small scale biorefineries - opportunities and challenges

STATUS OF THE BIOECONOMY

Oslo, 2-3 September 2015

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The new challenges in a biobased Economy:

1st step: Biomass production
- Biomass sources
- Agro-food production
- Byproducts & waste

2nd step: Logistics & storage
- NL production
- Imports

Biomass feedstock:
- Agro-food production
- Byproducts
- Waste

Biomass conversion:
- Food pretreatment
- Food conversion
- Food production

Food/feed
- Existing conversion
- Existing production

Biobased Products
- New production
  - Performance materials
  - Base & platform chemicals
  - Performance chemicals
  - Bio Energy

Existing non-food:
- Paper
- Construction wood
- Additives
- Fibres/clothes
- Wood for cooking

Healthy, tasty, sufficient

1. Food/Feed
2. Biobased Products
3. Existing non-food
Many drivers for the Biobased Economy

- Shortage of cheap oil
- High energy prices
- Security of energy supply
- Climate change by greenhouse gases
- Rural development
- Developing countries
- Geo-political conditions

Different countries/groups are confident however that a BbE can contribute to their goals.
Design rules for a sustainable Bio-economy

People, Planet, Profit

- Improve our overall energy efficiency
- Increase field yield but keep components on the field that are required for soil fertility
- Use all biomass components and choose the right raw material
- Use each component at its highest value: (molecular) structure is much better than caloric
- Reduce capital cost to speed up innovation and to benefit from small scale without the disadvantages

Following these rules, will we have enough resources?
Our daily food needs a 20-fold higher energy input.

20 000PJ is more than 20% of our European energy bill!

**Biomass**
- NL 635 PJ
- EU 20,000 PJ

**Fossil**
- NL 575 PJ
- EU 20,000 PJ

**Dutch Agriculture**
- 475 PJ

**Net Import**
- 160 PJ

**EU 1,800 PJ**

**2500 kcal/day = 55 PJ**

- **Food Industry**
  - 150 PJ

- **Household**
  - 165 PJ

- **Transportation Food**
  - 100 PJ

- **Greenhouses/Food**
  - 100 PJ

- **Other Agriculture**
  - 60 PJ
Economic carriers in the BioEconomy

- High value, Too low volume
- High value, And high volume!
- Very high volume, too little value

Proteins
Chemicals
Materials
How biomass can best compete with fossil feedstocks

Value of biomass is 10 times higher as chemical building block than to use it for biogas or bio-electricity
Epichlorohydrin a good example of using biomass functionality

\[
\begin{align*}
\text{H}_2\text{C} & = \text{CHCH}_3 + \text{Cl}_2 & \longrightarrow & \text{H}_2\text{C} & = \text{CHCH}_2\text{Cl} + \text{HCl} \\
\text{H}_2\text{C} & = \text{C} & \text{HCH}_{2}\text{Cl} & \text{Ca(OH)}_2 & \longrightarrow & \text{H}_2\text{C} & = \text{C} & \text{HCH}_2\text{Cl} + \text{H}_2\text{C} & = \text{C} & \text{HCH}_2\text{Cl} \\
\end{align*}
\]

- **Price:** €1300 - 1500 per tonne
- **Volume:** 0.5 mln tonnes per annum
- **Capital required:** 300€/tonne?
- **Raw material cost:** glycerol, HCl, NaOH

- Solvay ‘Epicerol’ process: glycerol to epichlorohydrin

Margin??
Use of plant molecular structures leads to little heat exchange and valuable product.

- Diaminobutane
- Acrylonitrile
- N-Methylpyrrolidone
- N-Vinylpyrrolidone
- Glutamic acid

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The route to NEP, new vs conventional NMP

New route

Biomass → Glutamic acid

- CO₂ → NH₂ COOH

enzyme, 30 °C

hydrolysis, separation

Glutamic acid

step 1

NH₂ COOH → NH₂ COOH

ethanol

cat, 250 °C

step 2

NEP

Conventional route

Gas → CH₃OH → O │ │ CH₂

+ 90-150 °C

cat, 90-150 °C

HO → HO

+ H₂ cat, 80 °C

HO

cat, 180-240 °C

- H₂

N₂ + 3 H₂

+ CH₃OH

NH₃

100 bar

200-350 °C

CH₃NH₂

CH₃

Amino acids contain N and O.

Less steps (= factories) & energy for the same product!
Biobased NMP, makes an ethanol plant profitable

500 Million liters bioethanol
(≈ 400 kton) = 200M€

360 kton DDGS (≈130 €/ton) = 46M€

23 kton NMP
(≈2500 €/ton)
= 58 M€/y
3D-foamed polylactic structures (Wageningen UR)

- Expandable bead technique
  - Good cell structure
  - Density <30 g/l
Protein as economic carrier in BioEconomy in North Netherlands / Weser Ems area

<table>
<thead>
<tr>
<th></th>
<th>rapeseed</th>
<th>rapeseed meal</th>
<th>maize</th>
<th>grass</th>
<th>grass</th>
</tr>
</thead>
<tbody>
<tr>
<td>max. area (kha)</td>
<td>60</td>
<td>not applic.</td>
<td>465</td>
<td>70</td>
<td>620</td>
</tr>
<tr>
<td>yield (€/ha)</td>
<td>1800</td>
<td>20</td>
<td>3000</td>
<td>5200</td>
<td>2500</td>
</tr>
<tr>
<td>inv. / unit (M€)</td>
<td>0.1</td>
<td>20</td>
<td>3</td>
<td>50</td>
<td>1.2</td>
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</tbody>
</table>

