Avantium Renewable Chemistries Update for IFBC2017

Alan Smith
9-May-2017
Avantium, a Leading Renewable Chemicals Technology Company

From Strong shareholder base with strategic and financial partners to Listed company

€254m capital raised

Catalysis

Renewable Chemistries

YXY Technology

Founded in 2000 In Amsterdam

100+ patent families

140 employees

18 nationalities

1) IPO 15-Mar-2017; Euronext Amsterdam and Brussels: AVTX
Strategic Options to Deploy Renewable Chemistries Projects

- Lab-scale
- Pilot plant
- Reference plant
- Industrial scale

- Sale of products
- Licensing

Strategic choices

- Business model / earnings
- Scale
- Coherent portfolio, each targeting blockbuster markets

- Partnering
- Sell technology

Coherent portfolio, each targeting blockbuster markets

- ZAMBEZI
- Glucose
- FDCA
- YXY Technology
- MEKONG
- PEF
YXY Deployment Example
Higher Performance Bio-Plastics Delivered via JV with BASF

Plant-based sugars

MMF (MethoxyMethyl Furfural) > FDCA (FuranDiCarboxylic Acid) > PEF (Poly Ethylene Furanoate)

Avantium + BASF = Synvina™

ZAMBEZI
2G Biorefinery
Sugar from 1G & 2G Biomass

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

Now
- Corn
- Sugar cane
- Sugar beet

• Well established technology
• Delivers high quality sucrose & dextrose

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

Future
- Wood
- Corn stover
- Waste paper

• Technologies still in development
• A challenge to deliver high quality dextrose
Bergius HCl Hydrolysis technology
A rich history: proven technology

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

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

- Technical Breakthroughs
  - Acid sugar separation
  - Material construction
  - Lignin de-acidification

IP filed
Glucose is a central building block for many bio-based polymers.
Market Potential for Glucose
Bio vs fossil market size 2015 – Growth potential

Bio-Market Sales
$65 bn

Related Fossil & Bio Sales
$400 bn

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

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

- Demand for sugars will increase
  - Arable land will come under increasing pressure
    - Demand for 1G products (grain, starch, sugars) will increase
    - More 1G milling will need to come on-line (primarily for food and feed)
  - Demand for 2G glucose to support bio-fuels will increase
  - Volume of plastics, especially bio-based, will increase
    - Demand for high purity 2G glucose will increase

- 2G Advantages:
  - free-up more 1G sources for food
  - reduce pressure on arable land
  - reduce volatility due to reduced seasonal effects

- We believe Zambezi, more than any other 2G technology, addresses the feedstock demands for the growing bio-based chemicals industry
Flagship Deployment Timeline

Stage 1: Build Pilot Plant
- Pre-PDP
- Flagship PDP
- Flagship FEED

Stage 2: Flagship Commercial scale design and EPC
- Flagship launch

Stage 3: Expansion Commercial scale design and EPC
- Expand to Full Capacity

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
Features

- Concentrated acid, low temperature, two-stage, high selectivity
- Near quantitative conversion of cellulose to glucose
- Basic technology capable of delivering high purity glucose
  - Desirable for chemical and biochemical application
  - Produces a drop-in 2G glucose cf. dextrose
- Fractionation: glucose, extractives, C5/C6 sugars and lignin
- Static Biomass
- Feedstock flexibility: forestry waste (wood) & wastepaper, (corn) stover and bagasse

Technical Breakthroughs

- Acid sugar separation
- Material construction
- Lignin deacidification
MEKONG
Bio-MEG
Production Routes for MEG

**Prime Raw Material**

<table>
<thead>
<tr>
<th>Fossil based</th>
<th>Biomass based</th>
<th>Biomimetic</th>
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<tbody>
<tr>
<td>Crude Oil/Naphtha/Gas/Fuel Oil</td>
<td>Sugar Cane</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>Natural Gas/Shale Gas</td>
<td>Maize/Corn</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>1G and 2G C6 carbohydrates</td>
<td></td>
</tr>
</tbody>
</table>

**Intermediates**

- Ethylene
- Methanol
- Ethanol
- Sorbitol
- Oxalic acid

**Product**

- EO
- MEG
- Mix of Glycols

**Legend**

- White MEG (W)
- Black MEG (B)
- Green MEG (G)

**Notes**

- Direct hydrogenolysis – Efficient conversion
- Multi-step: Low atom efficiency
- Difficult separation

Nov 2016, Avantium acquired Liquid Light Inc,
Using Bio-MEG
Trend: Shifting from Petroleum to Plant-based

Yesterday
100% Petroleum

Today
70% Petroleum,
30% Plants

Tomorrow
100% Plants

i.e. General PET
e.g. Plant Bottle™
e.g. PEF
MEKONG: Superior Carbon Efficiency
Superior economics

Current Commercial Production of Bio-based MEG

**Fermentation**

\[
\begin{align*}
\text{CO}_2 & \quad \text{EG} & \quad \text{EG} & \quad \text{CO}_2 \\
\text{OH} & \quad \text{OH} & \quad \text{OH} & \quad \text{OH}
\end{align*}
\]

Fermentation, dehydration, oxidation, hydration

4 steps

Max theoretical yield = 67%

\[
\begin{align*}
\text{OH} & \quad \text{OH} \quad + \quad 2\text{CO}_2 \\
\text{EG} & \quad \text{EG}
\end{align*}
\]

Avantium MEKONG Process

**Hydrogenolysis**

\[
\begin{align*}
\text{OH} & \quad \text{OH} & \quad \text{OH} & \quad \text{OH} \\
\text{EG} & \quad \text{EG} & \quad \text{EG}
\end{align*}
\]

Catalysis

1 step

Max theoretical yield = 100%

\[
\begin{align*}
\text{OH} & \quad \text{OH} & \quad \text{OH} & \quad \text{OH} \\
\text{EG} & \quad \text{EG} & \quad \text{EG}
\end{align*}
\]
MEKONG: Process / Technology Assessment

Process outline

1G or 2G Carbohydrates

Reactor 1

Water removal

Reactor 2

Distillation

Cat. recycle

Hydrogen

Light Ends Recovery

PG

MEG
MEKONG: Process / Technology Assessment
Application Testing: Polyester polymerization

- Polymerization trial with distilled-only EG
- Mn/Mw similar to Petro- and Bio-MEG
- Color very similar

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<thead>
<tr>
<th></th>
<th>Monomers</th>
<th>Ex-Reactor PEF</th>
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<tbody>
<tr>
<td></td>
<td>MEG</td>
<td>Mn</td>
</tr>
<tr>
<td>1</td>
<td>Bio-MEG</td>
<td>16100</td>
</tr>
<tr>
<td>2</td>
<td>Petro-MEG</td>
<td>16100</td>
</tr>
<tr>
<td>3</td>
<td>Mekong-MEG</td>
<td>16100</td>
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Global (incl. Petro) MEG Market Potential
Market Growth and Players

Source: Nexant from 2015 data set
Options and Timelines

Scale

Lab-scale → Pilot plant → Reference plant → Industrial scale

Mekong

- H2 2016: Pilot scale trials
- 2017: Pilot plant design, Pilot plant construction
- 2018: Investment decision, Start construction pilot plant
- 2019: Start up pilot plant
- 2020: Site selection, Basic engineering, Construction commercial plant

Partnerships
THANKS FOR YOUR ATTENTION

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