BioRefine-2G workshop, 12. June 2017, Stockholm

BORREGAARD – 70 YEARS+ EXPERIENCE IN RUNNING A LEADING INTEGRATED BIOREFINERY

UTILISATION OF WASTE STREAMS

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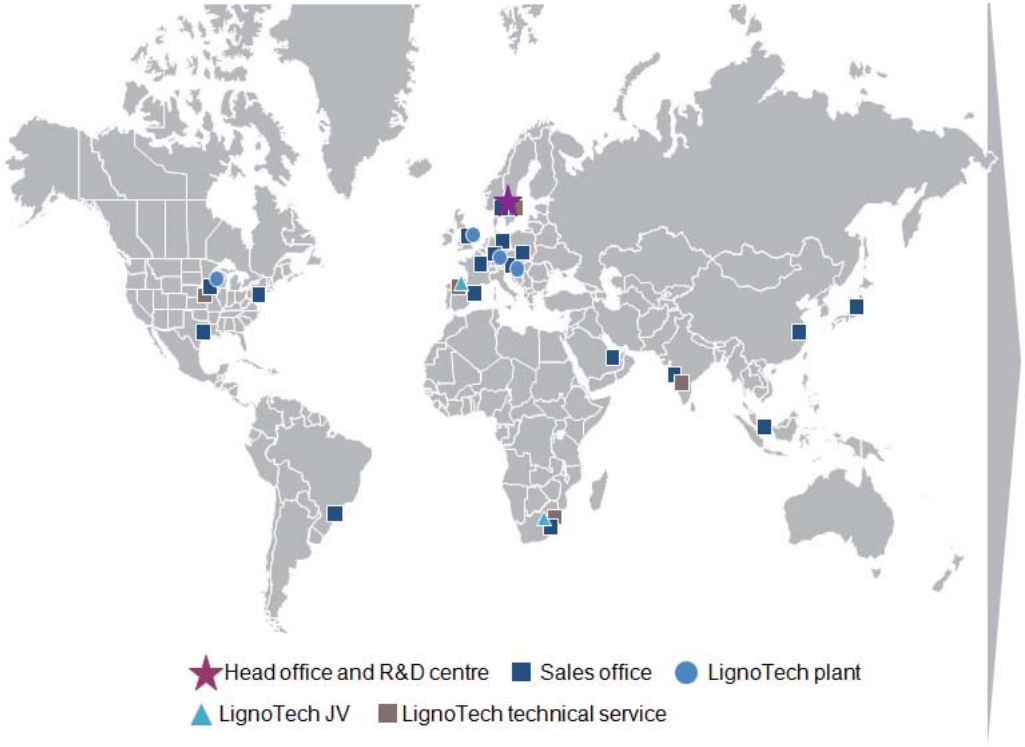
Borregaard AS

Borregaard
The Sustainable Biorefinery

BORREGAARD



HQ in Norway
Leading global biorefinery
1050 employees
Annual sales 450 mill EUR
Production in 6 countries

Leading supplier of lignin based performance chemicals
"The lignin company"

The largest producer of ethanol from wood 20 mill litres/y

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Bio-chemicals from wood

High value added through full raw material utilisation

500 000 tpa

LIGNIN
AND VANILLIN — 1500 tpa

▲ 30% BINDING MATERIAL

170 000 tpa

SPECIALTY-
CELLULOSE

▲ 45% FIBRES

BIOETHANOL — 20 mill litres/y

▲ 25% SUGAR

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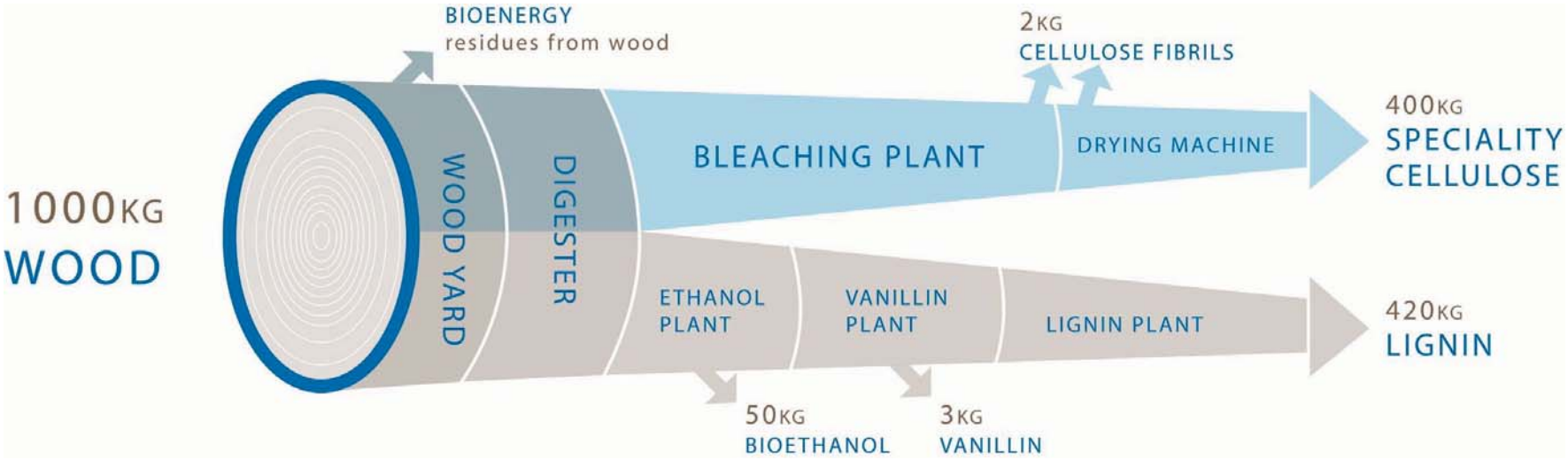
Turning all parts of the wood log into products

High raw material utilisation gives high value added



SPECIALTY CELLULOSE
- Construction materials
- Filters
- Inks and coatings
- Casings
- Food/Pharma/Personal care
- Textiles

LIGNIN
- Concrete additives
- Animal feed
- Agrochemicals
- Batteries
- Briquetting
- Soil conditioning

