Zambezi Biorefinery:

“Pure” glucose from 2nd generation feedstocks

06-Feb-2018

Ed de Jong

Avantium

Innovative Technologies for Today's Bioeconomy

EURONEXT

Amsterdam & Brussels

Ticker: AVTX

avantium

€109M

Raised from **IPO**

15 March 2017

Renewable Chemistries

2-Gen Sugars, Renewable Technologies, Electrocatalysis of CO_2

YXY® Technology: FDCA to PEF

Novel Bio-Based Plastic

JV BASF / Avantium

SYNVINA™

Catalysis

Foundational Technology and Expertise

Leading Systems and Services Provider for Catalyst R&D

Sinopec · AkzoNobel · IFP Energies nouvelles · Shell · Argonne · sabic

Founded in 2000

Amsterdam

60+

patent families

Hall of Fame

CleanTech

160 employees

>75% scientists

20+ nationalities

Avantium's Renewable Chemistries

Leadership in innovative renewable technology

avantium

Commercialization enables the transition to a sustainable bioeconomy

Several Early Stage Projects

New products, processes & technologies

VOLTA
Electrocatalysis

- CO2 capture
- Platform technology
- Novel conversions

MEKONG
Bio-Based Ethylene Glycol (MEG)

- Single step process
- 100% bio-based bottle
- Pilot plant phase

ZAMBEZI
2nd Generation Sugars

- High purity glucose and mixed sugar output
- Pilot plant phase

YXY®
Bio-Based Plastic (PEF)

1st commercial plant planned in Antwerp

A Coherent Program Portfolio

ZAMBEZI ▶ Glucose ▶ FDCA / MEKONG MEG ▶ YXY® ▶ PEF

VOLTA ▶ High value chemicals

Catalysis — Foundational Technology and Expertise — SYSTEMS + SERVICES

Partnering Strategy

avantium

Strategic Choices

- Stand-alone
- Partnering
- Sell

Stand-alone = Create Value

Explore Value Maximizing Strategies

Partnering

- Explore Strategic Alignment
- Validate Combined Competencies
- Resource and Execute

Sell

- License(s)
- Technology

Development Phases

Lab-scale	Pilot plant	Reference plant	Industrial scale
Ideation	Phase I	Phase II	Phase III
In-House	Stand-alone	Partnering	Business Model Execution

