte til videreutvikling av selskapets bioraffineri.

Borregaard er et av verdens mest avanserte bioraffineri. Med tømmer som råstoff produserer selskapet miljøvennlige og bærekraftige biokjemikalier, biomaterialer og biodrivstoff som alternativer til oljebaserte produkter.

- Med formuleringer som forskningshøyde, gjennomføringsevne og positiv verdiskaping, har NFR gitt Borregaard et kvalitetsstempel. Det er stor konkurranse om midlene, og 19 millioner kroner er en stor tildeling, sier teknologidirektør for Forretningsutvikling i Borregaard, Gudbrand Rødsrud.

Økt forskning gir økt støtte
Støtten fra NFR fordeles ut over fem år. Bevilgningen går ut på at Borregaard får støtte til 35 prosent av total prosjektkostnad, til utgiftsposter som arbeidstimer, innkjøpte FoU-tjenester, reisekostnader, samt leie av utstyr. Skal Borregaard oppnå en støtte på 19 millioner kroner, må selskapet investere nærmere 54 millioner kroner i forskning og utvikling innen de

Teknologidirektør for Forretningsutvikling i Borregaard, Gudbrand Rødsrud, og forskningsleder for bioraffinerigruppen, Martin Lersch. Borregaard er glad for forskningsstøtten på 19 millioner kroner.

Relevante lenker:
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http://www.norskindustri.no/kjemisk/19-mill-til-mer-bioraffineriutvikling-article3087-187.html (March 2, 2009)

Borregaard funding position

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EU projects

- EuroBioRef (U. of Lille: 2010 - 2013) - FP7 Joint Biorefinery call, BRG grant 3.0M€
- Suprabio (U. of Oxford: 2010 - 2013) - FP7 Joint Biorefinery call, BRG grant 1.1M€
- Sustaincomp (Innventia: 2009 - 2012) – FP7, BRG grant 0.85M€
- Biorenew (U. of Madrid: 2006 - 2010) – FP6

Norwegian/Nordic grants

- XIXU (BIP BRG: 2008 – 2011) – NFR BIA – total max grant 6 MNOK
- Biomass2Products (BIP BRG: 2009 – 2014) – NFR BIA – total max grant 19 MNOK
- LignoRef (KMB PFI: 2009 – 2012) – NFR Renergi – total max grant 24 MNOK
- NER Ethanol "New, innovative pretreatment of Nordic wood for cost-effective fuel-ethanol production" ("KMB" PFI: 2007 – 2010) – NER – total max grant of 12 MNOK.
- LigniMatch "Lignin as raw material for chemicals" ("KMB" CTH: 2007 – 2009) – NIC – total max grant 2 MNOK
- (NFR = Norwegian research council, NIC = Nordic innovation centre, NER = Nordic energy research)

The incentives paradox

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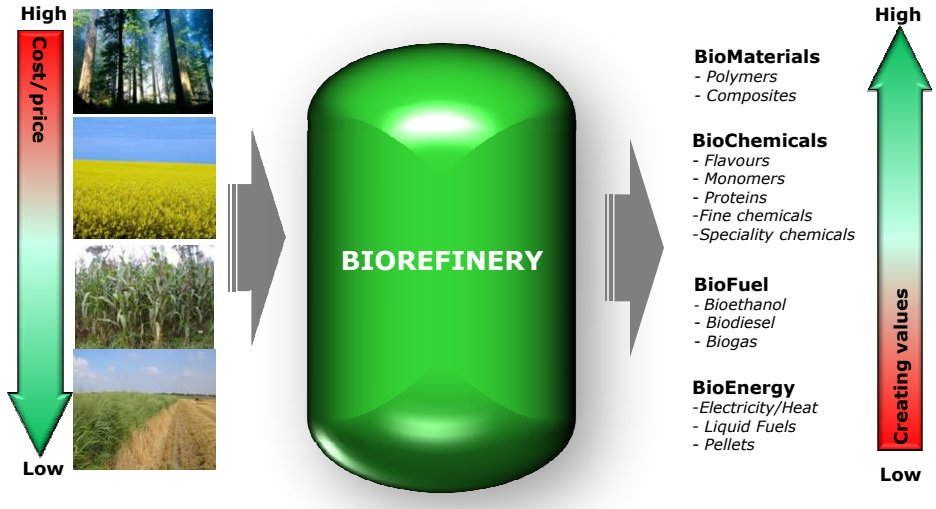

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