Biorefineries in Europe – Status quo and future perspectives

SMIBIO Workshop
Small-scale Biorefineries for Rural Development in Latin America and Europe

23 November 2016
Buenos Aires, Argentina

Dr. Rainer Janssen
WIP Renewable Energies, Germany
Content

• Brief introduction – WIP Renewable Energies
• Biorefineries – concept and classification
• Commercial biorefineries in Europe
• Biorefineries - incentives and tools
• Small-scale biorefineries
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• Pilot and demonstration facilities in Europe
• Conclusions
WIP – Renewable Energies

...founded in 1968 (48 years) to support infrastructure projects

...interdisciplinary private institute for the development and promotion of renewable energy projects

...bridges the gap between research and implementation of renewable energy systems

• Ranging between 15 and 20 employees
• More than 20 on-going (renewable energy) projects
• Overall portfolio: >300 international, multi-disciplinary projects
• WIP was ranked among the 25 most successful SMEs in FP7
Main Activity Fields – examples 2007 to 2016

Bioenergy
- S2Biom
- CORE-JetFuel
- biorefine 2G
- Bin-GRID
- BioSTEP
- BioLYFE
- SMIBIO
- RE Grid
- NEMO for bioethanol
- BioTop
- BioTrade2020+
- URBAN BIOMASS
- BABEL REALS

Wind
- 7 MW
- 5MW off-shore

PV
- Photovoltaic Technology Platform
- PV Parity
- PV enlargement
- Crowdfunder
- SUNRise

RE Grid Integration
- IndustRE
- ORPHEUS
- GridTECH.eu

Energy and Water Nexus
- RED way to power
- REAPower
- PRODES
- Mediras

Development
- AfriCAN climate
- Community Power

www.wip-munich.de
Main Project Types – examples 2007 to 2016

Research

Market Development

Demonstration

Social, economic & educational/training

International Cooperation

www.wip-munich.de
Books, Handbooks, Publications, Videos, Websites
Biorefining is the sustainable processing of biomass into a spectrum of marketable Bio-based Products and Bioenergy

(Definition by IEA Bioenergy Task 42 Biorefineries)
Four main features to classify biorefinery systems

- **Platforms** (e.g. C5/C6 sugars, syngas, biogas)

- **Product groups: Energy** (e.g. bioethanol, biodiesel, synthetic fuels) and **Products** (e.g. chemicals, materials, food and feed)

- **Feedstock groups** (e.g. energy crops, biomass residues from agriculture, forestry, trade and industry)

- **Conversion processes** (e.g. biochemical, thermo-chemical, chemical, mechanical)
Energy vs. product driven biorefineries

Energy driven biorefineries
- Target: production of biofuels/energy; added value through co-products
- Infrastructure (value chains) exist
- Often (public) financial support required and/or regulated markets
- Up-grading of existing plants to multi-product biorefineries

Product driven biorefineries
- Target: production of chemicals, materials, food and feed; side-products used for energy (power/heat) production
- Only limited new facilities in operation yet
- Key technologies often still at R&D phase
- High potential (interested stakeholders, advanced properties)

Bioenergy will be the “lubricating oil” in a future circular BioEconomy
Commercial biorefineries in Europe

Source: https://biorrefineria.blogspot.de/p/listado-de-biorrefiern.html?m=1
# Commercial biofuel driven BR in Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
<th>Company</th>
<th>Platform</th>
<th>Products</th>
<th>Feedstock</th>
<th>Process</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>Joensuu Bio-oil Plant</td>
<td>Fortum</td>
<td>Pyrolysis oil, power, heat</td>
<td>Bio-oil, power, heat</td>
<td>Forest residues, wood</td>
<td>Pyrolysis</td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>UPM Lappeeranta</td>
<td>UPM Biofuels</td>
<td>Oil</td>
<td>Biodiesel</td>
<td>Tall-oil</td>
<td>Pretreatment, hydrotreatment</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>Schwedt Biorefinery</td>
<td>Verbio</td>
<td>Starch, C5/C6 sugars</td>
<td>Bioethanol, biogas, fertiliser</td>
<td>Rye</td>
<td>Hydrolysis, fermentation</td>
<td>Convention BR</td>
</tr>
<tr>
<td>Italy</td>
<td>Crescentino Bioethanol Plant</td>
<td>Beta Renewables</td>
<td>C5/C6 sugars, lignin, power, heat</td>
<td>Bioethanol, animal feed</td>
<td>straws, giant reed</td>
<td>Hydrolysis, fermentation</td>
<td>Lignocellu. BR</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Delfzijl Biomethanol Plant</td>
<td>BioMCN</td>
<td>Syngas</td>
<td>Biomethanol</td>
<td>Glycerin</td>
<td>Evaporation, reforming</td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>Rotterdam Biorefinery</td>
<td>Neste Oil</td>
<td>Oil</td>
<td>HVO</td>
<td>Vegetable oil, animal fat</td>
<td>Hydrotreatment</td>
<td>HVO BR</td>
</tr>
</tbody>
</table>