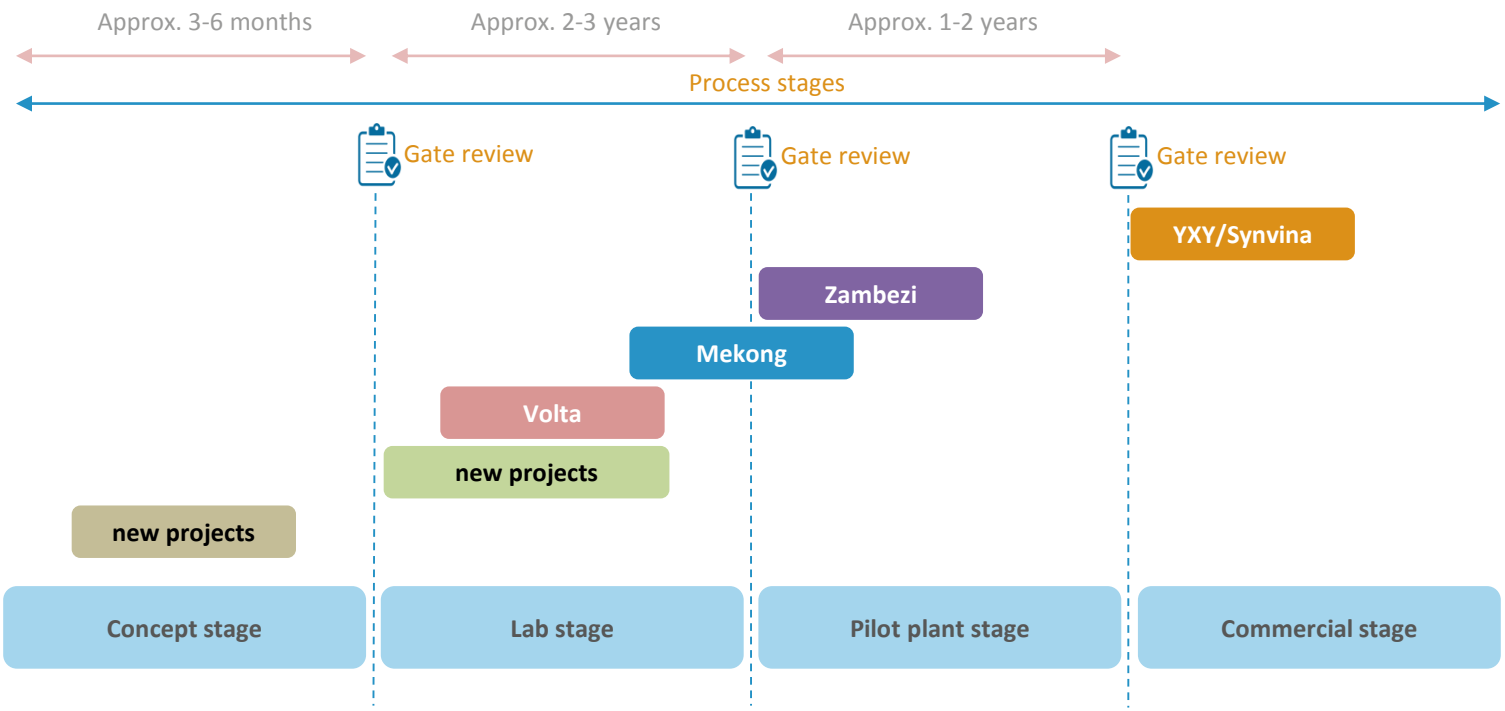
Activity

Ideation	Phase I	Phase II	Phase III
• Validate lab scale performance • Assess market position • Model business case (technoeconomic)	• Pilot plant build • Scale technology • Prove process economics • Partner criteria/ discussions	• Align partner intent • Combine core competencies • Decide commercial deployment • Structure agreements	• Continue technology improvements • Monitor market conditions • Execute against growth strategies

Potential Timeline

Year 0-2 | Year 1-2 | Year 3-4 | Year 5 →

Avantium's Renewable Chemistries Portfolio

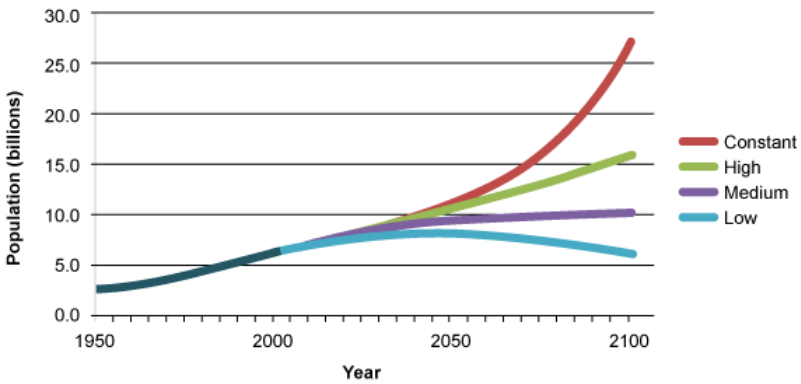


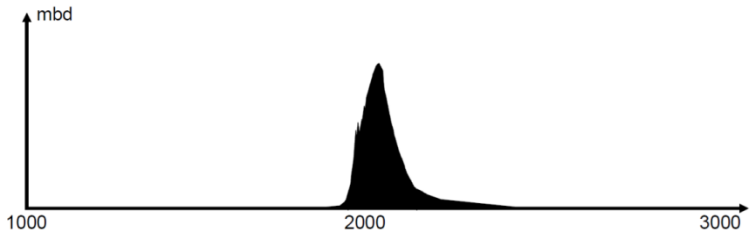
- Validate and optimize process
- Process economics to support business case

- Prove chemical process at lab scale
- Validate business case and evaluation of partnerships

- Validate technology at pilot plant scale
- Establish collaborations to address commercial risks