VANILLIN
- Food
- Perfumes
- Pharmaceuticals

BIOETHANOL
- Pharmaceutical industry
- Biofuel
- Paint/varnish
- Car care

CELLULOSE FIBRILS
- Adhesives
- Coatings
- Agricultural chemicals
- Personal care
- Home care
- Construction

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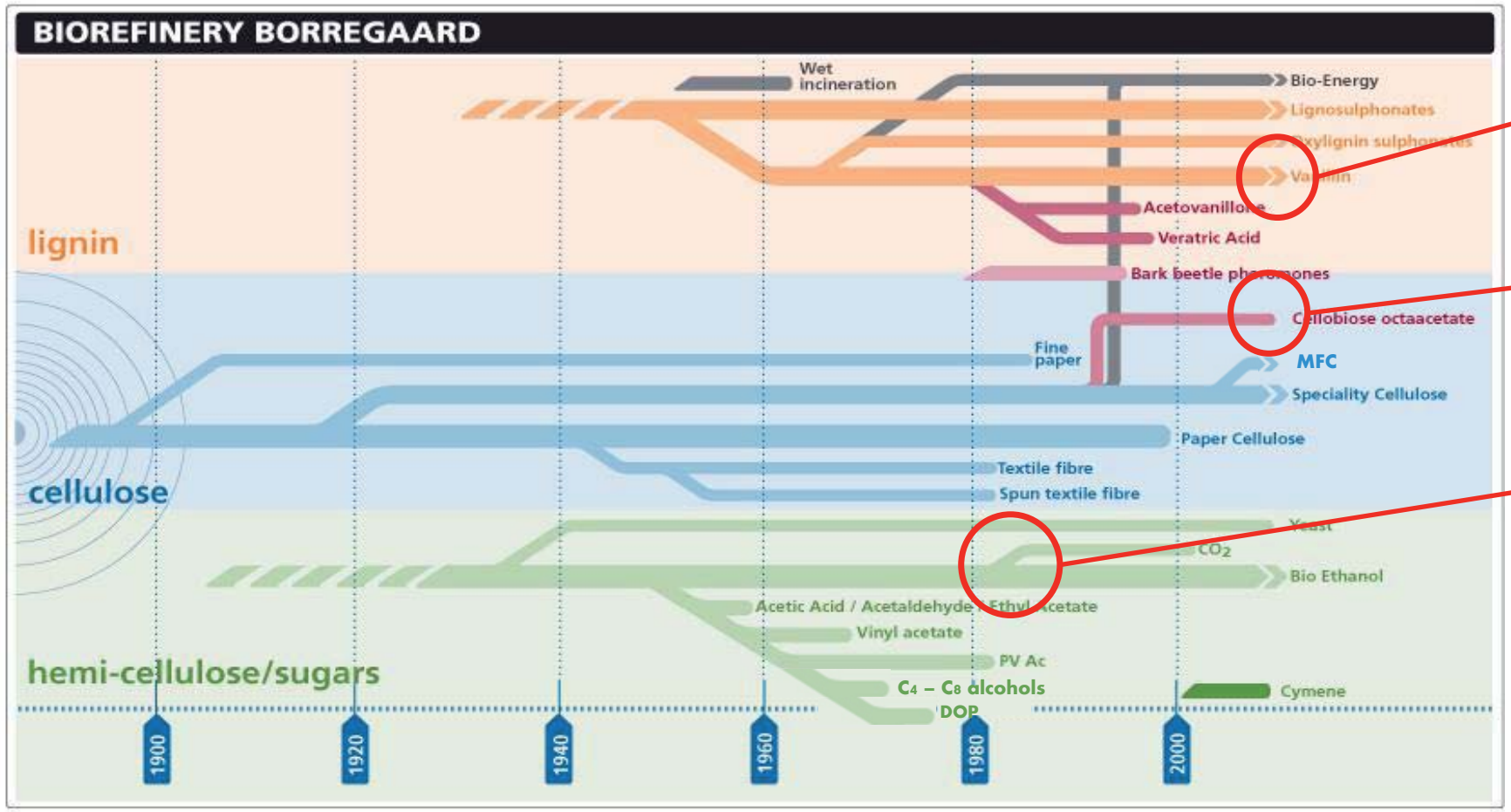
Manufacturing history of the Borregaard biorefinery



