1. Introduction

Industrial Biorefineries are the key to build a new biomass-based industry.

Biorefining is the transfer of logic and efficiency of the fossil based chemical, chemical processing and material converting industry as well as energy production onto the biomass industry.

The product range of a biorefinery includes both, materials producible from crude oil and also products, which can’t be produced on crude oil basis.
1. Introduction

Depending on the physiology of plant material, two basic systems are considered according to refinery, cuttings, fractions and products.

- Ligno-cellulosic feedstocks (LCF) ‘nature dry’ biomass, cellulosic biomass and waste, wood, fast growing lumbers, straw and reed > processing in the LCF-Biorefinery

- Green ‘nature wet’ raw-materials, green grass, alfalfa, clover, immature cereals > processing in the Green-Biorefinery.

Green Biorefineries (GBR’s) are complex systems based on ecological technology for comprehensive (holistic), material and energy utilization of renewable resources and natural materials using green and waste biomass and focalising on sustainable regional land utilization.

GBR’s orientate on the sustainability principles (sustainable land utilization, gently technologies, self-sufficient energy supply etc.).
3. Raw material

Green Biomass is for example

- Green grass from the cultivation of permanent grassland, set-aside agricultural land, nature conservation areas
- Green crops like alfalfa, clover, immature cereals from an extensive or modest intensive agriculture.

Utilizing green plants, proteins and carbohydrates are harvested at the place of syntheses, i.e. prior to translocation.

The loss of resources by translocation can be minimized, if the crops were harvested before flowering.

Green harvests generates more biomass and proteins per hectare and year than mature harvests or grain harvests.

4. Biorefinery-System

Green Biomass
Press

Press juice
Biochemical, biotechnological, physical

Proteins, soluble sugars

Feed, fuels, chemicals, materials

Cellulose, lignocellulose

Residues

Biogas combined heat and power generation

4. Biorefinery-Systems

Grass, alfalfa, foliage, et al.

Fermentation

Green pellets
Insulator
Cellulose raw material
Raw material for chemical industry

Press juice

Separation

Proteins
Enzymes
Carbohydrates
Flavourings
Dyes

Biogas

Lactic acid, lactates, ester
Amino acids
Proteins (SCP)
Enzymes
Organic acids
Ethanol

Combined heat and power unit (CHP)

Heat, electricity

Energy

Straw, wood, biogas

Fibres, cellulose

Crops: straw, seeds, potatoes, juice, molasses

Pretreatment

Fertilizer

Green Crop-Drying Plant

Wet Fractionation

Energy Heat, electricity
5. Technical aims

Combination of

- Technologies for the fractionation of green plant material
- Leaf-protein extraction technologies
- Biotechnological processes
- Extraction processes (chlorophyll, carotenoids)
- Technologies for the combination of biotechnological and chemical processing
- Technologies for biogas generation
5. Technical aims

Existing agricultural structure  
Green Crop Drying plant

Construction of a Primary refinery at the Green crop drying plant,  
Production of functional materials

Integrated industrial biorefinery  
Functional materials  
Platform chemicals  
Energy

- biotechnological-chemical processing  
- hydrothermic conversion of primary products to platform chemicals and secondary products

2000 2005 2010 2020  
Completion

Fractionation of raw materials, proteins, fermentation media in laboratory/ pilot scale
6. Mass balance and energy input
Examples: Green Biorefinery / selected and simplified view of Green Biorefinery processes

Fields, grassland
Alfalfa, grass, clover
Harvest and cutting
40,000 t (DM: 20 %)

Wet fractionation
Press

Press juice

Press cake

Protein coagulation
Membrane separation

Lactic acid/ Lysine fermentation

Decantation Separation
Protein purification

Separation

Drying

Silage fodder

Steam

Filtrate

Biogas plant

Feed protein
Cosmetic protein
Single cell biomass
Lactic Acid/ Lysine
# 6. Mass balance and energy input

## Scenario 1: Lactic acid

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Technologies</th>
<th>Process energy</th>
<th>Product-Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green ‘nature wet’ raw materials (Green grass, alfalfa, clover)</td>
<td>Milling</td>
<td>Heat 2200 GJ</td>
<td>Lactic acid (90 %) (DM: 90 %) 660 t</td>
</tr>
<tr>
<td>40.000 t (DM: 20 %)</td>
<td>Mechanical fractionation</td>
<td>Electricity 1005 MWh</td>
<td>White protein (DM: 90 %) 38 t</td>
</tr>
<tr>
<td></td>
<td>Protein separation (centrifugation, membrane techn.)</td>
<td></td>
<td>Green protein (DM: 90 %) 550 t</td>
</tr>
<tr>
<td></td>
<td>Fermentation and separation (membrane techn.)</td>
<td></td>
<td>Silage fodder (DM: 40 %) 13.000 t</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Single cell biomass (DM: 90 %) 33 t</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Residues for biogas (DM: 2 %) 17.690 t</td>
</tr>
</tbody>
</table>