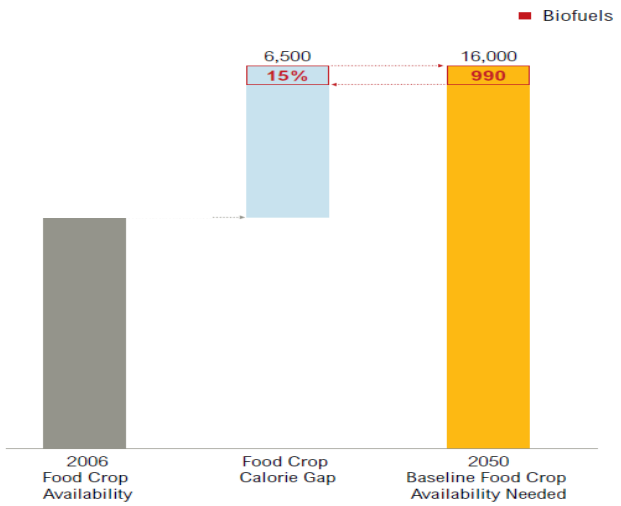
Megatrends

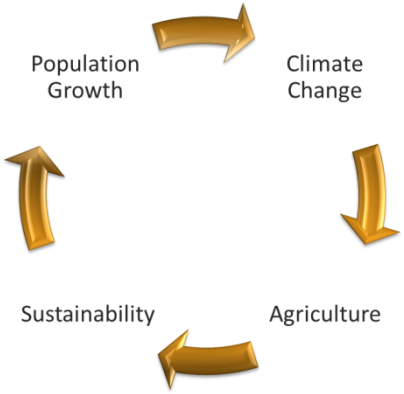




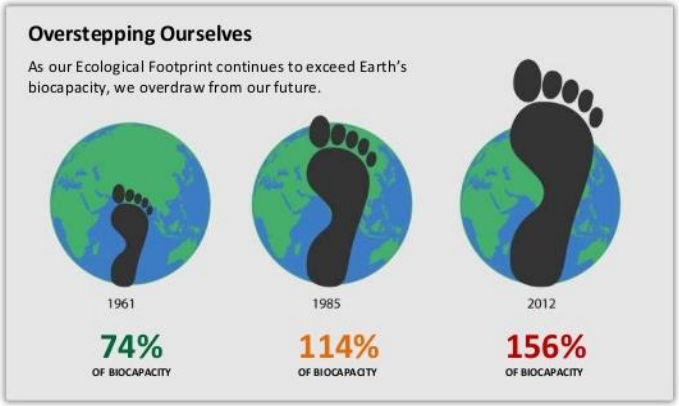
Living off the land — A brief moment in history — Living off the land

Source:
Fijke Sijbesma, DSM





We need 1.5 planets to sustain current consumption patterns ...



WORLD RESOURCES INSTITUTE
AVOIDING BIOENERGY COMPETITION FOR FOOD CROPS AND LAND
TIM SEARCHINGER AND RALPH HEIMLICH

Global Footprint Network®
Advancing the Science of Sustainability

Brands desire bio-based solutions

Brand-owners realize a system-wide approach is required to solve today's toughest sustainability challenges

avantium

Sustainable Apparel Coalition

... to build a standardized supply chain measurement tool for all industry participants to understand the environmental, social and labor impacts of making and selling their products and services.

bfa Bioplastic Feedstock Alliance

Encouraging the development of plant-based plastics

Plant PET Technology Collaborative (PTC)

Strategic working group focused on accelerating the development and use of 100% plant-based PET materials and fiber in their products

PEFerence

Replace a significant share of fossil-based polyesters, such as PET and packaging materials like glass and metal with 100% bio-based furanics polyesters (such as PEF)