Still active

Production stopped

Branching out a new product line

Composition of biomass i fixed

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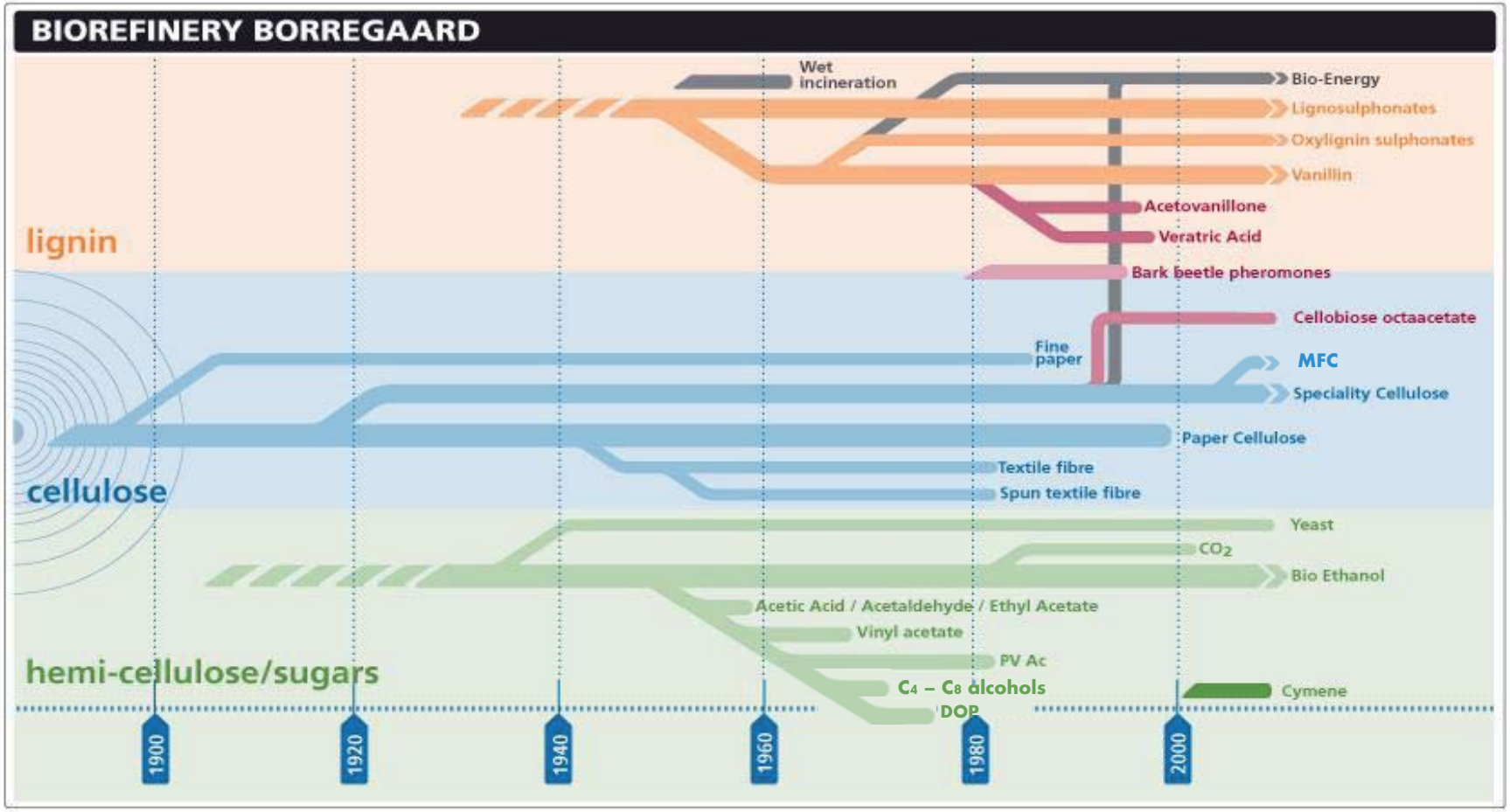
It all started as a pulping plant in 1889



Start: Pulp for paper

Soon branched out
- Fine paper
- Viscose staple
- Textile

Specialty cellulose to
- Acetate
- Ethers

MFC

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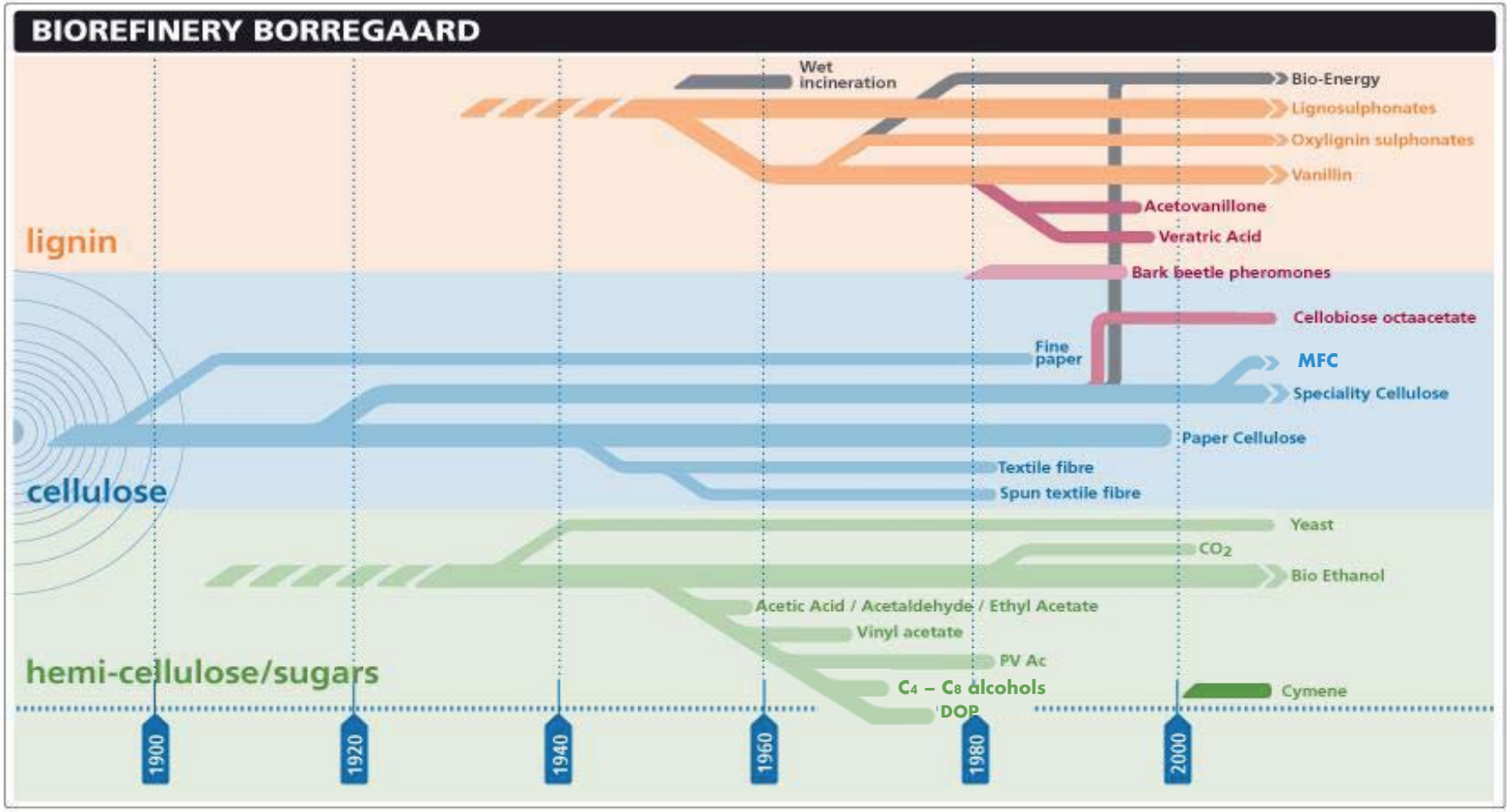
Hemicellulose – ethanol production started 1938



Ethanol from wood started 1938

20 mill litres/year

Largest producer of ethanol from wood

Large product tree from ethanol and acetaldehyde.