6. Mass balances and energy input
Scenario 2: Lysin

<table>
<thead>
<tr>
<th>Biomass</th>
<th>Technologies</th>
<th>Process Energy</th>
<th>Product mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green ‘nature wet’ raw materials (Green grass, alfalfa, clover)</td>
<td>Milling</td>
<td>Heat 2200 GJ</td>
<td>Lysin-HCl (50 %) (DM 90 %) 620 t</td>
</tr>
<tr>
<td>40.000 t (DM: 20 %)</td>
<td>Mechanical fractionation</td>
<td>Electricity 500 MWh</td>
<td>White protein (DM 90 %) 38 t</td>
</tr>
<tr>
<td></td>
<td>Protein separation (centrifugation, membrane techn.)</td>
<td>Hydrochloric acid (37 %) 167 t</td>
<td>Green protein (DM 90 %) 550 t</td>
</tr>
<tr>
<td></td>
<td>Fermentation and separation (membrane techn.)</td>
<td></td>
<td>Silage fodder (DM: 40 %) 13.000 t</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Single cell biomass (DM: 90 %) 31 t</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Residues for biomass (DM: 2 %) 17.770 t</td>
</tr>
</tbody>
</table>

7. Demonstration plant
Green Biorefinery – Havelland type

Region Havelland:
State of Brandenburg, to the west of Berlin
53 % of the area is under agricultural cultivation
62,000 ha cropland
29,000 ha grassland

Havelländisches Luch with the Green crop drying plant Selbelang as a central object
• Chemistry Park Premnitz
• High state of knowledge of the agro-industrial research- and educational institutions

Agrarbericht, Land Brandenburg, 2013
7.1 Site
7.2 Partner

Coordination and experimental work for basic material recovery of grass/alfalfa

**biopos e.V.**
Research Institute Bioaktive Polymer Systems
Research location Teltow-Seehof
www.biopos.de
Representative: Prof. Dr. Birgit Kamm

Primary refinery
Fractionation and storage
Production side

**Drying Plant Selbelang**
FMS-Futtermittel GmbH
Representative: Dipl.-Ing. Bernd Müller

Product line press juice
Production of proteins and fermentation juices

**biorefinery.de gmbh**
Pilot plant station, Teltow-Seehof
www.biorefinery.de
Representative: Dr. Jörg Beckmann

Product line press juice
Scale-up and engineering of the press-juice line

**LINDE Engineering Dresden GmbH**
www.linde-kca.com
Representative: Dr. habil. Karin Bronnenmeier
7.3 Primary refining process and products

- **Fields/ harvest**
  - Alfalfa, grass, clover
  - 20,000 t/a (DM: 20 %)

- **Green crop drying plant**
  - 151.2 m³/d
  - 165 working days per year
  - (May to October)

- **Fractionation step**
  - **Screw extruder**

- **Press juice**
  - 76.8 m³/d
  - (DM: 5 %)

- **Press cake**
  - 74.4 m³/d
  - (DM: 35 %)

- **Drying and pelletizing**

- **Drying and Pelletizing**

- **Waste heat**
  - Steam / hot water

- **Pellets for fodder**
  - Sale
7.3 Primary refining process and products

**Fields/ harvest**
Alfalfa, grass, clover
20,000 t/a (DM: 20 %)

**Green crop drying plant**
151,2 m³/d
165 working days per year
(May to October)

**Fractionation step**
Screw extruder

- **Press juice**
  76,8 m³/d
  (DM: 5 %)

- **Press cake**
  74,4 m³/d
  (DM: 35 %)

**Drying and Pelletizing**

**Drying and Pelletizing**

**Waste heat**
Steam / hot water

**Pellets for fodder**
Sale

**Green crop drying plant**
151,2 m³/d
165 working days per year
(May to October)
7.4 Process, functional proteins and fermentation media

**Press juice-line I (Thermo-section)**
- **Green proteins**
  - 1704 kg/d (DM 90%)
- **Heat exchanger**
- **Protein coagulation (75°C)**
- **Decantation Phase separation**
- **Protein Phase (Green protein)**
- **Fluidized bed drying**

**Fermentation reactor**
- 74.7 m³/d (DM 3%)

**Press juice-line II (Membrane-section)**
- **Protein coagulation (60°C)**
- **Decantation Phase separation**
- **Ultrafiltration**
  - Protein phase (White protein)
  - 720 kg/d (DM 1.4%)
- **Spray drying**
  - White proteins
    - 11 kg/d (DM 90%)

**Waste heat, hot water**
- Waste heat, steam
- Fermentation media
- Press juice
  - 76.8 m³/d (DM 5%)
  - 1 m³/d (DM 5%)