Source: https://biorefineria.blogspot.de/p/listado-de-biorrefiern.html?m=1
## Commercial product driven BR in Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
<th>Company</th>
<th>Platform</th>
<th>Products</th>
<th>Feedstock</th>
<th>Process</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finland</td>
<td>Metsä Bioproducts Mill</td>
<td>Metsä Fibre</td>
<td>Pulp, lignin, power, heat</td>
<td>Pulp, power, tall-oil, lignin, new prod.</td>
<td>Wood</td>
<td>Cooking, separation</td>
<td>Forest BR</td>
</tr>
<tr>
<td>France</td>
<td>Pomacle-Bezancourt BR</td>
<td>Soliance, Sugar ref., Cristanol, Air Liquid</td>
<td>Starch, C5/C6 sugars</td>
<td>Starch, glucose, feed, ethan., CO2</td>
<td>Sugar beet, wheat</td>
<td>Hydrolysis, fermentation</td>
<td>Integrated BR</td>
</tr>
<tr>
<td>Germany</td>
<td>Biowert Biorefinery</td>
<td>Biowert GmbH</td>
<td>Organic solutions, biogas</td>
<td>Cellulosic fibres, nutrients, biogas</td>
<td>Grass</td>
<td>Pressing, drying, separation</td>
<td>Green BR</td>
</tr>
<tr>
<td>Norway</td>
<td>Sarpsborg Biorefinery</td>
<td>Borregaard</td>
<td>C5/C6 sug., lignin, biogas, power, heat</td>
<td>Bioethanol, lignin, cellulose, vanillin</td>
<td>Lignocell. crops or residues</td>
<td>Cooking, fermentat., separation</td>
<td>Forest BR</td>
</tr>
<tr>
<td>Sweden</td>
<td>Domsjö Pulp Mill</td>
<td>Aditya Birla Group</td>
<td>C5/C6 sug., lignin, biogas</td>
<td>Bioethanol, lignin, cellulose</td>
<td>Lignocell. crops</td>
<td>Cooking, fermentat., separation</td>
<td>Forest BR</td>
</tr>
</tbody>
</table>

Source: https://biorrefineria.blogspot.de/p/listado-de-biorrefiern.html?m=1
Biorefineries – incentives and tools

**Biorefineries should be designed in a flexible way and aim for the integral use of feedstock**

- Feedstock flexibility (new crops as potential substitution)
- Combine high volume/low quality with high quality/low volume products
- Integration with value chains (avoid mismatch with market volumes)
- Decentralised models to facilitate biomass transportation

**Sustainability must be achieved and demonstrated**

- GHG reduction potential for whole value chain (difficult to calculate)
- Development of standardised methodologies
- Important aspects: biodegradability, GHG emissions, biodiversity, soil quality
- Environmental footprint internalised in price (of any product)
Biorefineries – incentives and tools

Rather than subsidies…the need for a stable and coherent policy framework

• Stable (timeline 10-25 years) European and national policy and regulatory frameworks
• Loan guarantees for development and retrofitting of commercial-scale biorefinery facilities (cf. USDA Biorefinery Assistance Programme)
• Policies at various levels (local, regional, national) (cf. biorefinery roadmaps developed in Scotland and Germany)

Rather than subsidies…the need for markets

• Key priority: supporting market up-take for bio-based products
• Tools: production mandates (difficult for bio-chemicals), green public procurement
Challenges and opportunities

_Promising technologies and products…_

- Lignin and hemicellulose valorisation (currently underutilised)
- Existing challenges on pre-treatment and conversion technologies
- Existing challenges on biomass (and product) fractionation and CCU

…to ensure that “the _best goes to the best_”

- Using high quality parts of biomass for high quality products
- Proteins should be first extracted for food and non-food use
- Biomass use in applications where it is only sustainable solution

…to _increase the profitability of biorefinery business models_

_Hurdles from specific pieces of legislation_

- Waste Framework Directive can hinder transport and valorisation

_Address possible local resistance_

- Open door policy, stakeholder involvement, local value chains
Small-scale biorefineries

- Biorefineries for feed, materials and chemicals create income and employment in local agricultural sectors.
- Small-scale processing reduces capital costs and costs for energy and transportation.
- Challenge: cooperation of local actors (networks, clusters).