Stopped

Outcompeted by oil

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Worlds largest production of woodbased ethanol

C6 sugars from spruce hemicellulose are fermented in a continuous process to produce 20 million liters ethanol yearly

Yeast recycled since 1938

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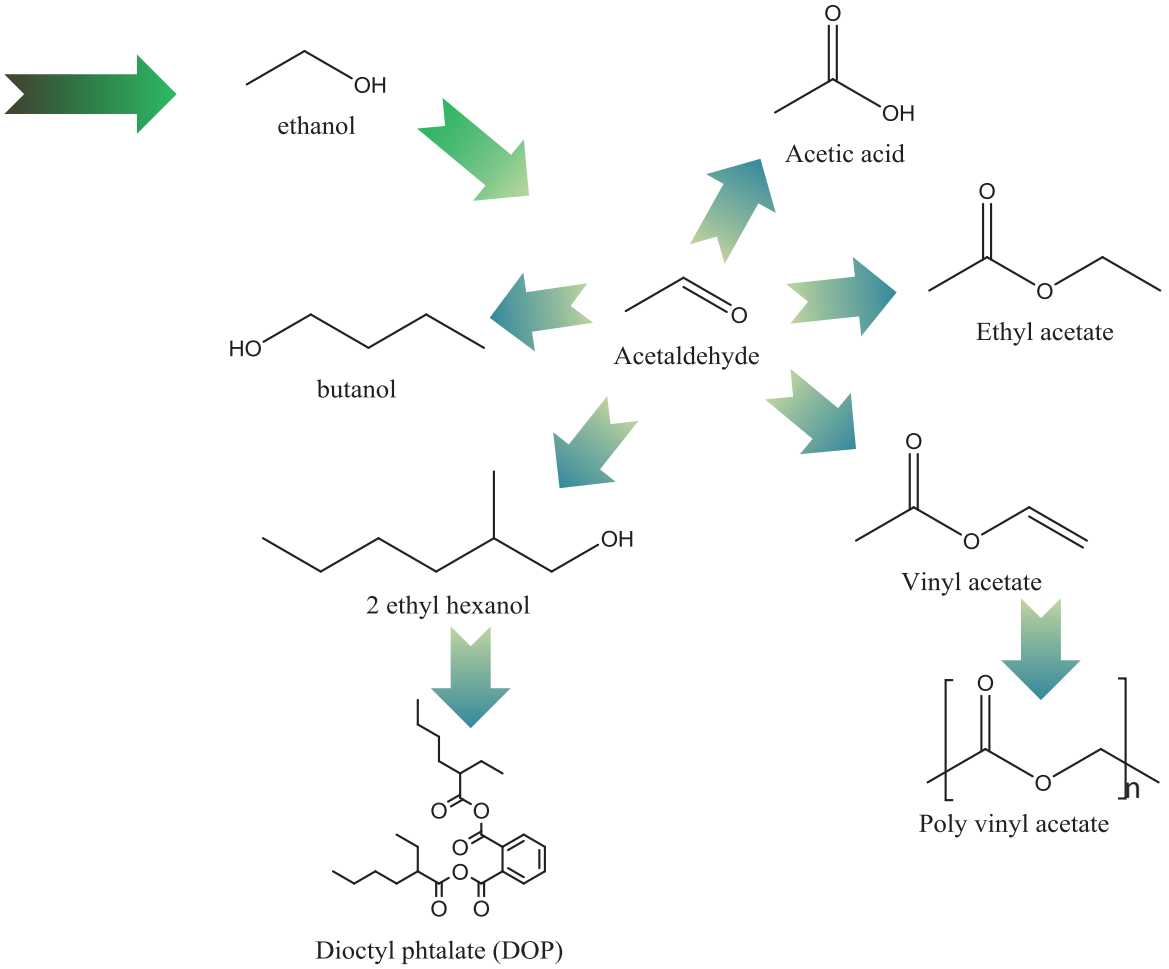
Product tree from ethanol 1950 - 1980



