Contents

- Green Biorefinery overview
- Array of products and technologies
- Demo and Pilot initiatives across Europe
- Operation concepts and logistics
- Summary
Green Biorefinery overview

A Green Biorefinery processes (fresh) green biomass to an array of products

Primary processing: Green Biomass → Juice → Solid cake

Secondary processing: Juice → Solid cake → Products
Green biomass

- Grass
  - Nature
  - Verge
  - Culture
- Clover
- Luzerne
- Sugar beet leaf

- Potato Leaf
- Green fertilizers
- Immature Cereals
- .....
Motivation

- Traditional use (dairy farming) of grasslands is decreasing
  - Grass is a surplus resources in many EU-regions
  - Green Biorefinery is an alternative concept for sustainable grassland utilisation
- Alternative cellulose sources are necessary
  - Demand for wood is increasing rapidly
- Alternative feed products
  - Soy import
General challenges in biomass processing

- Economy of scale
  - Transportation costs
  - Wet vs. dry products

- Central vs. decentral
  - Mobile units

- Storage vs. campaign
Products

Main focus current Green Biorefinery technology

- Proteins (amino acid)
- Soluble sugars
- Ligno-cellulose fractions (fibres)
- Special fine chemical

As product or valuable intermediate
Primary processing

- Mechanical Fractionation
  - Screw Press
  - Refiner

![Image of processing equipment]

- Green Biomass
- Juice
- Solid cake
Secondary processing: Juice
## Secondary processing: Juice

<table>
<thead>
<tr>
<th>Process technology</th>
<th>Product or intermediate</th>
<th>Application</th>
<th>Market size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agglomeration membrane technology</td>
<td>Protein recovery</td>
<td>animal feed</td>
<td>+++</td>
</tr>
<tr>
<td>Separation technology</td>
<td>Amino acids mixtures</td>
<td>High grade, e.g. nutrition supplement, body care</td>
<td>+</td>
</tr>
<tr>
<td>e.g. nanofiltration electro dialysis/</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>chromatography</td>
<td>Lactic acid</td>
<td>Bulk chemical food/ feed/ drinks/ PLA, Ethyllactat...</td>
<td>++</td>
</tr>
<tr>
<td>Direct fermentation</td>
<td>e.g. lactic acid ...</td>
<td></td>
<td>++</td>
</tr>
<tr>
<td>Biogas generation</td>
<td>Bio-methane</td>
<td>CHP or gas-grid biofuel</td>
<td>++(+)</td>
</tr>
</tbody>
</table>

+ small  ++ medium  +++ big
Secondary processing: Solid cake

Solid cake ➔ Products
Secondary processing: Solid cake

- **Direct use**
  - Biogas
  - Animal feed
  - Combustion

- **Upgrading to fibre products**
  - Insulation material
  - Fibre boards
  - Horticulture substrate
  - Bio-composites
  - Pulp & Paper
  - ...

- **Feedstock for ligno-cellulose biorefinery**
  - Hydrolysis & fermentation
  - Biofuels
  - Organic acids
  - Biopolymers
  - ...

FOOD & BIOBASED RESEARCH
WAGENINGEN UR
## Demo and Pilot plants in Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>Current Status</th>
<th>Products</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Pilot plant (Utzenaich)</td>
<td>Lactic acid, Amino acids, Biogas</td>
<td>LA + AA separation out of silage juice; fibres to biogas</td>
</tr>
<tr>
<td>Germany</td>
<td>Pilot Plant Brandenburg</td>
<td>Lactic acid</td>
<td>Fermentation of fresh green juice +starch hydrolysis</td>
</tr>
<tr>
<td></td>
<td>Demo „Biowert“</td>
<td>Biogas, feed , fibre</td>
<td>Mainly biogas</td>
</tr>
<tr>
<td>Ireland</td>
<td>Concept</td>
<td></td>
<td>Biogas + Insulation</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Pilot plant Grassa! facilities</td>
<td>Feed product focus, fibre utilisation</td>
<td>fibres for pulp and paper and various fibre products… „mobile“ operation concepts</td>
</tr>
<tr>
<td></td>
<td>planned</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>Demoplant</td>
<td>Grass fibre insulation product biogas and feed options</td>
<td>Commercial business for insulation material; biogas and feed not yet fully integrated</td>
</tr>
</tbody>
</table>
Green Biorefinery Utzenaich, Austria