- beet leaves
- roadside grass
- bermgrass
- maize
- wheat
- rapeseed meal
- rapeseed

**TCE GoFour**
- oil 10%
- protein 35%
- fibre 35%
- K+P biogas feed 20%

**MIMOSA**
- protein 50%
- amino acids 20%
- lactic acid 35%
- K+P 5%
- fuel (electricity) 10%

**ZeaFuels**
- protein 50%
- starch 10%
- ethanol 40%
- maize oil 15%
- K+P 5%

**HarvestaGG**
- protein 50%
- biogas 10%
- grass juice 15%
- amino + organic acids 5%
- K+P 5%

**Grassa**
- protein 15%
- fibres 50%
- grass 15%
- soil improver 5%
- K+P 5%
# Biorefining of Agricultural Residues

<table>
<thead>
<tr>
<th>Protein content</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>Group 5</th>
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<tbody>
<tr>
<td>0 %</td>
<td></td>
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<td></td>
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<tr>
<td>5 %</td>
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<td></td>
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<tr>
<td>15 %</td>
<td></td>
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<tr>
<td>35 %</td>
<td></td>
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<td></td>
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<tr>
<td>50 %</td>
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<td></td>
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<table>
<thead>
<tr>
<th>Examples</th>
<th>Wheatsstraw</th>
<th>cocoahull</th>
<th>Corncobs</th>
<th>Sugarcane leaf</th>
<th>Coffee pulp</th>
<th>Rape straw</th>
<th>Beet leaf</th>
<th>Rape meal</th>
<th>Soy meal</th>
</tr>
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<tbody>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost (€/ton)</th>
<th>50-80</th>
<th>50-110</th>
<th>100-140</th>
<th>150-180</th>
<th>300-350</th>
</tr>
</thead>
<tbody>
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### Notes:
- **Cellulose**, **Hemicellulose**, **Lignin**, **Minerals**, **Fat**, and **Protein** components are illustrated in the diagram. The cost values are given in €/ton.
Biorefinery enables power generation at 45€/ton and high quality 2\textsuperscript{nd} generation fermentation raw materials for 200€/ton \textit{at reasonable small scale}.
Small scale biorefinery reduces transport cost and seasonality

Present:
- Fields: 100% present
- Farm: Present
  - Return flow: 10%
- Processing: 100%

Concept:
- Fields: 100% present
- Farm: 100%
  - Return flow: 70%
- Processing: 30%
  - Concentration
  - Fermentation

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small scale beet sugar production (2-500ha) can beat large scale factories!

Less energy
Less transport
Minerals recycled to field

Kolfschoten et al
Anaerobic fermentation of bulk chemicals

Yield: 0.95 g/g or J/J
→ Little heat produced
→ Low capital required!

Productivity: up to 5 times higher
→ Low capital required

5 projects running
Mobile Cassava starch refinery in Africa, small scale started > 10 years ago
The separated components of grass value 700 – 800 €/ton as compared to 60€/ton raw materials.

- Water: 80-90%
- Dry substance: 10-20%
- Fibers: 30% (100)
- Polysaccharides: 15% (1500)
- Lipids: 3% (2000)
- Organic acids: 5% (2000)
- Oligo-saccharides: 3% (1500)
- Mono/di- saccharides: 150
- Minerals: 10% (500-1000)
- Protein / Amino acids: 20% (1000)
Mobile grass refinery unit Grassa (the Netherlands)

Grass juice

Grass protein (products)
- White grass protein
- Green grass protein

Protein

Compound feed

Fibers

Grass juice concentrate

Cattle feed

Compounds feed

Ethanol

Construction material + paper

Polymer extrusion products
Just protein is not sufficient to cover the costs

<table>
<thead>
<tr>
<th>bioraffinery</th>
<th>3 products</th>
<th>8 products</th>
<th>Norway income</th>
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<tbody>
<tr>
<td></td>
<td>income</td>
<td>costs</td>
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</tr>
<tr>
<td>Grass costs</td>
<td>60</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>Process costs</td>
<td>120</td>
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<td>440</td>
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<tr>
<td>protein</td>
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<td>160</td>
<td>120</td>
</tr>
<tr>
<td>fibers</td>
<td>30</td>
<td>35</td>
<td>30</td>
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<tr>
<td>Juice components</td>
<td>55</td>
<td>60</td>
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<tr>
<td>minerals</td>
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<td>Organ. acids</td>
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<td>60</td>
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<tr>
<td>Amino acids</td>
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<td>75</td>
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<tr>
<td>sugars</td>
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<tr>
<td>sugarpolymeren</td>
<td></td>
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<td>225</td>
</tr>
<tr>
<td>fat</td>
<td></td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>total</td>
<td>395</td>
<td>180</td>
<td>355</td>
</tr>
</tbody>
</table>
Grass processing on very small scale (500kg/h)
protein/oil/ethanol/biogas from small scale corn-biorefinery

Less investment costs/liter ethanol than American ethanol production that operate at 200 x larger scale
Byosis (Lelystad, Netherlands)
Conclusions

- Biorefinery for feed, materials and chemicals will create good income for agriculture and enables even to compete with coal, natural gas and Brasilian feedstocks!
- Small scale processing reduces capital as well as costs for energy and transportation and
- will lead to higher employment
- Biorefining is not easy because we have to collaborate