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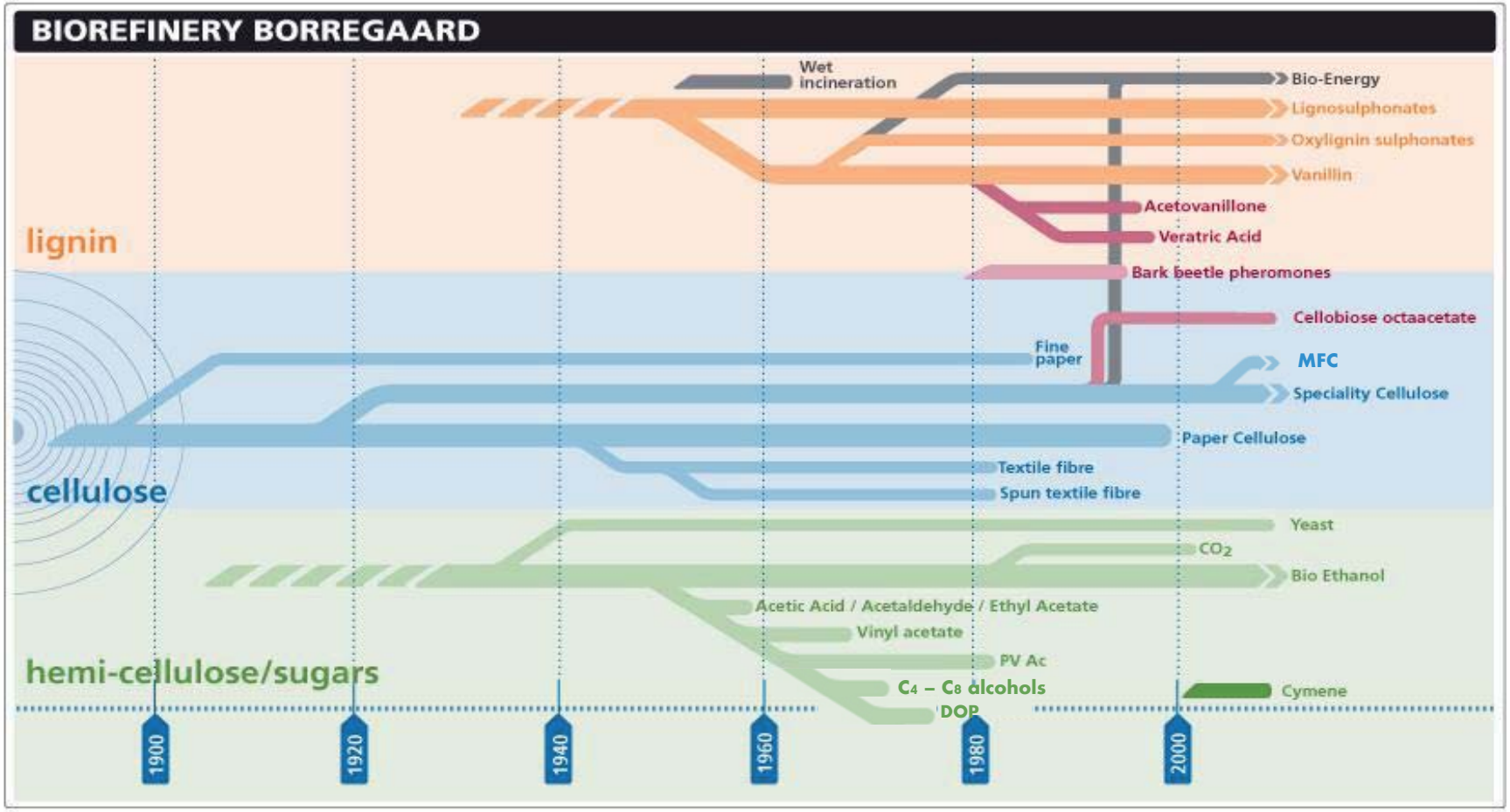
Lignin – where most operations struggle to make a business



Lignin performance chemicals started around 1940

Substantial volume growth in the 1970'ies

Vanillin from spruce lignin

Expansions in the 1990'ies

Lignin now is the main growth area

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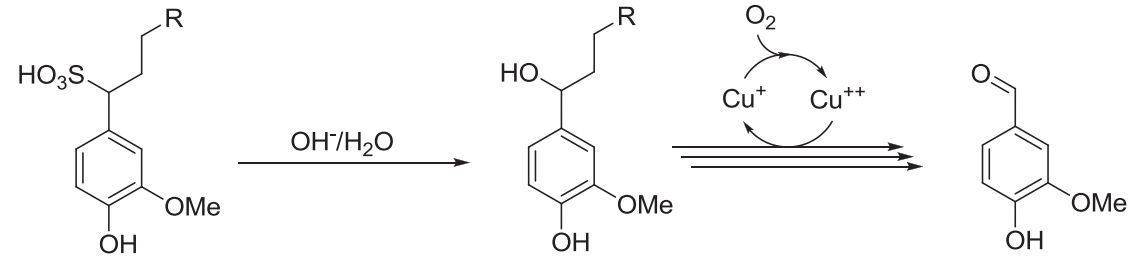
Oxidation of lignosulfonate to vanillin (started 1963)



crude softwood lignin

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

EURO Vanillin

Annual Vanillin production

Non-renewable raw materials

14 000 MT

Renewable raw materials

60 MT

1500 MT

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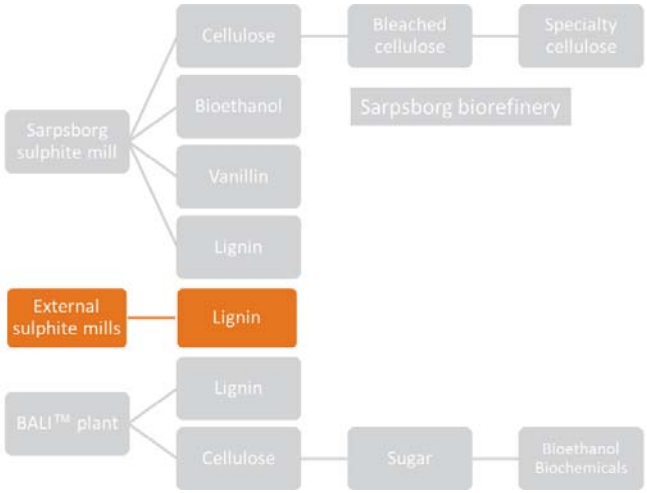
Borregaard – Raynoier Advanced Materials (RYAM) JV



RYAM Fernandina Beach Pulp Mill, Florida

LignoTech Florida LLC, a JV between Borregaard (55%) and RYAM (45%)
Total investment 110 mill. USD, in two steps
Capacity of 150.000 MTDS lignin performance chemicals
Production start Q1 2018

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Waste treatment – bio energy

- Anaerobic granular sludge bed
- End of life for dilute waste streams
- Energy production
- Replaces LPG

COD reduction	MT/day	41.3
CH_4 from COD reduction	Nm^3/day	14160
Energy production	MWh/day	156
	GWh/year	57

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Research and development

~14% of Borregaard's revenues come from new products

- Innovation in Borregaard – top management involvement and responsibility
- 98 employees in R&D, of which 80 at Corporate R&D in Sarpsborg