Brands want to become **sustainability champions**

ZAMBEZI
Second Generation Biorefinery

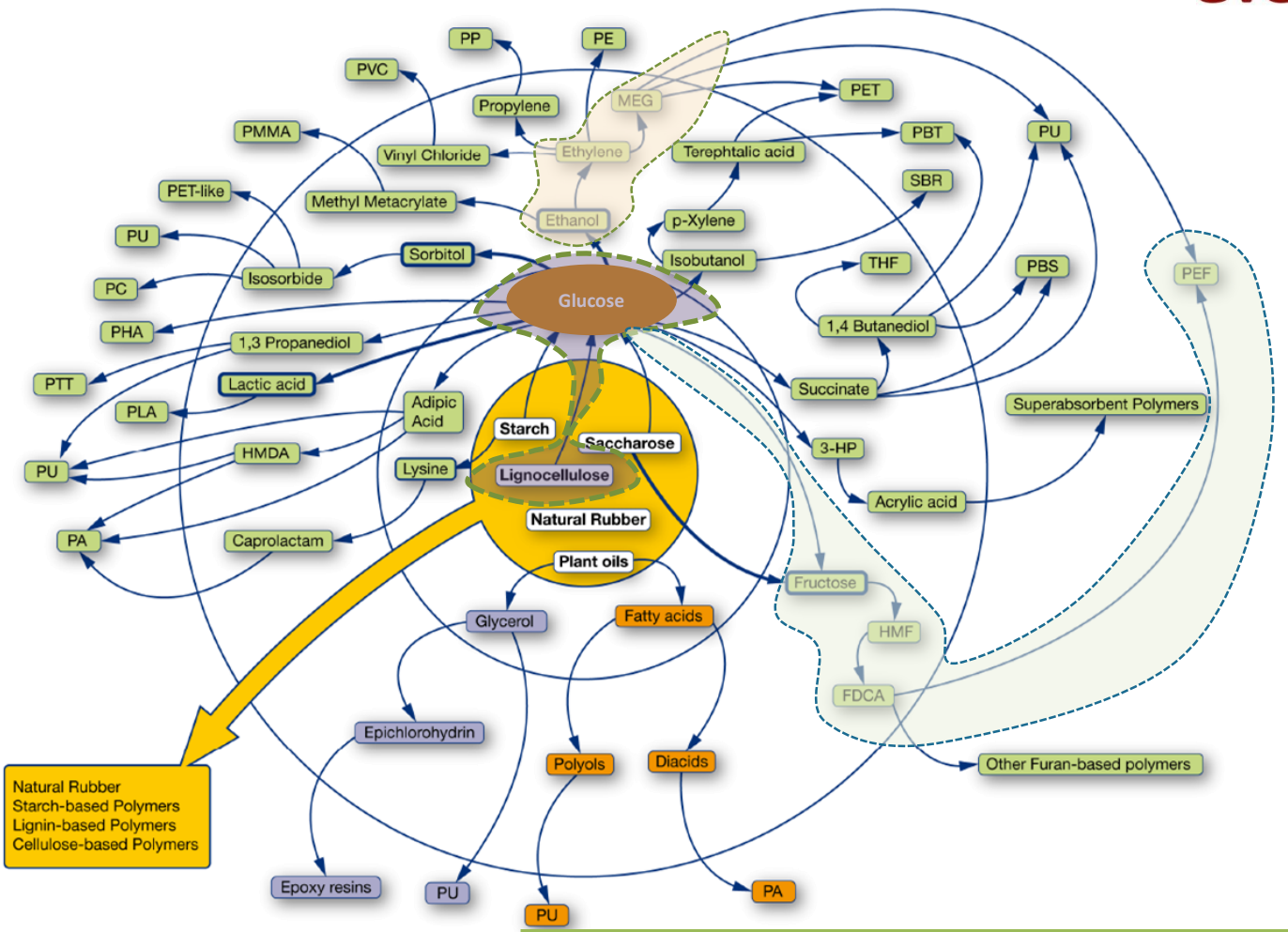
avantium

Zambezi Summary

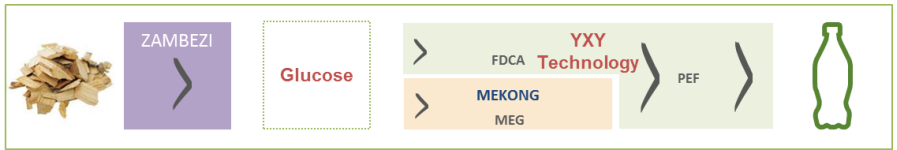
- Zambezi:
  - Avantium transformed the economics of the Bergius process
- Market:
  - Today polymer market ˜300mpta increasing 1.2Bn tpa by 2050 (4x increase)
  - Growth in renewable fuels and materials will demand a 2G solution
  - Currently no commerically viable high purity 2G glucose available today for chemical applications
- Technology:
  - Feedstock flexible
  - Innovation in :
    - Acid sugar separation
    - Material construction
    - Lignin deacidification
  - Lab demonstration in Hydro \2 unit
  - Pilot Plant design completed
  - Pilot Plant build initiated
- Application:
  - Successfully made FDCA from Zambezi 2G glucose and polymerized to PEF
  - Multiple collaborations on qualification on feedstock and product stream qualification
- Commercialization:
  - Identified partnership to support Reference Plant business case in Delfzijl (Netherlands)
  - Actively evaluating multiple business cases in multiple locations around the world

Glucose

Glucose is a central building block for many bio-based polymers



Coherent portfolio, each targeting blockbuster markets



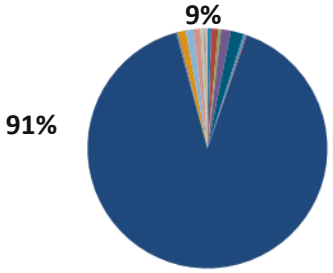
Confidential

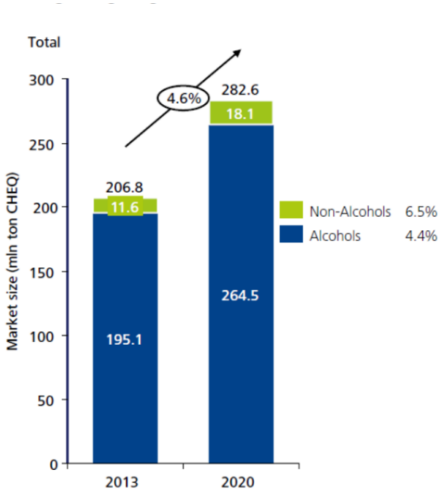
Market Potential for Glucose

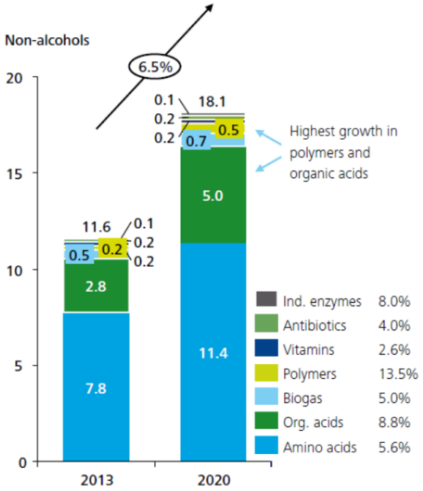
Bio vs fossil market size – Growth potential