**Fermentation media**
- Fermentation reactor
- Fermentation media
  - 720 kg/d (DM 1.4%)

**Waste heat / steam hot water**
## Patent application

**Applicant:** biorefinery.de GmbH  

**Title:** Method and apparatus for continuous extraction of proteins from plant press juices  

**Inventors:** Birgit Kamm, Petra Schönicke, Christoph Hille, Reinhard Weber, Matthias Franz Josef Nomayo  

**Date of filing:** June, 21, 2011  

**File reference:** 10 2011 077 921.3
7.4 Functional proteins and fermentation media

**White proteins (Making to market: 3.000 Euro/ton)**
High functional potential
- for foams, foam stabilizer, films (cosmetic)

**Green proteins (for high-quality feed) (Making to market: 390 EURO/ton)**
- Amino acids (Asp, Glu, Ser, His, Gly, Thre, Arg, Ala, Tyr, Val, Phe, Ile, Leu, Lys, Pro, Hydroxypro, Met, Cys, Trp)
- Carotene
- Xantophyll
- Fat

**Fermentation media (for biotechnological processes)**
- Glucose
- Proteins, amino acids
- Fats
- Minerals (Na⁺, K⁺, Ca²⁺, Mg²⁺, P, NO₃⁻, SO₄²⁻, Cl⁻)
### 7.5 Estimation of investment costs

<table>
<thead>
<tr>
<th>Technology costs</th>
<th>K €</th>
<th>Building occupancy expenses</th>
<th>K €</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project specific subsystems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Package unit costs</td>
<td>1.438</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipments costs</td>
<td>1.390</td>
<td></td>
<td></td>
</tr>
<tr>
<td>inclusive bulk and assembly costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PLS costs</td>
<td>263</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td>3.136</td>
<td><strong>Open up</strong></td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Exterior</strong></td>
<td>102</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Building</strong></td>
<td>817</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td>982</td>
<td><strong>Sub-total</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Engineering costs</strong></td>
<td>K €</td>
<td><strong>Engineering costs</strong></td>
<td>K €</td>
</tr>
<tr>
<td>Package unit</td>
<td>180</td>
<td>Open up</td>
<td>18</td>
</tr>
<tr>
<td>Equipments</td>
<td>382</td>
<td>Exterior</td>
<td>25</td>
</tr>
<tr>
<td>PLS</td>
<td>95</td>
<td>Building</td>
<td>75</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td>657</td>
<td><strong>Sub-total</strong></td>
<td>118</td>
</tr>
</tbody>
</table>

**Total investment costs incl. escalation (+/- 20 %) and management**: 6,2 Mio €
## 7.6 Efficiency calculation
### Operation costs per year

<table>
<thead>
<tr>
<th>Specific product costs</th>
<th>K €/a</th>
<th>€/kg product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material</td>
<td>16.5</td>
<td>0.07</td>
</tr>
<tr>
<td>Fuels</td>
<td>10.5</td>
<td>0.04</td>
</tr>
<tr>
<td>Other raw materials and supplies</td>
<td>68</td>
<td>0.28</td>
</tr>
<tr>
<td>Personnel</td>
<td>60</td>
<td>0.24</td>
</tr>
<tr>
<td>Spare parts</td>
<td>10</td>
<td>0.04</td>
</tr>
<tr>
<td>Utilities</td>
<td>10</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Sub-total</strong></td>
<td><strong>175</strong></td>
<td><strong>0.71</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reduction of costs Drying Plant</th>
<th>K €/a</th>
<th>€/kg product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating energy costs</td>
<td>104</td>
<td>0.42</td>
</tr>
</tbody>
</table>

**Operating costs considering the heating energy savings in the drying plant**: 71 K €/a, 0.29 €/kg product
7.7 Effect on climate protection
Processing of 20,000 t biomass (1st step of construction)

<table>
<thead>
<tr>
<th>Savings potential by connecting the facility to the existing drying plant</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal</td>
<td>2.073 t/a</td>
</tr>
<tr>
<td>CO₂</td>
<td>4.172 t/a</td>
</tr>
<tr>
<td>GHG reduction per € investment funds</td>
<td>37.18 € charges / t CO₂</td>
</tr>
<tr>
<td>Facility operating time: 40 years</td>
<td></td>
</tr>
<tr>
<td>Data according to Basic Engineering, variation (+/- 20%)</td>
<td></td>
</tr>
</tbody>
</table>
7.8 Layout production facility
7.9 Layout pilot plant
8. Outlook

- Upgrading of the Primary refinery in a 40,000-100,000 t scale (year-round operation)
- Addition of fermentation units to the production of platform chemicals
- Addition of technologies for press cake processing outside of the fodder sector (chemical raw material, carbohydrate source for platform chemicals)
- Addition of the product line synthesis gas

9. Contact

Prof. Dr. Birgit Kamm  
Director of the Institute Biopos e.V. and BTU Cottbus  
Research Centre Teltow-Seehof  
Kantstraße 55, D-14513 Teltow  
Email: kamm@biopos.de  
Fon: +49 (0)33 28-33 22-10  
Fax: +49 (0)33 28-33 22-11  
www.biopos.de

biorefinery.de GmbH  
Kantstraße 55, D-14513 Potsdam  
Email: office@biorefinery.de  
www.biorefinery.de  
www.biorefinica.de