  34 with PhD
- R&D and innovation intensity ~5% of revenues

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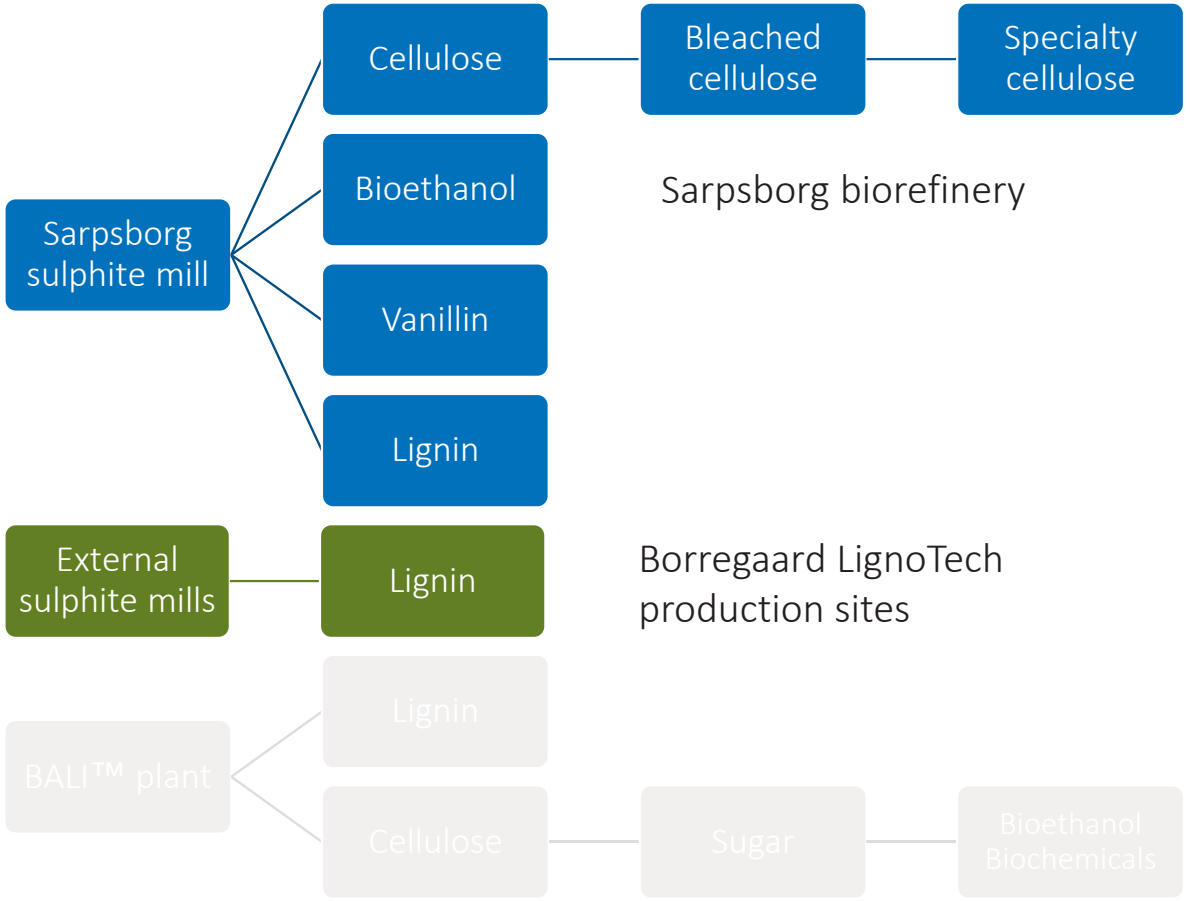
Borregaard business setup

Cellulose

- Sarpsborg mill is the fully integrated biorefinery
  - Norwegian Spruce as feedstock
- Growth by specialization

Lignin performance chemicals

- Additional production of lignin performance chemicals outside Norway
  - Other wood species
- Demand growth in the lignin market
- No more free sources of lignin feedstock



The BALI project – enabling expansion of the lignin business

Expanding the lignin operation

Biomass pretreatment and separation technology

Co-production of lignosulfonates and sugars

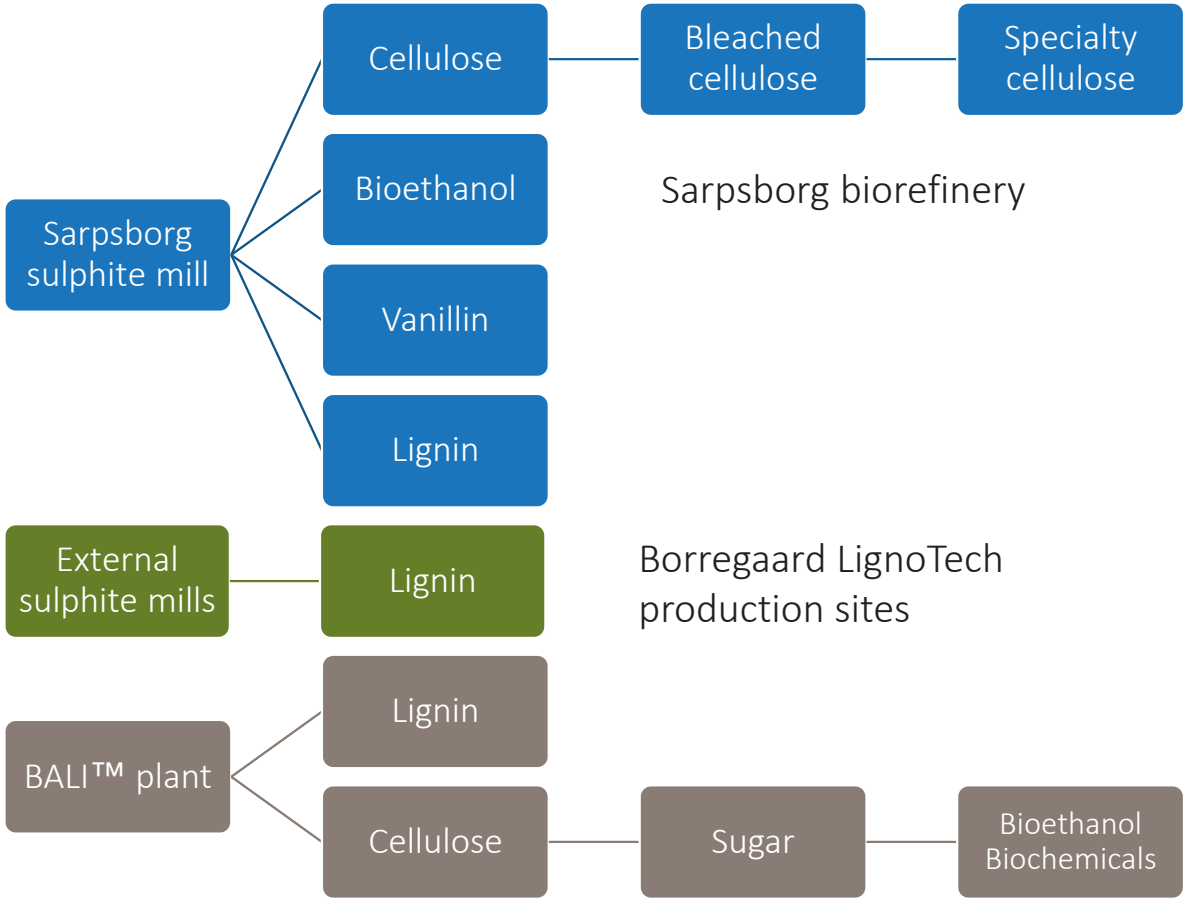
A demo plant has been in operation from Jan 2013.