Bio-Market Sales

$ 65 bn



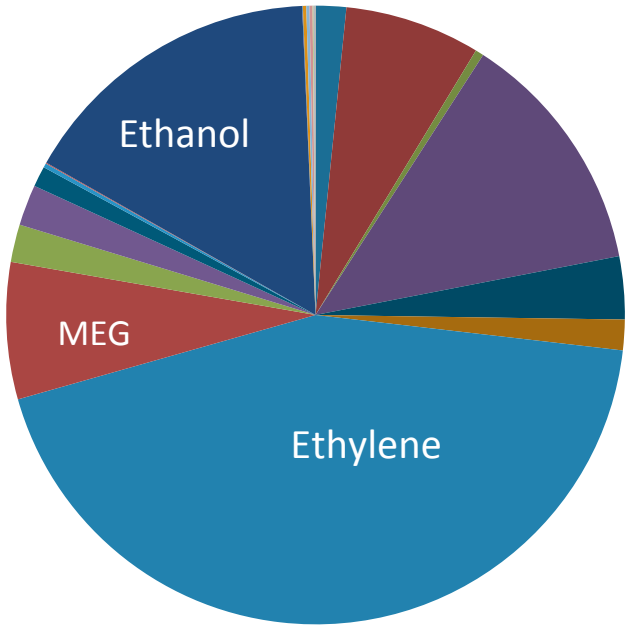




From Opportunities for the Fermentation Based Chemical Industry; Analysis of Market Potential and Competitiveness in North West Europe – Deloitte 2014

Related Fossil & Bio Sales

$400 bn



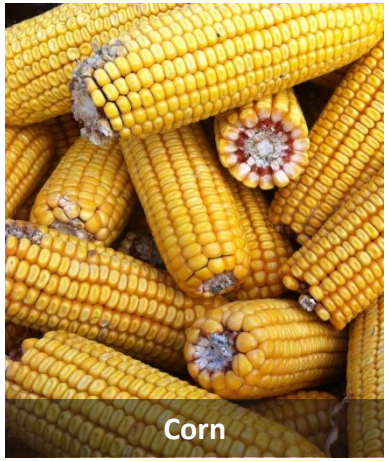
- Adipic acid
- Iso-butene
- Isoprene
- p-xylene
- Acrylic acid
- BDO
- Ethylene
- MEG (Ethylene glycol)
- Acetone
- Acetic acid
- n-butanol
- 5-HMF
- Isobutanol
- Succinic acid
- Ethanol
- Farnesene
- Itaconic acid
- Lactic acid
- Furfural
- Xylitol
- PDO
- Algal lipids
- PHAs
- Sorbitol
- Levulinic acid
- FDCA
- 3-HPA

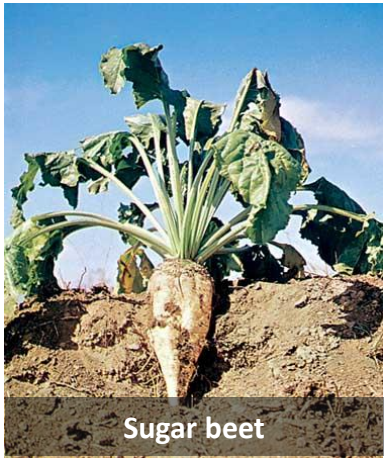
From the Sugar Platform to Biofuels and Biochemicals
Final report for the European Commission Directorate-General Energy
N° ENER/C2/423-2012/SI2.673791
April 2015

First and second generation biomass (glucose)

Now

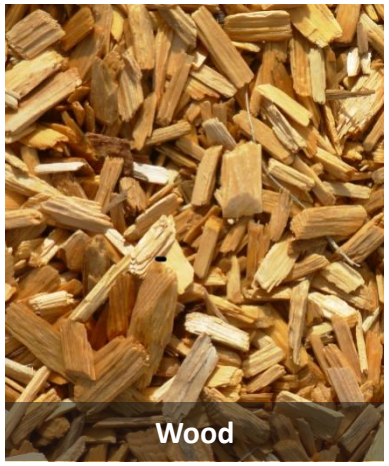
First generation (1G) – Sugar cane, corn, sugar beet, wheat

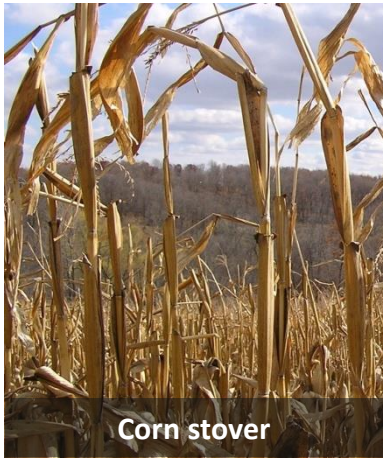




Future

Second generation (2G) - Wood, agricultural residue, recycled paper, energy crops





Why Woody Biomass?