Source: J. Sanders, Wageningen UR, Status of the Bioeconomy, Oslo, 2-3 Sept. 2015
Mobile grass refinery unit Grassa (Netherlands)

- Separated components of grass value 700-800 EUR/ton, compared to 60 EUR/ton costs of raw material

Source: J. Sanders, Wageningen UR, Status of the Bioeconomy, Oslo, 2-3 Sept. 2015
Mobile grass refinery unit Grassa (Netherlands)

Source: J. Sanders, Wageningen UR, Status of the Bioeconomy, Oslo, 2-3 Sept. 2015
Small-scale corn biorefinery (Byosis, NL)

Source: J. Sanders, Wageningen UR, Status of the Bioeconomy, Oslo, 2-3 Sept. 2015
Future market perspectives – Advanced biofuels

Figure 5. Potential additional demand for advanced biofuels triggered by the proposed revision of the RED (Option A: Current proposal, Option B: 2.5% subtarget for advanced biofuels).

Source: R. Janssen et al., Biofuels, Bioprod. Bioref. (2013); DOI: 10.1002/bbb
Future market perspectives – Bioplastics

**Global production capacities of bioplastics in 2014 (by region)**

Total: 1.7 million tonnes

- Asia: 14.0%
- South America: 15.4%
- North America: 12.0%
- Europe: 0.5%
- Australia/Oceania: 58.1%

**Global production capacities of bioplastics in 2019 (by region)**

Total: 7.85 million tonnes

- Asia: 80.6%
- South America: 4.1%
- North America: 4.9%
- Europe: 19.3%
- Australia/Oceania: 0.1%

**Global production capacities of bioplastics 2014 (by material)**

Total: 1.7 million tonnes

- Biobased/non-biodegradable: 60.9%
- Biodegradable: 39.1%

1. Other (biobased/non-biodegradable)
2. Biodegradable cellulose
3. Biodegradable starch blends
4. Biodegradable polyesters
5. PHA
6. Regenerated cellulose
7. Other (biodegradable)

Source: European Bioplastics, Bioplastics – facts and figures
## Biomass-derived chemical building blocks