- Pretreatment
- Enzymatic hydrolysis
- Fermentation
- 1-1.5 ton biomass dry matter pr day
- 24/7 operation

No inhibitors (enzymes, microbes)

Low enzyme consumption

Very cost efficient



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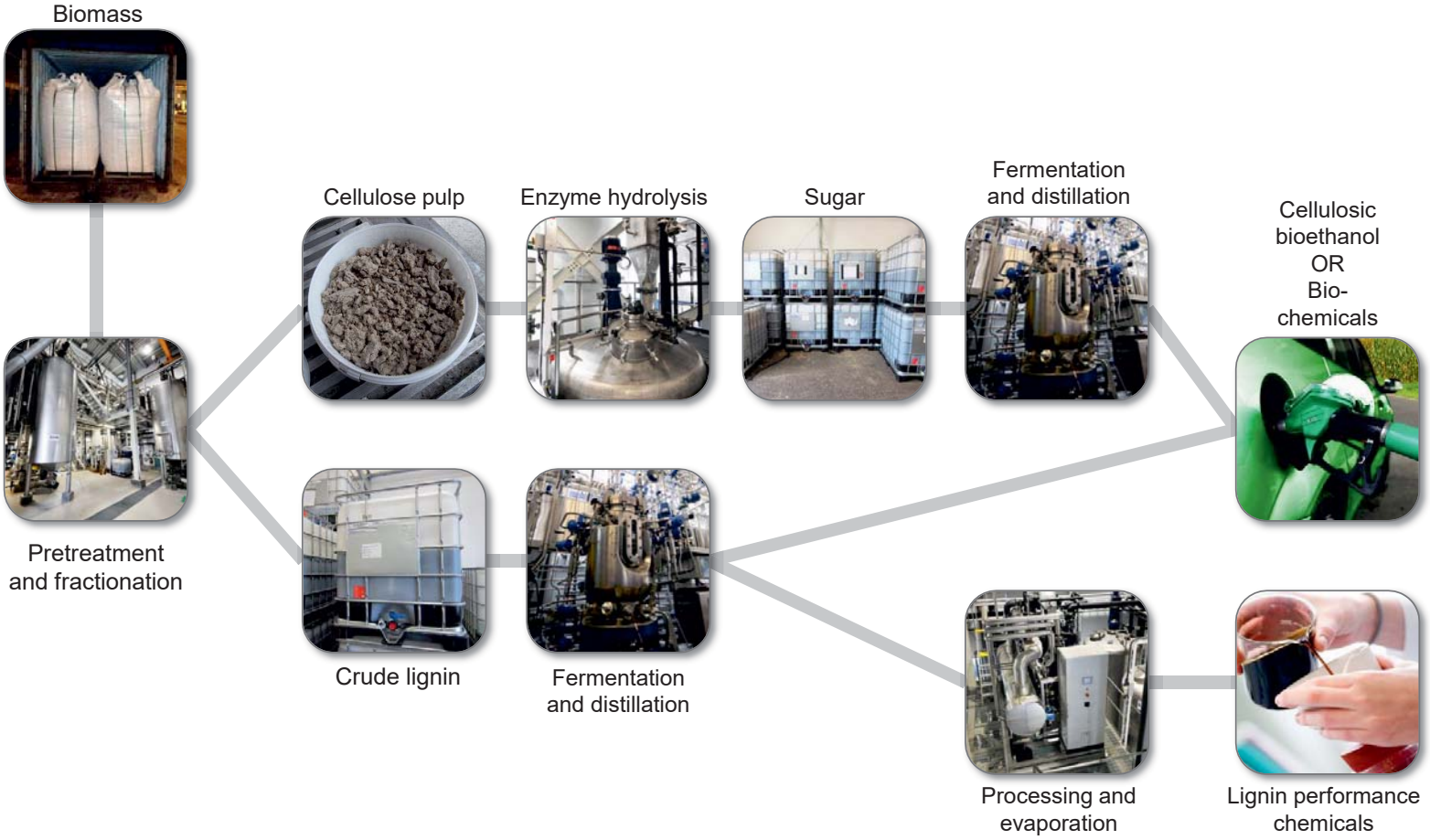
BALI™ process in a nutshell