- Reasons:
  - Economic:
    - Economically available feedstock
    - Efficient and mature logistics
  - Technological:
    - Tests at lab scale have been done on the basis of wood chips
    - Does not require other pre-processing step
    - Retains structural integrity after process (does not crumble or slump)
  - Sustainable:
    - Good ecological footprint
    - Undisputed

- We continue to evaluate other alternative feedstock options

2G Sugar Technologies Evaluated by Avantium

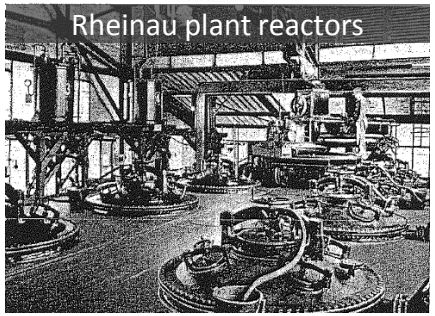
Key technology identified : fit-for-purpose in biobased chemicals

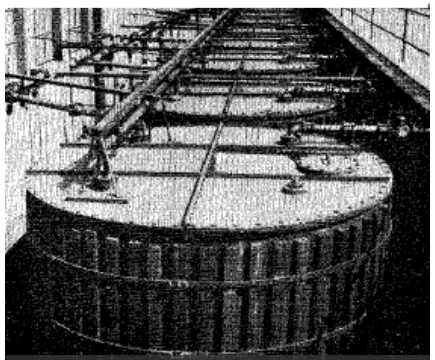
Technology	Example Companies	Advantages	Disadvantages	Application Area
Pre-treatment + enzymatic hydrolysis	M&G Chemtex /Beta Renewables Sweetwater Comet	+ High yield + Mild conditions	- Mixed products - enzyme cost	- Biofuel
Dilute acid / high temperature		+ Cheap process	- Low yield - Impure product - Dilute stream	
Organosolv + enzymatic hydrolysis	Lignol CIMV	+ High grade lignin	- High solvent & enzyme costs - Dilute product stream	- Biofuel
Hot Compressed Water	Renmatix	+ Low cost reagents	- Low yield - High pressure/temp	- Biofuel - Biochemical
Concentrated acid / low temperature hydrolysis ('Bergius process')	Avantium Virdia (Stora Enso) Green Sugar	+ High stream yield + High purity	- Acid / sugar separation - Corrosion	- Biofuel - Biochemical

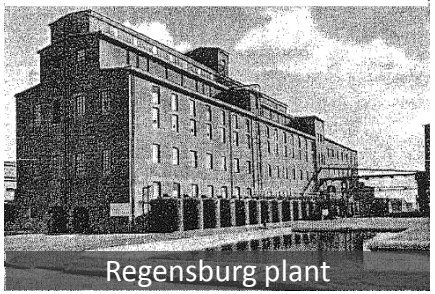
Avantium selected technology

Bergius HCl Hydrolysis technogy

1916	Bergius began development of industrial process of saccharification
1933	Mannheim-Rheinau plant completed (single step hydrolysis) 6-8 kt/a mixed sugars
1939	Regensburg plant completed (destroyed 1945) 20 kt/a sugars
1948-59	Modified- Rheinau process (with sugar fractionation) 12 kt/a glucose
1953-55	Japan pilot plant
1957–87	Russia pilot plants (10 m3 scale hydrolysis reactors)
1980's	Dow USA: Pilot Plant - HCl recovery by solvent extraction
2007	HCl CleanTech (Israel) → → Stora Enso (2014) (HCl recovery via amine complexation)