<table>
<thead>
<tr>
<th>No.</th>
<th>Chemical</th>
<th>Company</th>
<th>Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Methanol</td>
<td>RE/MON, Chemrec</td>
<td>Growth</td>
</tr>
<tr>
<td>2</td>
<td>Formaldehyde</td>
<td>Marine Bio Products</td>
<td>Pipeline</td>
</tr>
<tr>
<td>3</td>
<td>Methanol</td>
<td>Mary</td>
<td>Growth</td>
</tr>
<tr>
<td>4</td>
<td>Syngas</td>
<td>RE/MON, Chemrec</td>
<td>Growth</td>
</tr>
<tr>
<td>5</td>
<td>Ethylene</td>
<td>Braskem, Dow/Isia, Songyuan JY Biochemical</td>
<td>Growth</td>
</tr>
<tr>
<td>6</td>
<td>Ethyl acetate</td>
<td>Zechem</td>
<td>Pipeline</td>
</tr>
<tr>
<td>7</td>
<td>Ethanol</td>
<td>Mary</td>
<td>Growth</td>
</tr>
<tr>
<td>8</td>
<td>Glycolic acid</td>
<td>Metabolic Explorer (Metex)</td>
<td>Pipeline</td>
</tr>
<tr>
<td>9</td>
<td>Ethylene glycol</td>
<td>India Glycols Ltd, Greencool Taiwan</td>
<td>Growth</td>
</tr>
<tr>
<td>10</td>
<td>Acetic acid</td>
<td>Wacker</td>
<td>Growth</td>
</tr>
<tr>
<td>11</td>
<td>Lactic acid</td>
<td>Pern, NatureWorks, Galactic, Henan Jinda, BB BA</td>
<td>Growth</td>
</tr>
<tr>
<td>12</td>
<td>Acrylic acid</td>
<td>Cargill, Pernisar, OPXBio, Dow, Arkema</td>
<td>Pipeline</td>
</tr>
<tr>
<td>13</td>
<td>Glycerol</td>
<td>Mary</td>
<td>Growth</td>
</tr>
<tr>
<td>14</td>
<td>3-Hydroxy propanoic acid</td>
<td>Corpol</td>
<td>Pipeline</td>
</tr>
<tr>
<td>15</td>
<td>Propylene</td>
<td>Braskem/Toyota Tsusho, Mitsubishi Chemical, Misui Chemicals</td>
<td>Pipeline</td>
</tr>
<tr>
<td>16</td>
<td>Epichlorohydrin</td>
<td>Solvay, Dow</td>
<td>Growth</td>
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<tr>
<td>17</td>
<td>1,3-Propanediol</td>
<td>DuPont/Tate &amp; Lyle</td>
<td>Growth</td>
</tr>
<tr>
<td>18</td>
<td>n-Propyl alcohol</td>
<td>Braskem</td>
<td>Pipeline</td>
</tr>
<tr>
<td>19</td>
<td>Ethyl lactate</td>
<td>Vertex BioSolutions</td>
<td>Growth</td>
</tr>
<tr>
<td>20</td>
<td>Isopropanol</td>
<td>Genomatica, Misui Chemicals</td>
<td>Pipeline</td>
</tr>
<tr>
<td>21</td>
<td>Propylene glycol (1,2-Propanediol),</td>
<td>ADM</td>
<td>Growth</td>
</tr>
<tr>
<td>22</td>
<td>n-Butanol</td>
<td>Cargill Industrial Bioenergy, Pernisar, Mobaco, Celho/Phoffa</td>
<td>Growth</td>
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<tr>
<td>23</td>
<td>1,4-Butanediol</td>
<td>Genomatica/Misui, Cargill/Toyo Tsushio, Mitsubishi</td>
<td>Growth</td>
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<tr>
<td>24</td>
<td>Isobutene</td>
<td>Genomatica/Misui</td>
<td>Pipeline</td>
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<tr>
<td>25</td>
<td>Isobutanol</td>
<td>Dubois, Gore</td>
<td>Growth</td>
</tr>
<tr>
<td>26</td>
<td>Isobutene</td>
<td>Genomatica/Misui</td>
<td>Pipeline</td>
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<tr>
<td>27</td>
<td>Methyl methacrylate</td>
<td>Lucite/Mitsubishi Rayon, Evonik/Arkema</td>
<td>Pipeline</td>
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<tr>
<td>28</td>
<td>Succinic acid</td>
<td>BiOrb, Myriant, BASF/Parac, Reverdia</td>
<td>Growth</td>
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<tr>
<td>29</td>
<td>Pyruvic acid</td>
<td>(USM/Requies), PIT/Chem/Mitsubishi CC</td>
<td>Growth</td>
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<tr>
<td>30</td>
<td>Furfural</td>
<td>Mary</td>
<td>Growth</td>
</tr>
<tr>
<td>31</td>
<td>Xyloarabinose</td>
<td>ARB Corporation/Prins, Vyko, Arboresin</td>
<td>Pipeline</td>
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<tr>
<td>32</td>
<td>Xylose</td>
<td>ARB Corporation/Prins, Vyko, Arboresin</td>
<td>Pipeline</td>
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<tr>
<td>33</td>
<td>Isocitric acid</td>
<td>Goodman/Sennexor, GlycosBio, Amyris</td>
<td>Pipeline</td>
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<tr>
<td>34</td>
<td>Glutamic acid</td>
<td>a.o. Global Biotech, Meltia, Fujian, Fujian, Juhua</td>
<td>Growth</td>
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<tr>
<td>35</td>
<td>Lactic acid</td>
<td>Marine Bio Products, Avantium, Segeris, Circa Group</td>
<td>Pipeline</td>
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<tr>
<td>36</td>
<td>Sorbitol</td>
<td>a.o. Roquette, ADM</td>
<td>Growth</td>
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<tr>
<td>37</td>
<td>Acetic acid</td>
<td>Verenium, Venova, BioAmber, Genomatica</td>
<td>Pipeline</td>
</tr>
<tr>
<td>38</td>
<td>Lysine</td>
<td>a.o. Global Biotech, Evonik/BioBiotec, BBG, Draths, Ajinomoto</td>
<td>Growth</td>
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<tr>
<td>39</td>
<td>FADCA</td>
<td>Avantium</td>
<td>Pipeline</td>
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<tr>
<td>40</td>
<td>Tocopheride</td>
<td>Requeste</td>
<td>Growth</td>
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<tr>
<td>41</td>
<td>Glutaric acid</td>
<td>Riverpic renewables</td>
<td>Pipeline</td>
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<tr>
<td>42</td>
<td>Citric acid</td>
<td>a.o. Cargill, DSM, BBIGA, Unichem, TCCA, RZGC</td>
<td>Growth</td>
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<tr>
<td>43</td>
<td>Caprolactam</td>
<td>DSM</td>
<td>Pipeline</td>
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<tr>
<td>44</td>
<td>FIAH</td>
<td>Metabolic Explorer (Metex), Meridian Polymers (103), Tianjin Green Bioenergy Co.</td>
<td>Growth</td>
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<tr>
<td>45</td>
<td>Para Xylene</td>
<td>Gevo, Draths*, UOP, Ansellotech, Vinest</td>
<td>Pipeline</td>
</tr>
<tr>
<td>46</td>
<td>Dichloroacetic acid</td>
<td>Cargill, Evonik</td>
<td>Growth</td>
</tr>
<tr>
<td>47</td>
<td>Fatty Acid derivatives</td>
<td>Creeds, Eleveco</td>
<td>Growth</td>
</tr>
</tbody>
</table>