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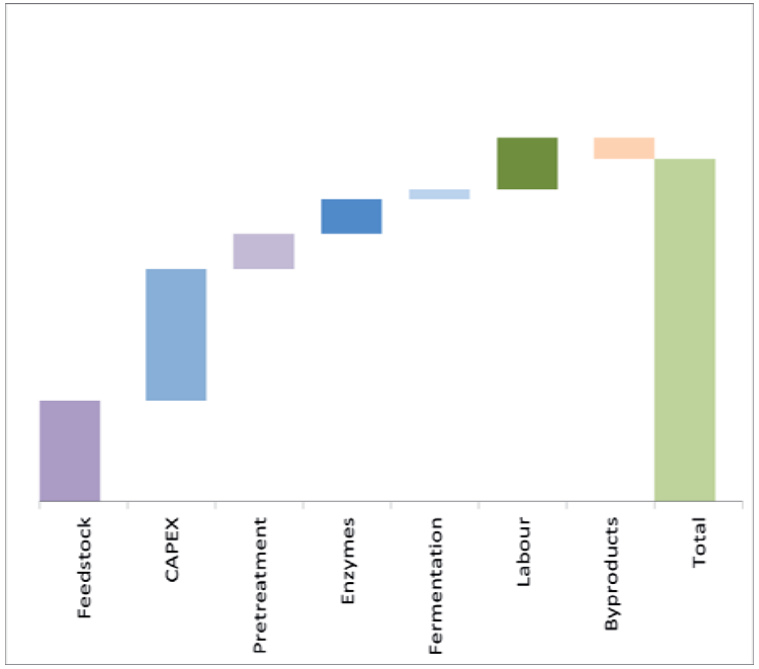
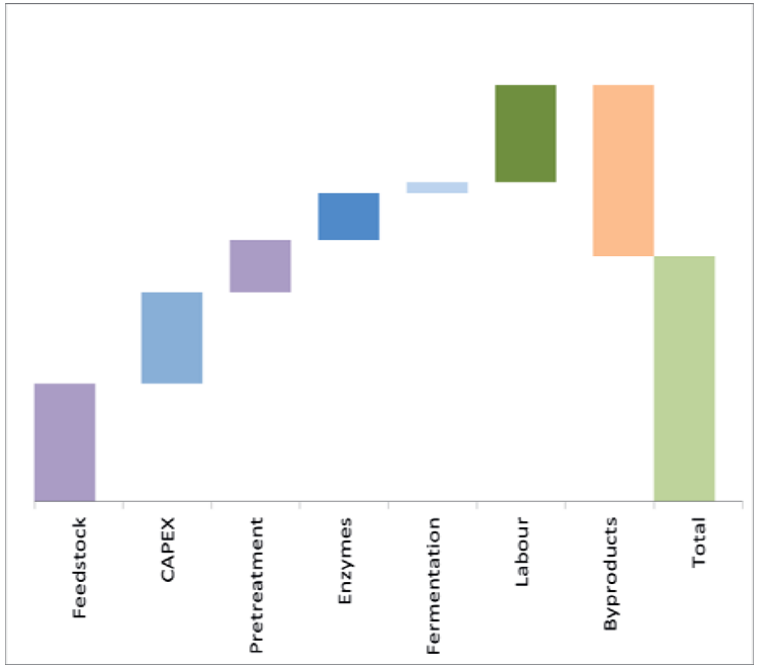
Minimum Ethanol selling price (MESP)

Breakdown for a "state of the art" cellulosic plant and BALI™

Cellulosic ethanol 2016



BALI™



Data from Bloomberg New Energy Finance, Pres Next generation Fuel Investments and returns, 17 September 2013. Notes: CAPEX (depreciation over 10 years), investment (cellulosic ethanol 3,2 USD/L capacity, BALI 2,1 USD/L capacity), feedstock cost 75 USD/MT, Labour cost Bloomberg adjusted to US level (+0,1 USD/L).

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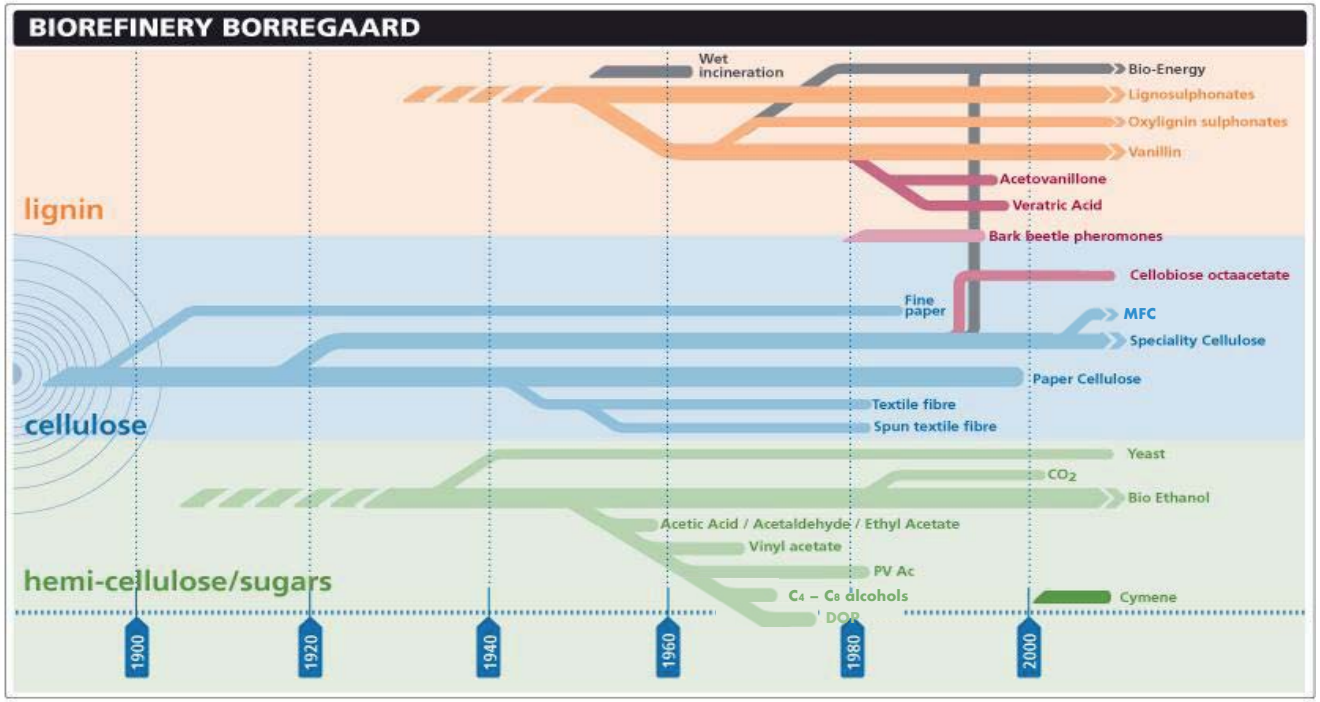
Learning points



Markets are never in balance

Expect lots of dynamics in markets, demands, competition, business conditions, feedstock supply, …..

Choose flexible technologies

Avoid dependence on subsidies, tax reductions etc.

Avoid dependance on one single product

Use all side streams, diversify and upgrade

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