Rheinau plant reactors


Rheinau plant acid tanks

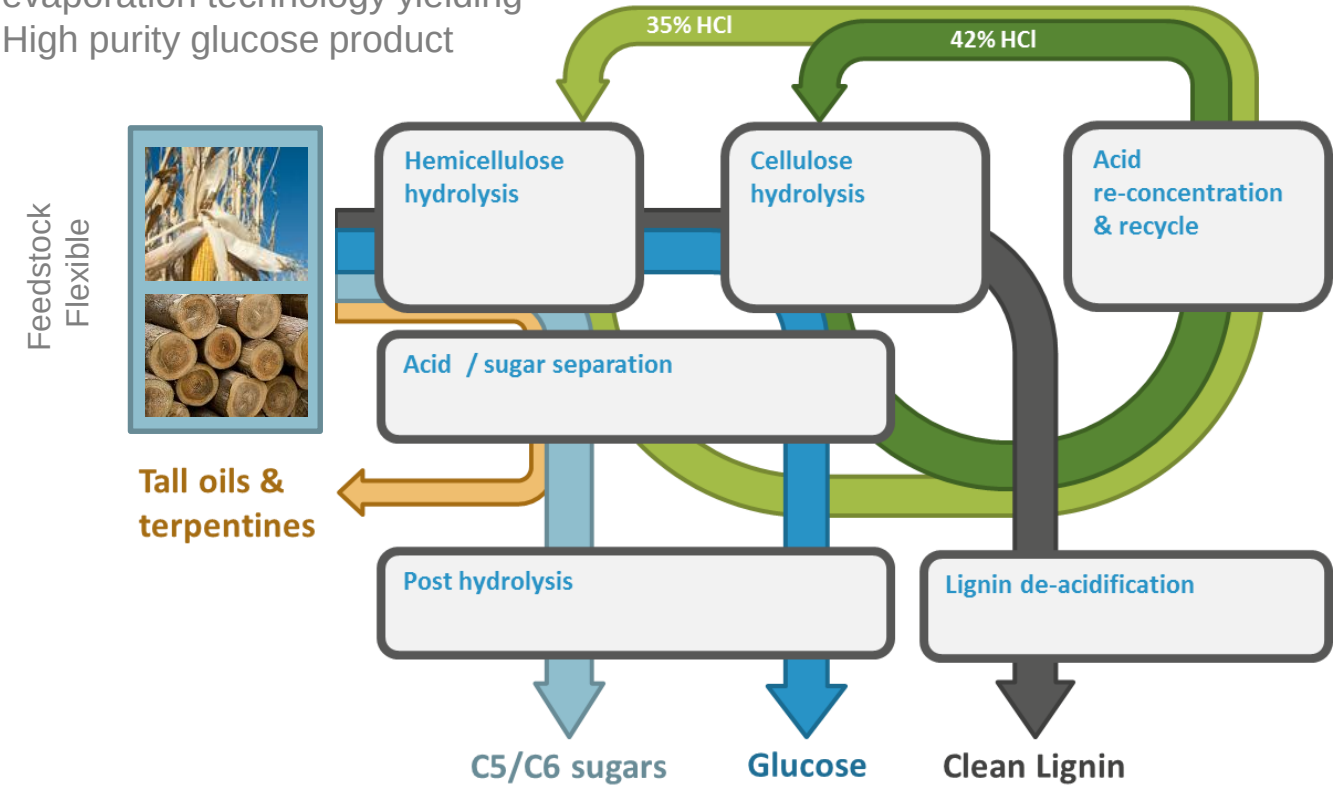

Regensburg plant

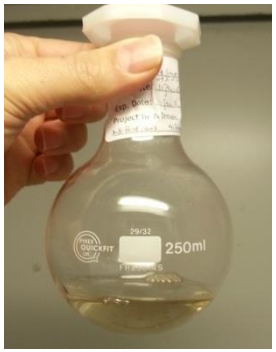
2013-2015 Avantium studies all available know-how on Bergius process and developed proprietary improvements leading to glucose production competitive to 1G glucose

avantium

Zambezi Process in a Nutshell

Improved Bergius-Rheinau process:
Two-stage, concentrated HCl hydrolysis
Acid / sugar separation by proprietary evaporation technology yielding
High purity glucose product