Upgrading grass silage to lactic acid, amino acids and biogas

feedstock silage (Grass, Clover, Lucerne)

Mechanical Fractionation

Juice

Amino Acids Separation

Lactic Acid Separation

Biogas digester

Fibre for different applications

optional

additional feed (manure, maize)

Press Cake Fibres

Amino Acids mixtures

Lactic Acid, Electricity Heat

Fertiliser

Fibre Processing

Electricity Heat

Fertiliser

Upgrading grass silage to lactic acid, amino acids and biogas
Green biorefinery Netherlands

Grass

- Prograss
  - central

- Courage/de Haan
  - mobile unit

- GRASSA!

Sugar beet leaf

- CSM
  - digester

- Suikerunie
  - Fibre
  - Protein

GRASSA!!
Pilot Plant Brandenburg, Germany

Use of fresh grass juices for lactic acid fermentation

- Pre-treatment of plant substrates for microbial conversion processes
- Kinetics of cell growth and product processing of lactic acid bacteria
- Development of continuous processes for the production of basic chemicals, valuable products and biomass

Pilot plant facility for biotechnological manufacture of valuable products based on renewable resources

Source: Joachim Venus, ATB
Source: Joachim Venus, ATB
Pilot Plant in Obre, Switzerland

Biomass Process Solution (BPS) upgrades grass fibre to insulation products

Use of liquid phase for biogas generation

Source: Stefan Grass, BPS
Benchmarking grass insulation properties

<table>
<thead>
<tr>
<th>Product</th>
<th>Heat conductivity [W/m,K]</th>
<th>Greenhouse potential [kg CO₂-aequiv./kg]</th>
<th>Sound absorption</th>
<th>Sommer heat protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stonewool</td>
<td>0.035</td>
<td>1.4</td>
<td>good</td>
<td>medium</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>0.035</td>
<td>3.2</td>
<td>poor</td>
<td>medium</td>
</tr>
<tr>
<td>Flax</td>
<td>0.04</td>
<td>0.4</td>
<td>good</td>
<td>good</td>
</tr>
<tr>
<td>Gramitherm®</td>
<td>0.035</td>
<td>-0.9 (!)</td>
<td>good</td>
<td>good</td>
</tr>
</tbody>
</table>

Use of liquid phase for biogas generation

Source: BPS, S. Grass
Green Biorefinery integration: Austria

- Grass Biorefinery in the centre of a supply area (r = 10-20km)
- Possible Integration of surrounding region
Green Biorefinery integration: Netherlands

- Fibre Industry in the centre of a supply area
- Integration of surrounding region
…some answers to build on

- Feedstock logistics strongly determine the size of Green Biorefinery (not “economy of scale” factors)
  → regional embedding of technology
- Regional circumstances determine biorefinery setup and product array
- Ensiling feedstock enables continues operation
- From the long term perspective security of raw material supply requires sustainable agriculture!
“Take home message…”

- Economic feasibility: 2-3 product outlet is required
- Incentives for biogas generation (green power legislation) could boost Green Biorefinery
- Grass protein for animal feed products is economically challenging but offers a very big market for big scale implementation
- Grass is good in crop rotation and has proven to be a sustainable long term resource
“Take home message…”

- Logistics are part of the process setup which lead to regional adopted biorefinery solutions
- Lack of funding for pilot activities is a major bottleneck for stepping into the market
- Linking Green Biorefinery with Ligno-Cellulose Refinery pathway is an attractive concept
  → further R&D needed!
Thank you for your attention