* Draths is recently acquired by Amyris.
Ecoduna Algae Biorefinery, Austria

- **State-of-the-art:** Demonstration Plant
- **Type of biorefinery:** 3-platform biorefinery
- **Location:** Bruck an der Leitha, Austria
- **Owner:** Ecoduna produktions-GmbH
- **Feedstocks:** Microalgae
- **Outputs:** Biofuels, electricity & heat, omega-3/6 fatty acids and Fertilizer

Source: IEA Bioenergy Task 42 Biorefining, August 2014
Maabjerg Energy, Denmark

- **State-of-the-art**: Commercial Scale (project)
- **Type of biorefinery**: A 5-platform (C5&C6 sugar, lignin, biogas, bio-methane, electricity&heat) biorefinery
- **Location**: Maabjerg, Denmark
- **Owner**: Vestforsyning A/S, Struer Forsyning A/S, Nomi I/S, DONG Energy A/S, Novozymes A/S
- **Feedstocks**: Wood chips, straw, manure, sewage sludge and MSW
- **Outputs**: Bio-methane, bioethanol, fertilizer, electricity and heat

Source: IEA Bioenergy Task 42 Biorefining, August 2014
LEUNA, Germany

- **State-of-the-art**: Pilot Plant
- **Type of biorefinery**: A 2-platform (C5&C6 sugars, lignin)
- **Location**: Leuna, Germany
- **Owner**: Fraunhofer Center for Chemical-Biotechnological Processes CBP
- **Feedstocks**: Ligno-cellulosic residues (wood, straw)
- **Outputs**: Bio-based synthesized building blocks and polymers

Source: IEA Bioenergy Task 42 Biorefining, August 2014
BTG Bioliquids Refinery, Netherlands

- **State-of-the-art**: Commercial Scale, start-up 2015
- **Type of biorefinery**: 1-platform (pyrolysis-oil) biorefinery
- **Location**: Hengelo, the Netherlands
- **Owner**: Empyro BV
- **Feedstocks**: Wood
- **Outputs**: Pyrolysis-oil, power, heat

Source: IEA Bioenergy Task 42 Biorefining, August 2014
Avantium YXY Fuels & Chemicals, Netherlands

- **State-of-the-art**: Pilot Plant
- **Type of biorefinery**: 3-platform (C5, C6 sugars and lignin)
- **Location**: Furanics, Amsterdam/Geleen, the Netherlands
- **Owner**: Avantium Chemicals B.V.
- **Feedstocks**: Cellulose, hemi-cellulose, starch, sucrose
- **Outputs**: Furan-based biofuels, monomers for polymers (furan dicarboxylic acid, furan diamine), fine and specialty chemicals (organic acids, solvents, flavors & fragrances), solid fuels (humins and lignin residues)

**PEF** (Polyethylenefuranoate) bottles

*Figure 28. Pilot-plant in Geleen, the Netherlands (Avantium)*

*Figure 29. 100% PEF-bottles (Avantium)*

**Source**: IEA Bioenergy Task 42 Biorefining, August 2014
Conclusions

• Biorefining (co-production of food/feed, bio-based products and bioenergy) can **maximise value** for sustainable biomass use

• Bioenergy will be the “lubricating oil” in a future circular BioEconomy

• Multitude of commercial, demonstration and pilot biorefinery concepts exist in Europe and globally (long experience in food and paper sector)

• **Development and demonstration of (new/innovative) technologies** is still needed to further increase efficiency and reduce costs

• **Small-scale biorefineries** may create additional income and employment in local agricultural sectors

• **Stable policy and regulatory frameworks** needed (level playing field)

• Key priority: **supporting market up-take** for bio-based products
Thanks for your attention!

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