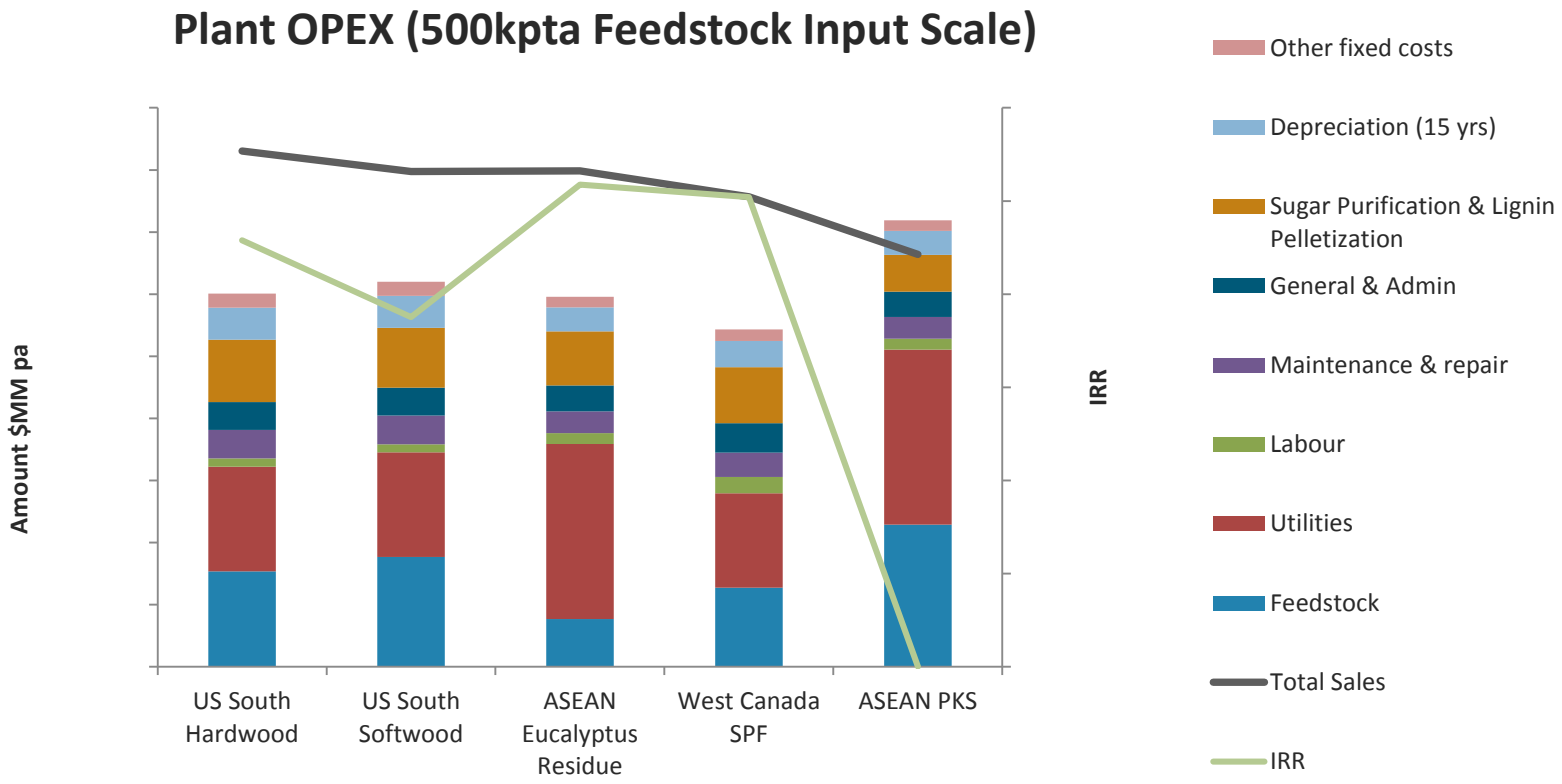


- Technical Breakthroughs
  - Acid sugar separation
  - Material construction
  - Lignin deacidification

Intellectual Property captured through patent filings

Examples Business Cases

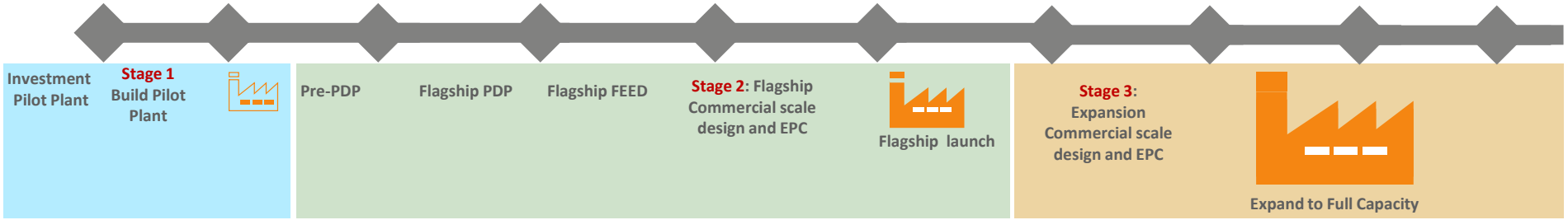
Case by case number crunch



Flagship Plant: Zambezi Wood Biorefinery

- Can be implemented in the Netherlands !
- Strong partnership established
- Available locations for Demonstration plant, flagship plant and commercial plant
- Logistics Rail/ Road/ Port
- Availability & knowledge of concentrated HCl
- Woodchips/residues availability
- Utilities (Steam, Electricity, waste water)
- Site Services/Engineering
- Availability of personnel
- Lignin (co-)firing possibilities
- Global licensing (also for other feedstocks)

Delfzijl Technology Deployment Strategy



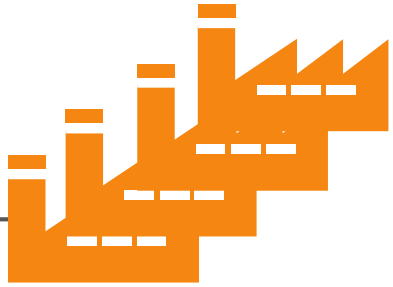
Phase I
Flagship Consortium Agreement Level

Phase II
Ownership Vehicle & Operational Level for Flagship

Phase III
Full Commercial Scale Operation

Collaborations & JDA's

Business Cases for Global Deployment



Licence multiple plants in multiple locations

Partnering Universe

avantium

Feedstock

- Pulp & paper
- Forestry
- Agricultural

Conversion

- Chemical
- Engineering
- Site / Services

Off-takers

- 2G Glucose
- Mixed Sugars
- Lignin (specialty or energy)
- Tall oils

Summary Zambezi

- Avantium has radically improved the Bergius bio-refining process to achieve cost competitiveness and high purity 2G glucose output
  - Market:
    - Large market for glucose and a growing need for high purity 2G glucose
    - Growing interest from energy industry for biomass cascading (for lignin)
    - Potential for higher value lignin applications
    - Strong interest for mixed sugars for biofuel and biogas
  - Technology:
    - Avantium innovations in hydrolisis, acid-sugar separation, lignin-deacidification drive process economics and product quality
    - Ability to use diverse range of 2G feedstock; initial focus on woody biomass
    - Pilot plant design completed; technology is ready for scale-up to demonstrate Zambezi technology at pilot scale
  - Partnering:
    - Avantium is actively looking worldwide for partners along the value chain
    - Avantium is working with industrial partners for the preparation of a flagship plant in Delfzijl, and in parallel on a range of business cases across the globe

Thank you for your attention.

Questions??

ed.dejong@avantium.com
alan.smith@avantium.com

avantium